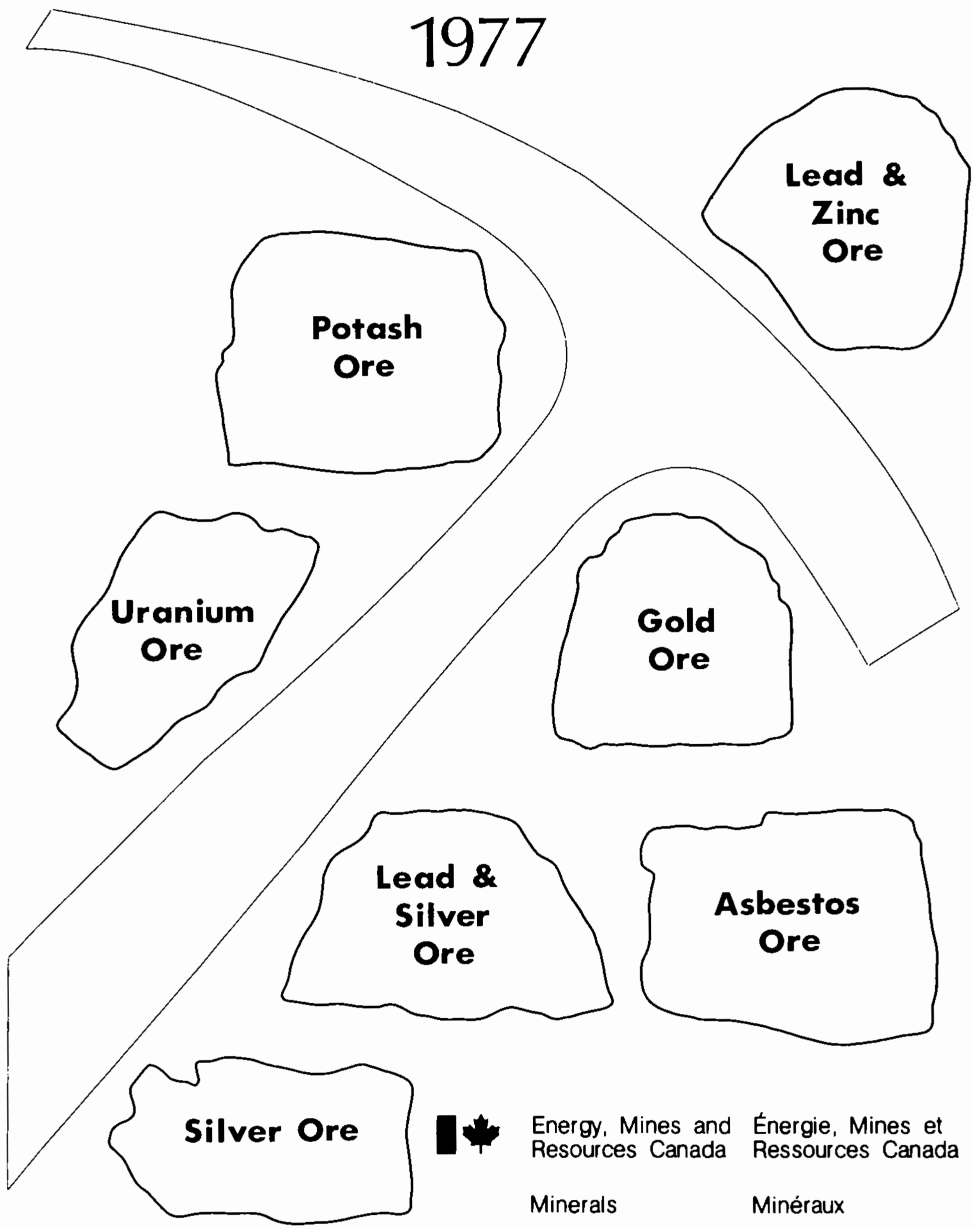
MINERAL REPORT 27

CANADIAN MINERALS YEARBOOK
1977



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Foreword

This issue of the Canadian Minerals Yearbook is a report of developments in the mineral industry for 1977. The 53 chapters dealing with specific commodities were issued in advance as Preprints, Canadian Minerals Yearbook 1977 to provide information as soon as possible to interested persons. The Statistical Summary, prepared specifically for the Yearbook each year, deals with the overall position of the industry in its national and international perspective; it comprises 70 statistical tables not readily available from other sources. The Company Index provides full and accurate company names and a complete cross reference to corporate activities in the Canadian industry, supported again by pocket map 900A, Principal Mineral Areas of Canada.

The Yearbook is the permanent official record of the mineral industry in Canada and is preceded by similar reports under various titles dating back to 1886. Those wishing to refer to previous reports should consult departmental catalogues, available in most libraries.

The basic statistics on Canadian production, trade and consumption were collected by Statistics Canada, unless otherwise stated. Company data were obtained directly from company officials or corporate annual reports by the authors. Market quotations were mainly from standard marketing reports.

The Department of Energy, Mines and Resources is indebted to all who contributed the information necessary to compile this report.

October 1978

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Readers wishing more recent information than that contained in the present volume should obtain the 1978 series of mineral reviews: a complete set costs $48, individual copies sell for $1.00 and may be obtained from Canadian Government Publishing Centre, Supply and Services Canada, Hull, Quebec, Canada K1A 0S9. For shipments outside Canada add 20 per cent to prices shown. Prices subject to change without notice.

Front End Leaf

Prairie wheat fields, which knew only combines in the way of heavy equipment until comparatively recent years, are now crossed from time to time by side-boom tractors installing crude oil and natural gas pipelines to transport these valuable natural resources south and east to United States and Canadian markets. (J.A. Thorburn photo).

Frontispiece

Still common at many small underground mining operations in Canada is this scene at Canadian Talc Industries, Madoc, Ontario, of a mucking machine operator loading ore into cars to be taken to the shaft, then hoisted for processing. (Information EMR photo)

Contents

1977 Mineral Production

In 1977 the total output of Canadian minerals, including metals, nonmetals, structural materials and mineral fuels, reached a level of $18.14 billion, compared with $15.45 billion the previous year. In general, this reflected increases in both the quantities of the various commodities produced and their prices.

The highest production value was in the mineral fuels sector, including coal, natural gas, natural gas byproducts and crude petroleum, which rose in total to $10.01 billion in 1977 from $8.11 billion in 1976. Alberta's output of fuels increased to $8.32 billion in 1977 from $6.74 billion in 1976.

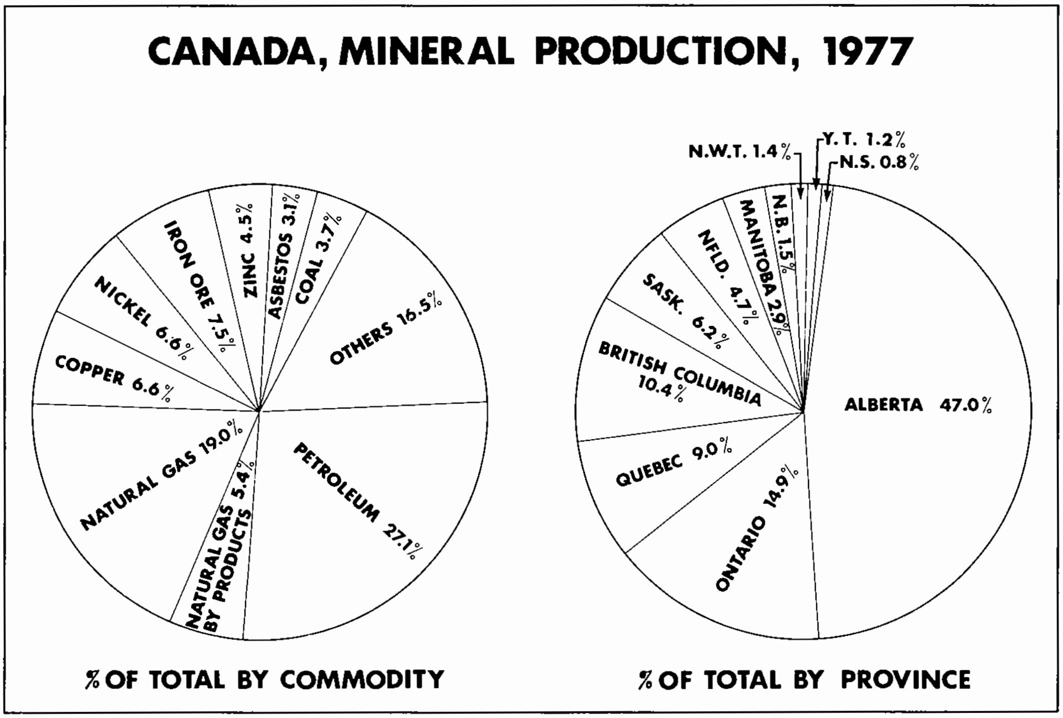


Figure 1

Metal mining production had a value of $5.60 billion in 1977, up from $5.07 billion in 1976. Ontario was the leading province in metals output, with a production value of $2.19 billion, down from $2.22 billion in 1976.

In nonmetals mining, production was $1.37 billion in 1977, compared with $1.16 billion in 1976. Leading minerals in the group were: asbestos, at $564.13 million in 1977, up from $452.21 million in 1976; and potash, at $421.28 million, up from $353.51 million in 1976.

The total value of structural materials was $1.16 billion in 1977, up from $1.10 billion in 1976. Leading materials were: cement, at $408.67 million, up from $381.11 million; sand and gravel, at $343.90 million, up from $334.41 million; and stone, at $246.40 million, up from $230.64 million in 1976.

Figure 1 shows mineral production by commodity and by province for 1977 in percentage terms. As in the previous year, petroleum was the dominant mineral commodity in terms of value of output, with 27.1 per cent of the total. In terms of provincial mineral production, Alberta made the largest single contribution, 47.0 per cent of the total, followed by Ontario, which contributed 14.9 per cent.

Figure 2 illustrates growth of the three major sectors of the Canadian mineral industry between 1960 and 1977. The value of mineral production has grown at about 12.38 per cent a year during the period, with mineral fuels growing at a higher rate than metallic and industrial minerals. During 1977, the per capita value of mineral production rose by $107.18 to $779.02, while mineral production, as a percentage of GNP, rose from 8.07 to 8.63.

CANADA
VALUE OF MINERAL PRODUCTION

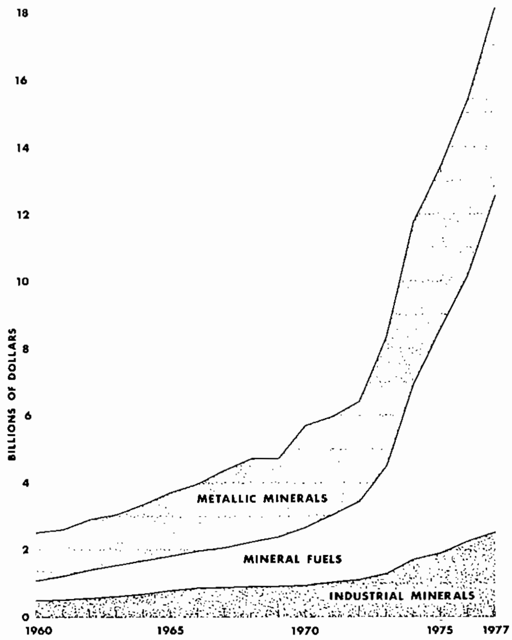


Figure 2

Conversion Factors

Imperial units to Metric (SI) Units

Ounces to grams	**x**	**28.349 523**
Troy ounces to grams	**x**	**31.103 476 8**
to kilograms	**x**	**.031 103 476**
Pounds to kilograms	**x**	**.453 592 37**
Short tons to tonnes	**x**	**.907 184 74**
Gallons to litres	**x**	**4.546 09**
Barrels to cubic metres	**x**	**.158 987 220**
Cubic feet to cubic metres	**x**	**.028 316 85**

Source: *Canadian Metric Practice Guide.*

Lightweight Aggregates

D.H. STONEHOUSE

Aggregates commonly used to provide bulk in concrete and concrete products are sand, gravel and crushed stone. These commodities have an average unit weight of approximately 2 000 kilograms (kg) a cubic metre. Until the mid-1940s comparatively little attention was paid to designing concrete products to meet a specific requirement other than a certain predetermined strength and setting time. At that time increased housing demand accentuated the need for prefabricated structures and techniques of construction were developed which could utilize structural sections and panels. It soon followed that panels, beams and trusses of much lighter unit weight could be fabricated with no sacrifice in strength by utilizing lightweight aggregates, a variety of rock and mineral materials weighing in the neighbourhood of 1 300 kg a cubic metre.

Four categories generally used to classify the lightweight aggregates combine elements of source, processing methods and end-use. Natural lightweight aggregates include materials such as pumice, scoria, volcanic cinders and tuff. Manufactured lightweights are bloated or expanded products obtained by heating certain clays, shales and slates. Ultra-lightweights are made from natural mineral ores, such as perlite and vermiculite, which are expanded or exfoliated by the application of heat and used mainly as plaster aggregate or as loose insulation. Fly ash, which is obtained from the combustion of coal and coke; and slag, which is obtained from metallurgical processes, are classed as byproduct aggregates.

The use of lightweight concrete in commercial and institutional projects has facilitated the construction of taller buildings and the use of longer clear spans in bridges and buildings. Additional advantages from the use of lightweight aggregates lie in the fact that they supply thermal and acoustical insulation, fire resistance, good freeze-thaw resistance, low water absorption and a degree of toughness to the concrete product. Disadvantages stem from the fact that in production of both manufactured and ultra-lightweight aggregates heat processing is required. As the cost of fuel increases the competitiveness of these types will be reduced unless the insulation values more than offset the heat units consumed in processing.

Canadian industry and developments

All types of lightweight aggregates are used in Canada, but only expanded clays, shale and slag are produced from materials of domestic origin. Vermiculite is imported mainly from Montana, U.S.A., although a small amount is brought in from the Republic of South Africa. Perlite is imported mainly from New Mexico and Colorado, and pumice is imported from Oregon and Greece. Most processed lightweight aggregate is utilized in the construction industry, either as loose insulating material or as aggregate in the manufacture of lightweight concrete units. The scope of such applications has not yet been fully investigated.

Any lightweight material with acceptable physical and chemical characteristics could substitute for the mineral commodities generally used. The most significant substitute for vermiculite, for instance, is styrofoam or polyurethane, which offers insulating value and comparable strength. However, these materials are petroleum-based and higher fuel prices could limit their use. Mineral wool is a competitive insulation material but its manufacture requires a pyroprocessing stage, as does the production of perlite and vermiculite. Transportation costs for high-bulk, lightweight materials are high; those materials, such as perlite and vermiculite, that can be transported to a consuming centre prior to expansion, have obvious advantages.

Perlite. Perlite is a variety of obsidian or glassy volcanic rock that contains 2 to 6 per cent of chemically combined water. When the crushed rock is heated rapidly to a suitable temperature (1400°F to 1800°F) it expands to between 4 and 20 times its original volume. Expanded material can be manufactured to weigh as little as 30 to 60 kilograms (kg) a cubic metre, with attention being given to preblending of feed to the kiln

Table 1. Canada, production of lightweight aggregates, 1976 and 1977

	1976		1977	
	m^3	$	m^3	$
From domestic raw materials				
Expanded clay, shale and slag	661 908	7 530 095	576 637	6 919 646
From imported crude materials				
Expanded perlite and exfoliated vermiculite[1]	589 864	11 831 545	620 305	15 108 723
Pumice	49 030	748 145	42 700	698 125
Total	1 300 802	20 109 785	1 239 642	22 726 494

Source: Company data.
[1]Grouped to protect individual company confidentiality.

and retention time in the flame. Thermal conductivity (Btu's per hour per square foot per °F per inch of thickness) ranges from as low as 0.267 for loosely packed perlite to 1.25 for perlite gypsum plaster.

In Canada, imported perlite is expanded and used mainly by gypsum products manufacturers in plaster products such as wallboard or drywall, and in fibre-perlite roof insulation board, where its value as a lightweight material is augmented by its fire-resistant qualities. It is also used as a loose insulation and as an insulating medium in concrete products. Perlite, vermiculite, and expanded shale and clay are becoming more widely used in agriculture as soil conditioners and fertilizer carriers.

Imports of crude perlite for consumption in Canada are from New Mexico and Colorado deposits, worked by such companies as Johns-Manville Corporation, United States Gypsum Company, United Perlite Corp. and Grefco Inc. In 1977 seven companies at nine locations in Canada reported production of expanded perlite.

Perlite occurs in British Columbia but no commercial deposits have as yet been located.

Pumice. Pumice is a cellular, glassy lava, the product of explosive volcanism, usually found near geologically-recent or active volcanoes. It is normally found as a loosely compacted mass composed of pieces ranging in size from large lumps to small particles. It is not the lightest of the lightweight aggregates, but when utilized as a concrete aggregate, particularly for the manufacture of concrete blocks, it exhibits strength, density and insulating values that have made it a preferred material.

In Canada, a number of concrete products manufacturers use pumice imported from Greece or from the northwestern United States, mainly in the manufacture of concrete blocks. A major use for pumice, as yet unexplored in Canada, has been in highway construction, where lightweight aggregate surfaces have been shown to have exceptional skid resistance.

Table 2. Canada, consumption of expanded clay and shale, percentage by use, 1975-77

Use	1975	1976	1977
Concrete block manufacture	77.4	70.7	72.4
Precast concrete manufacture	10.9	10.8	4.9
Ready-mix concrete	7.0	12.7	18.1
Horticulture and miscellaneous	4.7	5.8	4.6

Source: Company data.

Pumicite, distinguished from pumice by its finer size range (usually minus 100 mesh), is used in concretes mainly for its pozzolanic qualities. (A pozzolan is a siliceous material possessing no cementitious qualities until finely ground, in which form it will react with calcium hydroxide in the presence of moisture to form insoluble calcium silicates.)

Extensive beds of pumicite have been noted in Saskatchewan and British Columbia.

Vermiculite. The term vermiculite refers to a group of micaceous minerals, hydrous magnesium-aluminum silicates, that exhibit a characteristic lamellar structure and expand or exfoliate greatly upon being heated rapidly. Mining is normally by open-pit methods, and beneficiation techniques include the use of hammer mills, rod mills, classifiers, screens, dryers, and cyclones. Exfoliating is done in oil- or gas-fired, vertical or inclined furnaces, usually close to the

Table 3. Canada, consumption of expanded perlite, percentage by use, 1975-1977

Use	1975	1976	1977
Insulation	91.1	82.2	84.0
— in gypsum products		(13.9)	(27.0)
— in other construction materials		(68.3)	(57.0)
Horticulture	5.2	8.5	13.0
Other (incl.loose)	3.7	9.3	3.0

Source: Company data.

consuming facility to obviate the higher costs associated with shipping the much-bulkier expanded product. Required temperatures can vary from 1100°C to 1650°C depending on the type of furnace in use. A controlled time and temperature relation is critical in order to produce a product of minimum bulk density and good quality.

The expansion process has been improved technologically to enable production of various grades of expanded vermiculite as required. The uses to which the product is put depend on its low thermal conductivity, its fire-resistance and, more recently, on its lightweight qualities.

Canadian consumption is mainly as loose insulating material, with smaller amounts being used as aggregate in the manufacture of insulating plaster and concrete. The energy situation will undoubtedly result in continued increases in domestic fuel costs, and greater use of insulation in both new construction and older buildings will continue to tax the production capability of manufacturers for some time.

The major producer of vermiculite is the United States. The principal company supplying Canada's imports is W.R. Grace and Company, from operations at Libby, Montana and from the Enoree region of South Carolina. Canada also imports crude vermiculite from the Republic of South Africa, where Palabora Mining Co. Ltd. is the major producer. At both the Grace and Palabora operations milling limitations have necessitated new mill installations in an effort to keep up with demand. Minor amounts of vermiculite are produced in Argentina, Brazil, India, Kenya and Tanzania.

Vermiculite occurrences have been reported in British Columbia, and deposits near both Perth and Peterborough in Ontario have been investigated but, as yet, no commercial deposits have been developed in Canada.

Three companies operated a total of eight vermiculite processing plants in Canada during 1977.

Clay, shale and slag. Common clays and shale are used throughout Canada as raw material for the manufacture of lightweight aggregates. Although the Canadian industry began in the 1920s in Ontario, it did not evolve significantly until the 1950s when it grew in support of demands from the construction industry. The raw materials are usually quarried adjacent to the plant sites at which they are expanded. Clays receive little beneficiation other than drying before being introduced to the kiln in which they are heated. Shales are crushed and screened before burning. Six plants in Canada produced lightweight aggregates from clay and shale during 1977, each using a rotary kiln process.

One company produces an aggregate material from slag as a byproduct of a blast furnace operation. In steelmaking, iron ore, coke and limestone flux are melted in a furnace. When the metallurgical process is completed, lime has combined with the silicates and aluminates of the ore and coke and formed a nonmetallic product (slag) which can be subjected to controlled cooling from the molten state to yield a porous, glassy material. Slag has many applications in the construction industry. The statistics relative to expanded slag production are included in those of clay and shale.

Although Canada does not produce large amounts of fly ash, the technology of fly-ash processing and utilization is well advanced. The largest single use for fly ash is as a cementitious material, in which application its pozzolanic qualities are utilized. Use of fly ash as a lightweight aggregate could become increasingly important. Great West Industries (Alta) 1976 Ltd. of Edmonton, Alberta, which produced brick using fly ash and bottom ash as raw material, was taken over by Great West Steel Industries Ltd. of Vancouver in 1972 and closed in 1977 because of marketing difficulties. Ontario Hydro produces over 400 000 tonnes* of fly ash a year from three coal-fired stations. Experimentation continues towards successful utilization of this material at the Lakeview plant in the production of pozzolan, iron oxide and lightweight pellets. Disposal costs of $2 to $3 a tonne add incentive to such programs.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 4. Canada, consumption of exfoliated vermiculite, percentage by use, 1975-77

Use	1975	1976	1977
Insulation			
— loose	77.0	71.9	75.1
— in concrete and conrete products	3.9	7.3	4.7
— in gypsum products	1.0	2.0	1.4
Horticulture	8.8	8.8	10.0
Other	9.3	10.0	8.8

Source: Company data.

Table 5. Lightweight aggregate plants in Canada, 1977

Company	Location	Product
Atlantic Provinces		
Avon Aggregates Ltd.	Minto, N.B.	Expanded shale
Quebec		
F. Hyde & Company, Limited	Montreal	Vermiculite
Laurentide Perlite Inc.	Charlesbourg West	Perlite
Masonite Canada Ltd.	Gatineau	Perlite
Perlite Industries Reg'd.	Ville St. Pierre	Perlite
Vermiculite Insulating Limited	Lachine	Vermiculite
Ontario		
Canadian Gypsum Company, Limited	Hagersville	Perlite
Canadian Johns-Manville Company, Limited	North Bay	Perlite
Domtar Construction Materials Ltd.	Caledonia	Perlite
	Mississauga	Expanded shale
	Cornwall	Perlite
W.R. Grace & Co. of Canada Ltd.	St. Thomas	Vermiculite
	Ajax	Vermiculite
National Slag Limited	Hamilton	Slag
Prairie Provinces		
Cindercrete Products Limited	Regina, Sask.	Expanded clay
Consolidated Concrete Limited	Calgary, Alta.	Expanded shale
Domtar Construction Materials Ltd.	Calgary, Alta.	Perlite
Consolidated Concrete Limited, Edcon Block Division	Edmonton, Alta.	Expanded clay
W.R. Grace & Co. of Canada Ltd.	Winnipeg, Man.	Vermiculite
	Edmonton, Alta.	Vermiculite
Kildonan Concrete Products Ltd.	St. Boniface, Man.	Expanded clay
Northern Perlite & Vermiculite Limited	St. Boniface, Man.	Vermiculite
British Columbia		
W.R. Grace & Co. of Canada Ltd.	Vancouver	Vermiculite
Westroc Industries Limited	Vancouver	Perlite

Source: Company data.

Specifications

There are as yet no Canadian Standards Association (CSA) specifications for the lightweight aggregates. Production and application are based on the American Society for Testing and Materials (ASTM) designations as follows: ASTM Designations C 332-66 — Lightweight Aggregates for Insulating Concrete; C 330-75a — Lightweight Aggregates for Structural Concrete; and C 331-69 — Lightweight Aggregates for Concrete Masonry Units.

Outlook

Demand for all lightweight aggregates will continue to increase as their use in structural concrete and for insulation purposes becomes more popular. In view of increased costs of energy the amount of insulation which can be economically installed in new housing and, indeed, in older housing, has more than doubled during the past few years, thereby placing great demand pressure on the suppliers of these materials. The four main lightweight materials — perlite, pumice, vermiculite and expanded clays — are interchangeable for many applications and can, along with some synthetic materials, be considered substitutes or alternates for each other.

Mineral fibre and cellulose insulation products, also manufactured in Canada, are the principal insulation materials in use in building construction. Statistics Canada lists four companies producing mineral wool in 1977 at nine locations across Canada. The number of firms producing cellulose insulation is unknown because, since the energy crisis, many operations have started up as comparatively small local industries. The

Table 6. Canada, value of construction by province, 1976-78

	1976[1]			1977[2]			1978[3]		
	Building Construction	Engineering Construction	Total	Building Construction	Engineering Construction	Total	Building Construction	Engineering Construction	Total
					(thousands of dollars)				
Newfoundland	420 507	312 521	733 028	375 388	217 918	593 306	407 064	261 837	668 901
Nova Scotia	545 195	328 845	874 040	495 512	412 490	908 002	542 131	441 534	983 665
New Brunswick	499 409	393 570	892 979	454 697	428 982	883 679	493 082	443 490	936 572
Prince Edward Island	65 723	34 789	100 512	85 017	38 780	123 797	91 473	48 104	139 577
Quebec	5 127 246	2 775 934	7 903 180	5 064 075	3 612 443	8 676 518	4 803 376	4 255 293	9 058 669
Ontario	6 783 354	3 282 600	10 065 954	6 947 157	3 528 352	10 475 509	7 423 049	3 637 628	11 060 677
Manitoba	782 397	505 218	1 287 615	848 174	537 800	1 385 974	938 134	527 501	1 465 635
Saskatchewan	909 271	512 319	1 421 590	971 352	586 032	1 557 384	997 035	677 322	1 674 357
Alberta	2 572 610	2 624 830	5 197 440	2 895 463	3 299 950	6 195 413	3 035 623	3 492 889	6 528 512
British Columbia, Yukon Territory and Northwest Territories	2 765 953	1 888 908	4 654 861	2 804 756	2 148 863	4 953 619	2 925 313	2 423 573	5 348 886
Canada	20 471 665	12 659 534	33 131 199	20 941 591	14 811 610	35 753 201	21 656 280	16 209 171	37 865 451

Source: Statistics Canada.
[1]Actual; [2]Preliminary; [3]Forecast.

main raw material for cellulose insulation manufacture is shredded waste paper which must be impregnated with a fire-retardant chemical, usually borax or boric acid. Both the safety and lasting qualities of cellulose insulation are being questioned.

In response to projected demand for mineral wool, each of the two largest producers in Canada — Fiberglas Canada Limited and Canadian Johns-Manville Company, Limited — increased capacity in strategic locations. Fiberglas recently opened a new plant in Moncton, N.B., at a cost of $9 million and expanded three of its other plants: Sarnia, Ont., at a $6 million cost; Montreal, Que., at $6 million; and Edmonton, Alta., at $5 million. Construction of a new $25 million plant on a 20-hectare site in Scarborough, Ont. has begun, with start-up planned for 1979. Canadian Johns-Manville officially opened a new fiberglass insulation plant at Innisfail, Alta., on Oct. 3, 1977. The $11 million plant will have a capacity of 5 400 tonnes a month. Market growth in the region is estimated at 15 per cent a year.

World review

The United States and Greece are the main producers of perlite; smaller quantities are mined in Algeria, Turkey, the Philippines and New Zealand. New Zealand could become a major producer if huge deposits owned by Consolidated Silver Mining Co. are developed for export markets.

The major producers of pumice include the United States, Italy, West Germany and Greece, although production is recorded from other countries. As with other low-cost lightweight material, transportation costs are the main factor in determining the competitiveness of pumice. Prices have not varied greatly in recent years.

The use of fly ash should increase with the added incentives provided by environmental control. Using only about 20 per cent of ash production, industry in North America falls far short of European enterprises which use as much as 80 per cent of production.

The United States is the source of most of the lightweight raw materials consumed in Canada, exclusive of clay, shale and slag. The U.S. reserves are sufficient both for its domestic requirements and for exports to meet Canada's projected needs for many years.

The unit price of lightweight aggregates has shown a steady but unspectacular rate of increase during the past few years and is likely to continue to do so in pace with a steady increase in demand and inflationary conditions, each of which could have as its main contributing influence increased costs of energy, particularly the fossil fuels.

Aluminum

J.J. HOGAN

Non-communist world demand for aluminum in 1977 was comparatively stable throughout the year and increased by a small margin over that of 1976. Non-communist world smelters operated at 86 per cent of capacity. Some smelters in the United States lowered production because of power shortages, but overall output in 1977 increased by 6.8 per cent. Non-communist world production increased by 10.9 per cent. Two increases in the quoted price of primary ingot, totalling 5 cents, were announced by major producers, which raised the North American price from 48 cents to 53 cents a pound during the year.

Canada

No economic deposits of bauxite, the predominant ore of aluminum, have been found in Canada. Bauxite is imported from tropical countries for the production of alumina, an aluminum oxide, which is reduced in electrolytic cells to aluminum metal. Approximately 4.5 tonnes* of bauxite are refined to produce 2 tonnes of alumina, which in turn are smelted to obtain 1 tonne of aluminum. The electric power requirements in the production of aluminum are high; from 7 to 8 kilowatt hours (kWh) per pound of aluminum produced. For this reason, Canada's aluminum smelters have been advantageously located near large low-cost power sources. Also, because transportation is an important cost factor, the smelters have been located near ocean shipping ports.

Production

Canadian primary aluminum output in 1977 was 983 266 tonnes compared with 633 430 tonnes in 1976. Two companies operate primary smelters in Canada; the Aluminum Company of Canada, Limited (Alcan), a subsidiary of Alcan Aluminium Limited of Montreal (also referred to as Alcan) and Canadian Reynolds Metals Company, Limited, a subsidiary of Reynolds Metals Company of Richmond, Virginia. The operations of Alcan smelters returned to normal in 1977 following a labour strike which was settled late in 1976. The low Canadian production in 1976 was the result of the strike.

Some 2 755 300 tonnes of bauxite were imported from Guinea, Guyana, Sierra Leone, Surinam and elsewhere to produce alumina at Alcan's refinery at Jonquière (formerly Arvida), Quebec, the only alumina refinery in Canada. The capacity of the refinery is 1 258 000 tonnes a year and it supplies Alcan's four smelters in Quebec. Alumina for Alcan's Kitimat smelter in British Columbia was imported mainly from Australia. The Reynolds Metal smelter in Quebec imported alumina from Jamaica and the United States.

In 1977, Alcan's Canadian aluminum smelters produced 826 500 tonnes of primary aluminum compared with 492 600 tonnes in 1976. Included in the above figure is 45 400 tonnes produced on a toll basis for the Nippon Light Metal Company Ltd., a Japanese affiliate of Alcan, under an agreement signed in 1974 for a period of 24 years. The strike at Alcan's Shawinigan smelter, which continued into 1977, was settled towards the end of January. By the second quarter, all the company's smelters were back to normal operations. Alcan Aluminium Limited, a multinational company, has wholly- and partially-owned smelters in Japan, Norway, Spain, Great Britain, India, Sweden, Brazil and Australia. Alcan's total production in 1977, including Canadian production, was 1 875 200 tonnes, compared with 1 517 700 tonnes in 1976.

Canadian Reynolds Metals Company, Limited operates a smelter at Baie Comeau, Quebec. Production in 1977 was 156 800 tonnes, an increase of 13 per cent from the 138 400 tonnes produced in 1976.

In May, Alcan announced that it would proceed with the first phase of the planned 171 600-tonne Grande Baie smelter complex in the Saguenay region of Quebec. Ground clearing operations at the new site were completed in 1977. Construction of 57 200-tonne-

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

a-year smelter and service facilities will begin in 1978 and is scheduled for completion in 1981, at a capital cost of $200 million.

Canadian exports of aluminum, mainly in ingot form but also including further fabricated materials, were 698 815 tonnes, an increase of 30 per cent over the 536 084 tonnes exported in 1976. The United States was by far the major market for Canadian aluminum, accounting for 68 per cent of the Canadian exports; followed by Japan, with 8.5 per cent.

The value of 1977 aluminum exports from all sources in 1977 was $812,381,000 compared with $496,690,000 in 1976. Exports in 1976 were affected by a strike at the plants of Alcan in Quebec.

Consumption

Canadian consumption of aluminum was estimated at 330 000 tonnes for 1977 compared with 322 206 tonnes in 1976.

World review

World production of bauxite was 82.3 million tonnes in 1977, 3.4 per cent above the 79.6 million tonnes produced in 1976. Australia, the world's largest producer, produced 25.2 million tonnes in 1977 compared with 23.5 million tonnes in 1976. Guinea and Jamaica were the next-largest producers with 11.5 million and 11.4 million tonnes, respectively.

World production of aluminum increased by 8.7 per cent from 13.08 million tonnes in 1976 to 14.22 million tonnes in 1977. World consumption was up marginally in 1977 from the previous year. Stocks in the hands of producers in the non-communist world at the end of 1977 were 2.5 million tonnes, up slightly from 2.3 million tonnes at the end of 1976. Non-communist world aluminum producers operated at an average of 86 per cent of capacity during the year.

The International Bauxite Association (IBA), formed to further the interests of the bauxite-producing nations, consists of 11 member countries. Australia, Guinea, Guyana, Jamaica, Sierra Leone, Surinam and Yugoslavia were the founding members when the IBA was formed at Conakry, Guinea in March 1974; Haiti, Ghana and the Dominican Republic joined the Association at its meeting in Georgetown, Guyana in November 1974, and Indonesia became a member at the second annual meeting held in Kingston, Jamaica in 1975. One of the objectives of the IBA is the establishment of a minimum price for bauxite. In early December 1977 the IBA, at an annual meeting, agreed on a minimum pricing policy for base-grade bauxite in the North American market.The agreed price is $24 per tonne cif*, with adjustments for bauxite grades. While this pricing policy may be considered a psychological milestone, it has no economic impact. The price of bauxite imported into the United States at the time of the agreement was above the agreed price.

Jamaica, one of the leaders of the IBA, has one of the highest levies for bauxite. Under its Bauxite Production Levy Act, passed in 1974, the government has the right to acquire equity participation in the bauxite mining operations on the island and to buy back the land held by the aluminum companies. The rate of levy, based on the average United States price of a short ton of aluminum ingot, was set at 7.5 per sent for 1974, rising to 8.5 per cent in 1976.

The Jamaican government and Kaiser Aluminum & Chemical Corporation signed an agreement in February 1977 which gives the government a 51 per cent interest in the assets of Kaiser's operating subsidiary in Jamaica. As part of the agreement the government also purchased the companies' bauxite lands for $5.61 million. In return, Kaiser received a 40-year mining lease and a guarantee that its bauxite production levy will remain at 7.5 per cent through 1983. In March, Reynolds Metals Company and its subsidiary, Reynolds Jamaica Mines, Ltd., signed a similar agreement with the Jamaican government. In 1976, the Jamaican government reached an agreement with the Aluminum Company of America (Alcoa) with terms similar to the above two agreements. Negotiations are going on between Alcan and the Jamaican government for participation by Jamaica in Alcan's holdings in that country.

Early in 1977 the Alcan Aluminum Corporation of the United States, a subsidiary of Alcan, and Revere Copper and Brass Incorporated reached an agreement on the sale of Revere's 100 000-tonne-a-year aluminum smelter and adjacent sheet mill at Scottsboro, Alabama for about $140 million. The United States Department of Justice filed a lawsuit challenging the acquisition of the property by Alcan on anti-trust grounds. At year-end, Alcan advised the court that it did not intend to proceed with the acquisition because of expected prolonged delays in litigation, but a federal court requested the three parties involved in the proceedings to seek a settlement.

One-third of the United States smelting capacity is located in the Pacific Northwest and the plants obtain their power needs from the hydro plant of Bonneville Power Administration (BPA). Because of low precipitation the BPA curtailed power deliveries to the smelters by 25 per cent in February, requiring them to reduce their output. With precipitation returning to normal at year-end, it was expected that power deliveries would be back to normal early in 1978.

The Anaconda Company's Aluminum Division is increasing the capacity of its smelter at Sebree, Kentucky by 54 500 tonnes, for a total annual capacity of 163 200 tonnes. Scheduled completion date is 1979.

Alumax, Inc., in which AMAX Inc. has a 50 per cent interest, plans to increase its output by building a 179 000-tonne-a-year aluminum smelter near Charleston, South Carolina; by increasing the capacity of its

*cif —cost insured freight.

Table 1. Canada, aluminum production and trade, 1976-77

	1976		1977p	
	(tonnes)	($ 000)	(tonnes)	($ 000)
Production	633 430	. .	983 266	. .
Imports				
Bauxite ore				
Guinea	522 686	7 921	1 244 369	22 679
Surinam	133 703	9 171	251 321	11 426
Guyana	299 519	2 964	531 238	6 082
Sierra Leone	75 128	773	333 672	3 909
Trinidad-Tobago	91 902	814	329 986	3 064
United States	48 078	3 773	25 724	2 749
Other countries	59 036	3 653	38 990	2 556
Total	1 230 052	29 069	2 755 300	52 465
Alumina				
Australia	427 369	50 666	500 800	69 213
Jamaica	39 709	5 320	164 702	30 949
West Germany	83 616	13 105	73 881	14 141
United States	293 526	47 365	32 852	7 730
France	41 608	3 161	49 369	5 449
Other countries	22 127	2 506	6	3
Total	907 955	122 123	821 610	127 485
Aluminum and aluminum alloy scrap	8 936	4 260	16 126	10 936
Aluminum paste and aluminum powder	5 404	6 105	6 472	8 287
Pigs, ingots, shorts, slabs, billets, blooms and extruded wire bars	22 545	21 023	20 785	22 298
Castings	1 868	4 034	1 091	4 494
Forgings	333	1 822	426	2 651
Bars and rods, nes	2 286	3 446	1 854	4 084
Plates	8 739	11 086	9 295	15 490
Sheet and strip up to .025 inch thick	16 592	20 229	20 997	31 129
Sheet and strip over .025 inch up to .051 inch thick	5 774	9 091	7 228	13 543
Sheet and strip over .051 inch up to .125 inch thick	28 312	30 693	20 431	28 979
Sheet over .125 inch thick	19 429	21 901	23 957	33 013
Foil or leaf	465	780	364	780
Converted aluminum foil	. .	6 240	. .	7 072
Structural shapes	1 272	2 672	2 002	5 071
Pipe and tubing	1 088	2 978	1 275	3 272
Wire and cable, not insulated	1 684	3 033	1 570	3 389
Aluminum and aluminum alloy fabricated materials, nes	. .	21 796	. .	28 809
Total aluminum imports	. .	171 189	. .	223 297

Table 1. (cont'd)

	1976		1977[p]	
	(tonnes)	($ 000)	(tonnes)	($ 000)
Exports				
Pigs, ingots, shot, slabs, billets, blooms and extruded wire bars				
United States	356 073	303 948	454 667	499 080
Japan	8 748	7 991	59 372	42 517
South Korea	3 000	2 927	19 341	20 261
Hong Kong	17 413	12 545	14 646	13 527
Thailand	4 267	3 856	10 387	12 259
United Kingdom	16 085	12 986	8 478	11 267
People's Republic of China	22 895	16 303	9 997	10 306
Brazil	13 088	10 399	8 987	9 326
Malaysia	6 287	5 930	7 564	9 117
Israel	9 176	7 186	7 572	8 994
Turkey	13 399	10 977	6 836	7 707
Other countries	37 401	32 445	47 417	54 440
Total	507 832	427 493	655 264	698 801
Castings and forgings				
United States	812	5 819	651	6 072
West Germany	5	244	16	950
United Kingdom	9	477	14	925
France	9	573	10	774
Other countries	59	601	10	490
Total	894	7 714	701	9 211
Bars, rods, plates, sheets and circles				
United States	3 598	3 959	10 294	15 913
Venezuela	8 357	7 419	7 370	10 198
Pakistan	2 628	2 903	4 769	5 958
Switzerland	242	365	1 501	1 892
Spain	—	—	936	908
Portugal	—	—	679	813
Trinidad-Tobago	215	303	427	748
South Korea	—	—	239	393
Jamaica	304	417	208	323
United Kingdom	89	139	49	265
Other countries	1 967	2 178	701	1 320
Total	17 400	17 683	27 173	38 731
Foil				
Venezuela	268	488	587	1 275
United States	7	20	223	510
Trinidad-Tobago	—	—	32	63
El Salvador	—	—	16	27
Costa Rica	28	41	—	—
Other contries	12	24	5	9
Total	315	573	863	1 884

Table 1. (concl'd)

	1976		1977^p	
	(tonnes)	($ 000)	(tonnes)	($ 000)
Fabricated materials, nes				
United States	6 949	8 907	11 229	14 701
Ivory Coast	—	—	336	613
Tunisia	243	351	452	602
United Kingdom	243	555	253	581
Pakistan	1 272	1 771	351	547
Nigeria	166	280	219	467
Other countries	770	1 243	1 974	3 310
Total	9 643	13 107	14 814	20 821
Ores and concentrates				
United States	13 100	2 434	19 885	4 557
Spain	577	97	993	297
Italy	142	17	736	183
Venezuela	—	—	701	155
United Kingdom	1 125	205	631	149
France	626	79	283	71
Other countries	313	78	841	262
Total	15 883	2 910	24 070	5 674
Scrap				
United States	41 002	21 609	38 845	28 663
Japan	6 298	4 016	8 765	6 872
West Germany	1 678	640	1 439	753
Brazil	731	434	599	439
Spain	339	81	403	210
Taiwan	—	—	146	89
Italy	330	172	158	82
Colombia	—	—	38	38
Other countries	864	258	346	113
Total	51 242	27 210	50 739	37 259
Total aluminum exports	. .	496 690	. .	812 381

Source: Statistics Canada.
^p Preliminary; — Nil; . . Not available; nes Not elsewhere specified.

plant in Maryland by 80 000 tonnes, for an annual output of 240 000 tonnes; and by building a 170 000-tonne-a-year smelter in Oregon. Part of the program is expected to begin in 1978. The Aluminum Company of America is expected to expand its 13 000-tonne-a-year smelter at Palestine, Texas to 27 200 tonnes. The smelter uses Alcoa's new smelting process which is reported to use considerably less power than the 7 to 8 kWh required at present to produce a pound of aluminum.

Trinidad and Tobago has decided to build an aluminum smelter on its own, following the withdrawal of Guyana and Jamaica. The planned capacity of the smelter is 68 000 tonnes a year, using Trinidad's substantial natural gas and oil reserves for power and alumina from Guyana and Jamaica. In Guyana, the two government-owned aluminum companies were merged to form Guyana Mining Enterprise (Guymine), which will operate under the Bauxite Industry Development Company (BICO). The Mexican government approved the building of a $500 million, 150 000-tonne-a-year smelter in Veracruz State. Mexico will hold a 51 per cent interest, Jamaica 29 per cent and the remaining 20 per cent will be held by a foreign partner.

Brazil has enormous resources of bauxite and is expected to develop into a major world supplier. The country should also develop into a substantial producer

Table 2. Canada, primary aluminum production, trade and consumption, 1960, 1965, 1970, 1975, 1976 and 1977

	Production	Imports	Exports	Consumption[1]
	(tonnes)			
1960	691 286	454	500 907	109 616
1965	753 421	6 300	641 844	193 316
1970	862 541	12 179	761 671	250 150
1975	887 023	18 302	509 336	293 280
1976	633 430	22 545	507 832	322 206
1977[p]	983 250	20 785	655 264	332 393

Source: Statistics Canada.
[1]Excluding aluminum metal used in the production of secondary aluminum.
[p]Preliminary.

of aluminum metal. Major development programs are either underway or planned in the Amazon basin area, the source of the largest bauxite reserves in the country. Mineracao Rio do Norte S.A. is developing a large bauxite deposit in the lower reaches of the Trombetas River in Para State, a left-bank tributary of the Amazon River. Companhia Vale do Rio Doce (CVRD), a state-owned company, and other Brazilian interests hold 51 per cent of the company, Alcan 19 per cent and six other aluminum companies, 30 per cent. The initial phase of the project will cost an estimated $U.S. 300 million and output will be 3.3 million tonnes of bauxite. Alcan's share of the output will be 1.2 million tonnes. Shipments should begin in 1979. Two joint-venture companies have been formed to operate a Brazilian-Japanese aluminum project near Belem at the mouth of the Amazon River. The Alumino do Brasil S.A. (Albras) is owned 51 per cent by Brazilian interests and 49 per cent by Japanese interests. The Albras project calls for the construction of a 290 000-tonne-a-year aluminum smelter at a cost of $U.S. 950 million. The Alunorte project (60.8 per cent Brazilian interest, 39.2 per cent Japanese interest) calls for the construction of a 726 000-tonne-a-year alumina refinery at a cost of $U.S. 400 million. Production is expected to start about 1982. Bauxite for this project will come initially from the Trombetas deposit and later from a deposit in the Paragominas area, which is on the right bank of the Amazon and east of Trombetas. Rio Tinto Zinc Corporation Limited and CVRD hold this deposit. A new hydro plant is being constructed near Belem to meet the power needs of the Amazon developments. CVRD has an 82 per cent interest in the Valesul aluminum-smelting project under construction near Rio de Janerio. The smelter is expected to be completed by 1981 at a cost of $U.S. 260 million. Capacity will be 72 000 tonnes a year. Alcan is increasing the capacity of its Saramenha smelter by 28 000 tonnes and completion has been scheduled for 1978.

Industria Venezolana de Alumino, C.A. (Venalum), a company in which Venezuela's state-owned Corporacion Venezolana de Guayana (CVG) has an 80 per cent interest and a six-member Japanese consortium the remainder, is building a smelter complex which is expected to be in production by 1978 and have an initial output of 70 000 tonnes a year . The ultimate capacity of the complex will be 280 000 tonnes a year. Bauxite and alumina for Venezuelan smelting will initially be imported from Jamaica and Surinam. Japan will take 160 000 tonnes of aluminum per year when the plant is operating at full capacity. In 1977 CVG announced the discovery of bauxite deposits with substantial reserves in Eastern Venezuela. Interamericana de Alumina C.A. (Interalumina) was incorporated in 1977 as a joint venture of CVG, with 85 per cent interest, and Swiss Aluminum Ltd. (Alusuisse) and Billiton International Metals B.V., with 7.5 per cent each, to develop this deposit. Plans call for the construction of a one-million-tonne-a-year alumina plant, at a cost of $U.S. 686 million, with the first of two units of 500 000-tonne capacity each expected to be operational by 1981.

Australia is the world's largest producer of bauxite and in 1977 accounted for 35.5 per cent of the non-communist world total. In 1977 Australia produced an estimated 25.2 million tonnes, an increase of 8.3 per cent over the previous year. Plans have been initiated to construct two alumina refineries in Western Australia. Alcoa of Australia Ltd. has announced its intention to build an alumina refinery with an initial annual output of 200 000 tonnes. Alcoa withdrew from the $600 million Alwest project, but the original partners, Reynolds, Dampier Mining Company Limited and News Ltd. expect to proceed with it and are looking for a partner to replace Alcoa. This plant will have an alumina output of about 800 000 tonnes a year. Comalco Limited completed the 19 000-tonne-a-year expansion of its Bell Bay smelter in Tasmania, bringing the smelter's capacity to 112 000 tonnes a year. Comalco has a 50 per cent interest in New Zealand Aluminium Smelters Ltd. Power costs, supplied to this smelter by the New Zealand government, have been increased by about 400 per cent. Alcan Australia Limited, in which Alcan holds a 70 per cent interest, is expanding its 45 000-tonne-a-year Kurri-Kurri aluminum smelter by 22 500 tonnes and it is expected to be completed in 1979.

As a result of the increase in oil prices in 1973, the cost of energy to the Japanese aluminum smelters has risen sharply, increasing the cost of aluminum production. The generally slow economic recovery has resulted in a substantial inventory buildup at the smelters. To offset these adverse factors, the Japanese aluminum smelters reduced output in 1977 and operated at about 72 per cent capacity.

P.T. Indonesia Asahan Aluminum Company has been formed by the government of Indonesia and Nippon Asahan. The Asahan project involves a 204 000-tonne-a-year aluminum smelter and 510-megawatt power plant on the Asahan River in North-

Table 3. Canada, consumption of aluminum at first processing stage, 1974-77

	1974	1975	1976	1977^p
	(tonnes)			
Castings				
Sand	1 715	1 292	1 142	1 277
Permanent mould	13 937	13 152	17 116	21 836
Die	20 926	17 310	20 899	16 413
Other	2	49	16	65
Total	36 580	31 803	39 173	39 591
Wrought products				
Extrusions including tubing	96 140	77 989	83 814	84 019
Sheet, plate, coil and foil	141 721	106 175	134 527	134 278
Other wrought products (including rod, forgings and slugs)	73 705	64 469	53 889	61 318
Total	311 566	248 633	272 230	279 615
Destructive uses				
Nonaluminum base alloys, powder and paste deoxidizers and other	11 644	12 844	10 803	13 187
Total consumed	359 790	293 280	322 206	332 393
Secondary aluminum[1]	36 155	31 201	52 246	51 260

	Metal entering plant		On hand December 31	
	1975	1976	1975	1976
Primary aluminum ingot and alloys	269 620	293 144	83 049	80 597
Secondary aluminum	26 236	36 969	2 586	2 536
Scrap originating outside plant	15 071	54 623	1 940	14 426
Total	310 927	384 736	87 575	97 559

Source: Statistics Canada.
[1] Aluminum metal used in the production of secondary aluminum.
^{p} Preliminary.

ern Sumatra. The first 68 000 tonnes of capacity is expected to be on stream by 1981. P.T. Aneka Tambang, the state mining enterprise, is seeking finances to construct a 500 000-tonne-a-year alumina smelter on Bintan Island to feed the above smelter. Japan and Russia withdrew from the project.

The $600 million Dubai aluminum smelter is scheduled to come on stream in 1979 with an annual capacity of 122 000 tonnes. Alcoa of Australia has signed a ten-year agreement to supply 180 000 tonnes of alumina annually to the smelter.

The second 25 000-tonne unit of Bharat Aluminium Company of India, located in Madya Pradesh State, was brought into production in 1977.

A $1.9 billion aluminum complex in Libya, slated for production by 1980, has been announced by a Yugoslavian consortium. The group will construct an aluminum smelter, a petroleum coke facility and a thermal power station. Alumina for the smelter will be supplied by Yugoslavia and that country will increase bauxite output and alumina refining capacity to meet its commitment.

Empresa Nacional del Aluminio S.A. of Spain, in which Alcan holds a 25 per cent interest, has a 55 per cent interest in a large smelter and alumina complex under construction at San Ciprian on the Atlantic Coast. Alcan is providing the engineering design for the alumina plant which is expected to be in production

Table 4. World primary aluminum production and consumption, 1976 and 1977

	Production		Consumption	
	1976	1977^p	1976	1977^p
	(000 tonnes)			
United States	3 856.8	4 117.5	4 460.1	4 756.0
Europe[1]	3 347.3	3 486.1	3 508.4	3 471.2
Japan	919.4	1 188.2	1 609.8	1 572.3
Canada	633.4	983.2	322.2	330.0
Australia and New Zealand	372.1	392.7	190.8	191.7
Asia (excluding Japan and China)	445.2	421.3	467.9	496.0
Africa	337.2	364.2	139.2	124.5
America (excluding United States and Canada)	316.0	359.2	403.1	400.8
Sub-Total	10 227.4	11 312.4	11 101.5	11 342.5
Communist countries[2]	2 856.5	2 911.3	2 885.0	2 906.0
Total	13 083.9	14 223.7	13 986.5	14 248.5

Sources: World Bureau of Metal Statistics; for Canada, Statistics Canada; for United States production, U.S. Bureau of Mines, Mineral Commodity Summaries, 1978.
[1] Includes Yugoslavia. [2] Excludes Yugoslavia.
^{p} Preliminary.

in 1979 with an initial capacity of 800 000 tonnes a year. Tentative capacity of the aluminum smelter is 160 000 tonnes.

Alcan announced that it will proceed with the construction of a $500 million, 800 000-tonne-a-year alumina refinery on Aughinish Island in the mouth of the Shannon River, Ireland, with production to start in 1982. Aughinish Alumina Ltd., the company formed to operate the plant, is a joint venture in which Alcan Ireland Limited has a 40 per cent interest, Billiton Aluminum Ireland Limited 35 per cent, and Anaconda Ireland Co. 25 per cent.

Stockpiles

The Light Metals Stockpile Association in Japan did not add to its 9 750 tonnes of aluminum stockpiled in 1976. The ministry of International Trade and Industry (MITI) is seeking funds to add 10 000 tonnes of refined aluminum to the government's stockpile in 1978. The stockpile objectives of the United States government and present stockpile inventories of alumina, bauxite and aluminum remained unchanged at the end of 1977.

Technology

Research is being done on the development of an economic process to produce alumina from nonbauxite, alumina-bearing minerals such as clays, alunite, anorthosite and coal wastes. West German aluminum producer Vereinigte Aluminium Werke (VAW) reported that it had developed a new process for converting bauxite into alumina that significantly reduces the amount of fuel required to produce a tonne of alumina. VAW considers that the new technology could have value to companies planning new capacity, or expansion of alumina output. Alcoa is testing its new smelting process, designed to use 30 per cent less energy in the smelting cell than the present technology, at its new 13 600-tonne-a-year potline at Palestine, Texas.

Uses

The physical and chemical characteristics of aluminum make it an ideal metal for many industrial uses. The United States is by far the world's largest consumer of aluminum. According to the United States Bureau of Mines, construction continued to be the largest consumer of the metal in 1977, accounting for 25 per cent of the country's total consumption. Other large consumer industries were: packing, 22 per cent; transportation, 21 per cent; electrical, 11 per cent; consumer durables, 9 per cent and other uses, 12 per cent. In the

Table 5. Canadian primary aluminum smelter capacity, 1977

Smelter location	Annual capacity
	(tonnes)
Aluminum Company of Canada, Limited (Alcan)	
Quebec	
Jonquière (formerly Arvida)	421 900
Isle-Maligne	75 300
Shawinigan	82 500
Beauharnois	46 300
British Columbia	
Kitimat	267 600
Total Alcan capacity	893 600
Canadian Reynolds Metals Company, Limited	
Quebec	
Baie-Comeau	158 800
Total Canadian capacity	1 052 400

Source: Compiled from various company reports by the Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.

other major industrial nations, construction and transportation industries are the largest consumers of aluminum.

Aluminum usage in passenger cars has increased from 76 pounds per vehicle in the 1973 model-year to 100 pounds in 1977 and according to the Aluminum Association it is expected to increase to between 150 and 175 pounds per vehicle by 1980. The trucking industry is also turning more to the use of aluminum, and as transportation costs continue to escalate, aluminum use will grow because it provides substantial weight reduction and, as a result, fuel saving.

Prices

World prices of primary aluminum ingot increased in two steps during 1977; from 48 cents to 51 cents a pound effective April 1 and from 51 cents to 53 cents a pound effective the first part of July. Prices for other ingot forms and fabricated products were adjusted to match the above price increases. In 1977, any increase in the price of aluminum ingot or other aluminum products sold in Canada by Canadian producers required the approval of the Anti-Inflation Board (AIB). This did not apply to aluminum exported. An application submitted by Alcan to the AIB in March for a 3-cent-a-pound increase in the price of aluminum ingot was rejected. A subsequent reapplication to AIB was approved in June, as well as higher rates for a number of semifabricated products. In September the AIB approved a further 2 cents a pound on domestic ingot, increasing the price to 53 cents a pound. It also allowed increases on some product lines, but in the case of five other product lines restricted the price increase to reflect the 2 cent increase in ingot price.

In the second half of the year the world dealer price for ingot weakened and dropped to a range of 46 to 47 cents a pound. A number of price increases for rolled and fabricated products, which were to come into effect in October, were deferred because of consumer resistance.

Outlook

At the end of 1977 the supply-demand equation for the aluminum industry was in comparatively close balance and in the short term no problems are envisaged that will alter the stability of the industry. Stocks in the hands of producers are at a manageable level. The structure of the aluminum industry allows the major producers to keep inventory levels under control. It is expected that producers will continue to maintain selfdiscipline and preserve the financial viability of the industry.

Production of primary aluminum is expected to show a small increase in 1978 and 1979 and consumption is expected to parallel output. The building trades and transportation industry, the largest consumers of aluminum, are expected to remain strong. Increased production will come from new or expanded smelter capacity and increased efficiencies of present plants.

The aluminum industry is a high consumer of energy and increasing power costs should spur the growth of the recycling industry. Recycled aluminum consumes only about 5 per cent of the energy that is required to extract aluminum from bauxite.

Table 6. Estimated world production of bauxite in 1977

	Production
	(million tonnes)
Australia	25.2
Guinea	11.5
Jamaica	11.4
Surinam	4.6
Guyana	3.1
Greece	3.0
France	2.2
United States	2.0
Other non-communist countries	7.2
Total non-communist countries	70.2
Communist countries	12.1
World total	82.3

Source: United States Bureau of Mines, Mineral Commodity Summaries, January 1978.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
32910-1	Bauxite	free	free	free	free
35301-1	Aluminum pigs, ingots, blocks, notch bars, slabs, billets, blooms and wire bars	free	1¢ per lb	5¢ per lb	na
35302-1	Aluminum bars, rods, plates, sheets, strips, circles, squares, discs and rectangles	free	2¢ per lb	7.5¢ per lb	free
35303-1	Aluminum channels, beams, tees and other rolled, drawn or extruded sections and shapes	free	12½%	30%	free
35305-1	Aluminum pipes and tubes	free	12½%	30%	free
92820-1	Aluminum oxide and hydroxide; artificial corundum (this tariff includes alumina)	free	free	free	free

United States

Item No.		
417.12	Aluminum compounds: hydroxide and oxide (alumina)	free
601.06	Bauxite	free
618.01	Unwrought aluminum in coils, uniform cross section not greater than 0.375 inch	1.2¢ per lb
618.02	Other unwrought aluminum, excluding alloys	1¢ per lb
618.04	Aluminum silicon	1¢per lb
618.06	Other aluminum alloys	1¢ per lb
618.10	Aluminum waste and scrap	0.7¢ per lb

Sources: For Canada, The Custom Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa; for United States, Tariff Schedules of the United States Annotated (1978) TC Publication 843.
Various tariffs are in effect on more advanced fabricated forms of aluminum.
na Item does not qualify under the General Preferential Tariff.

Antimony

J.G. GEORGE

Canada's production of antimony is derived not only as a byproduct of lead smelting operations, principally in the form of antimonial lead, but also as an antimonial dross and, in much smaller quantities, as high-purity antimony metal. The value of the antimony content of primary antimonial lead alloy produced in 1977 was $2 491 000, compared with $1 636 871 in 1976. The value of antimony contained in ores and concentrates produced in 1977 was $6 463 000, compared with $6 777 620 in 1976. The quantity of antimony contained in ores and concentrates, as reported by Statistics Canada, is withheld to protect the confidentiality of the sole producer.

Imports of antimony oxide in 1977 totalled 626 184 kilograms (kg), of which the United Kingdom supplied 88 per cent, the United States 6 per cent, and Belgium and Luxembourg 5 per cent. Antimony regulus (metal) import statistics were discontinued in 1964.

Cominco Ltd., which operates a lead smelter and refinery at Trail, British Columbia, is the main producer of primary antimonial lead in Canada. It can produce antimonial lead with an antimony content ranging up to 23 per cent, depending on customer requirements. Cominco produced 596 tonnes* of antimony contained in a 19 per cent antimonial-lead alloy in 1977 compared with 447 tonnes in an 18 per cent antimonial-lead alloy in 1976. The only other primary producer of antimonial lead is Brunswick Mining and Smelting Corporation Limited, Smelting Division, which operates a lead plant at Belledune, New Brunswick. This company produced 210 tonnes of antimony contained in a slag in 1977, compared with 262 tonnes in a slag in 1976. Secondary smelters recovered antimonial lead from scrap metal, but no recent information is available concerning this production.

Domestic sources and occurrences

Most of the antimonial lead produced at Trail is a byproduct of the lead concentrate obtained from ores of Cominco's Sullivan mine at Kimberley, British Columbia. Other sources are the lead-silver ores and concentrates shipped to Trail from other Cominco mines and from custom shippers. The lead bullion produced from the smelting of these ores and concentrates contains about 1 per cent antimony, which is recovered in anode residues from the electrolytic refining of the lead bullion, and in furnace drosses produced during purification of the cathode lead. These residues and drosses are treated to yield antimonial-lead alloy, to which refined lead may be added to produce marketable products of the required grade. At Belledune, the Brunswick Mining and Smelting plant has facilities for producing antimonial-lead alloys of varying grades to suit market requirements.

Consolidated Durham Mines & Resources Limited operates Canada's only antimony mine. It mines low-angle dipping veins containing stibnite, Sb_2S_3, at its Lake George property near Fredericton, New Brunswick. Development of the new 213-metre (m) level continued during 1977, and exploration work at the property included a surface diamond drilling program of 6 100 m. The concentrator, with a capacity of 360 tonnes of ore a day, treated almost 78 000 tonnes of ore in 1977 to produce about 3 900 tonnes of concentrate averaging approximately 65 per cent antimony. Concentrates are shipped mainly to Europe, Japan and the United States. At the end of June 1977, reserves were 353 000 tonnes grading 4.22 per cent antimony, sufficient to continue operating at current levels for another four and a half years.

Equity Mining Corporation continued exploration of its silver-gold-copper-antimony property near Houston, British Columbia. The company is considering plans to bring the property into production late in 1979 at a rate of 3 000 to 4 500 tonnes of ore a day if suitable arrangements can be made to obtain senior financing. Reserves of ore mineable by open-pit methods have been estimated at 39.5 million tonnes, grading 95.3 grams of silver and 0.89 gram of gold a tonne, 0.33 per cent copper and 0.82 per cent antimony.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Metallurgical studies have indicated that antimony could be extracted from the concentrates and be an important byproduct.

Con-Am Resources Ltd. began a $245 000 three-phase exploration program on its Carbon Hill antimony prospect near Whitehorse in the Yukon Territory. The property was owned and developed in the period 1964 to 1967 by the Yukon Antimony Corporation Ltd. Reserves of 127 000 tonnes grading 4 per cent antimony were established by Yukon Antimony.

World review

Increasing use of the lead-calcium automotive battery continued to cut into the demand for antimony, and could lead to a significant buildup of antimonial-lead inventories. The declining demand for antimonial-lead auto batteries will be offset somewhat by growth in demand for other types of batteries with high antimony content, such as the traction battery used by industry, and by increased consumption of antimony oxide as a flame retardant.

Table 1. Canada, antimony production, imports and consumption, 1975-77

	1976		1977p	
	(kilograms)	($)	(kilograms)	($)
Production (primary)				
Antimonial lead alloy (antimony content)	477 003	1 636 871	590 000	2 491 000
Antimony in ores and concentrates	. .	6 777 620	. .	6 463 000
Total	. .	8 414 491	. .	8 954, 000
Imports				
Antimony oxide				
United Kingdom	614 346	1 851 000	553 881	1 827 000
United States	86 228	305 000	35 380	133 000
Belgium and Luxembourg	33 747	100 000	33 929	108 000
France	—	—	2 994	15 000
Total	734 321	2 256 000	626 184	2 083 000

	1976			1977p		
	Antimony regulus[1]	Antimonial lead alloy[2]	Total	Antimony regulus[1]	Antimonial lead alloy[2]	Total
Consumption[3]	(kilograms)					
Antimony used for, or in the production of:						
Antimonial lead	299 310	. . .	299 310	254 385	. . .	254 385
Babbitt	25 906	5 714	31 620	18 660	6 268	24 928
Batteries	. . .	899 323	899 323	. . .	1 067 298	1 067 298
Solder	18 966	16 107	35 073	17 929	15 518	33 447
Type metal	13 554	114 481	128 035	16 976	115 190	132 166
Other commodities	80 262	2 609	82 871	62 917	142	63 059
Total	437 998	1 038 234	1 476 232	370 867	1 204 416	1 575 283
Held by consumers on December 31[3]	30 338	224 664	255 002	27 932	132 262	160 194

Source: Statistics Canada.
[1]Antimony metal. [2]Antimony content of primary and secondary antimonial lead alloys. [3]Available data, as reported by consumers.
pPreliminary; . . Not available; — Nil; . . . Not applicable.

World mine production of antimony, as estimated by the United States Bureau of Mines, declined 4 per cent in 1977 to 66 469 tonnes, compared with 69 205 tonnes in 1976. Antimony is produced from ores and as a smelter byproduct in about 25 countries. The major sources of ore are Bolivia, the People's Republic of China, the Republic of South Africa, U.S.S.R., Turkey, Thailand, Mexico, Canada and Yugoslavia.

Table 2. Canada, consumption and consumers' stocks of antimony[1], 1968-1977

	Consumption			On hand at end of year		
	Antimony regulus[2]	Antimonial lead alloy[3]	Total	Antimony regulus[2]	Antimonial lead alloy[3]	Total
		(kilograms)			(kilograms)	
1968	530 536	963 840	1 494 376	170 249	66 863	237 112
1969	592 275	1 053 137	1 645 412	236 689	68 957	305 646
1970	518 007	635 212	1 153 219	131 501	91 563	223 064
1971	672 007	986 602	1 658 609	107 494	92 790	200 284
1972	919 114	983 762	1 902 876	125 983	125 180	251 163
1973	444 323	963 041	1 407 364	156 091	258 649	414 740
1974	983 785	1 196 805	2 180 590	79 142	240 963	320 105
1975	454 164	723 155	1 177 319	116 760	170 478	287 238
1976	437 998	1 038 234	1 476 232	30 338	224 664	255 002
1977[p]	370 867	1 204 416	1 575 283	27 932	132 262	160 194

Source: Statistics Canada.
[1]Available data, as reported by consumers. [2]Antimony metal. [3]Antimony content of primary and secondary antimonial lead alloys.
[p]Preliminary.

Consolidated Murchison Limited operates the world's largest antimony mine near Gravelotte in northern Transvaal, Republic of South Africa. The company processed 671 900 tonnes of ore in 1977 compared with 642 800 tonnes in 1976. Antimony concentrates and cobbed ore produced in 1977 totalled 19 825 tonnes with an average grade of 57.25 per cent antimony, compared with 18 341 tonnes averaging 57.93 per cent antimony in 1976. Reserves are sufficient for eight more years of mine operation at current production levels. About one-third of the mine's concentrate output is converted to crude antimony oxide at the nearby plant of Antimony Products (Proprietary) Limited, in which Consolidated Murchison holds a 37.5 per cent interest. Consolidated Murchison's pilot plant for treating its high arsenic concentrates to produce a saleable antimony sulphide was commissioned in 1977. However, the problem of recovering the solvent used in the process has still to be resolved before the process can be considered viable.

Bolivia was the world's largest antimony producing country in 1977 with an estimated mine output of 12 700 tonnes.

In October 1977, NL Industries, Inc. closed down its antimony smelter at Laredo, Texas and has no plans for reopening it. The closure was brought about because the plant was very old and needed extensive modernization. Operating costs were rising significantly. Other factors were declining antimony prices and the less than favourable outlook for antimony's use in the automotive battery industry. The plant was the world's largest smelter for processing antimony ores and concentrates.

In 1977 ASARCO Incorporated completed construction at El Paso, Texas of a new $7 million plant to produce refined antimony metal from concentrates produced at ASARCO's silver mines in Idaho. The plant, with a capacity of 1 650 tonnes of 99.5 per cent pure antimony metal a year, was expected to be in full production by the second quarter of 1978. ASARCO also began construction at Omaha, Nebraska of a new $2.6 million plant to produce antimony oxide. It was expected to be completed about mid-1978.

The United States was again the non-communist world's largest consumer of antimony and continued to depend on foreign suppliers, particularly South Africa, Bolivia, United Kingdom, Mexico and France, for the major portion of its requirements. Its total consumption of primary antimony in 1977, at 9 163 tonnes, was equivalent to almost 14 per cent of world primary production.

In 1977 there were no sales by the United States General Services Administration of antimony from the nation's strategic and critical materials stockpile. The goal of 18 260 tonnes of antimony established by the U.S. Federal Preparedness Agency late in 1976 remained unchanged. At the end of 1977 the stockpile contained 36 935 tonnes. The 18 675-tonne surplus of antimony may not, however, be disposed of without congressional approval. The disposal policy of the United States administration has yet to be determined.

Uses

Antimony is used principally as an ingredient in many alloys and in the form of oxides and sulphides.

Table 3. World mine production of antimony, 1975-77

	1975	1976p	1977e
	(tonnes)		
Bolivia	11 917[1]	15 307[2]	12 700
People's Republic of China	11 793	11 793	. . .
Republic of South Africa	15 923	10 786	10 886
U.S.S.R.	7 530	7 711	. . .
Turkey	3 638	4 328	. . .
Thailand	3 133	3 671	. . .
Mexico[3]	3 137	2 546	2 268
Canada[4]	1 833	1 987	. . .
Yugoslavia	2 183	1 914	2 722
Australia	1 923	1 649	. . .
Morocco	1 052	1 415	. . .
Guatemala	856	1 120	. . .
Italy	1 010	1 015	. . .
United States	804	257	699
Czechoslovakia	753	753	. . .
Peru (recoverable)	277	603	. . .
Other countries	1 819	2 350	37 194
Total	69 581	69 205	66 469

Sources: Preprint from the 1976 U.S. Bureau of Mines, *Minerals Yearbook* for 1975 and 1976 statistics. U.S. Bureau of Mines Mineral Commodity Summaries 1978 for 1977 statistics.
[1]Production by Corporacion Minera de Bolivia (COMIBOL) plus exports by medium and small mines and so-called other producers. [2]Total national production. [3]Antimony content of ores for export plus antimony content of antimonial lead and other smelter products produced. [4]Estimated on the basis of value of production.
pPreliminary; eEstimated; . . . Data not available but estimate included in figure for "other countries".

Antimony hardens and strengthens lead and inhibits chemical corrosion. The use of antimonial lead in storage batteries remains its major outlet, but due to technological developments the antimony content in batteries has been progressively reduced in recent years, from about 12 per cent to current levels that vary from 2.5 to 6 per cent of the antimonial lead contained. Because of this rapid technological change in the lead-acid battery market, the use of antimony in this sector is expected to decline substantially over the next 5 to 10 years through a replacement of antimony by calcium and other lead alloys.

Antimonial lead alloys are also used for power transmission and communications equipment, printing metal, solder, ammunition, chemical pumps and pipes, tank linings, roofing sheets and antifriction bearings. Antimony increases hardness, minimizes shrinkage, permits sharp definition, and lowers the melting point of type metal. In antifriction bearings, the antimony forms hard tin-antimony crystals that increase bearing life.

Table 4. Industrial consumption of primary antimony in the United States, by class of material produced

	1975	1976	1977p
	(tonnes, antimony content)		
Metal products			
Ammunition	217	57	126
Antimonial lead[1]	4 144	3 503	2 829
Bearing metal and bearings	365	367	179
Cable covering	21	17	13
Castings	16	22	—
Collapsible tubes and foil	8	21	14
Sheet and pipe	54	67	43
Solder	121	170	125
Type metal	68	72	22
Other	109	149	33
Total[1]	5 123	4 445	3 384
Nonmetal products			
Ammunition primers	13	12	7
Fireworks	9	11	6
Ceramics and glass	897	1 143	1 044
Pigments	291	377	197
Plastics	990	1 158	644
Rubber products	415	524	145
Other	597	1 207	403
Total	3 212	4 432	2 446
Flame retardants			
Plastics	2 269	3 426	2 456
Pigments	83	166	6
Rubber	156	181	143
Adhesives	114	128	54
Textiles	679	957	674
Paper	145	179	—
Total	3 446	5 037	3 333
Grand total	11 781	13 914	9 163

Sources: Preprint from the 1976 U.S. Bureau of Mines, *Minerals Yearbook* for 1975 and 1976 statistics.
[1]Includes primary antimony content of antimonial lead produced at primary lead refineries.
pPreliminary; — Nil.

Antimony oxide, Sb_2O_3, usually produced directly from high-grade sulphide ore, is used extensively in plastics and in flameproofing compounds, the most important growth area in antimony consumption.

Antimony trioxide or trichloride in an organic solvent has long been recognized as having significant flame-retardant properties and is now used extensively in carpets, rugs and carpet underlay. The trioxide is also a glass-former and is sought for its ability to impart hardness and acid resistance to enamel coverings for bathtubs, sinks, toilet bowls and refrigerators. Sodium antimonate is used in the production of high-quality glass and has a growing use in the manufacture of television screens. The pentasulphide, Sb_2S_5, is used as a vulcanizing agent by the rubber industry. Burning antimony sulphide creates a dense white smoke that is used in visual control, in sea markers and in visual signaling.

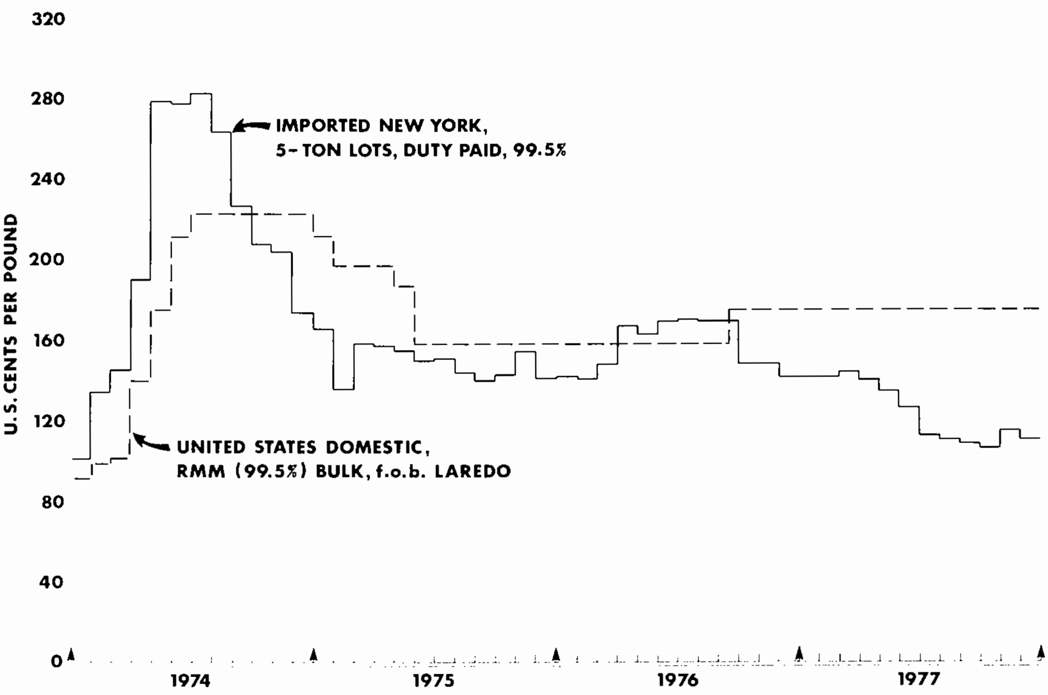
Antimony is valuable for paint formulation because of its high hiding power and, along with various chemical compounds, it produces a wide range of pigments. High-purity metal is used by manufacturers of indium-antimony and aluminum-antimony intermetallic alloys as a semiconductor in transistors and rectifiers.

Outlook

The world outlook for antimony is not as favourable as it was a few years ago. The traditional use of antimonial lead in battery grids is on the decline because the new "maintenance-free" batteries use either a lesser amount of antimony or no antimony at all. In many of these batteries antimony has been completely replaced by a calcium-tin-lead alloy or some other type of lead alloy. The declining demand for antimonial lead auto batteries will be offset somewhat by growth in demand for other types of batteries with high antimony content, such as the traction battery used by industry. Secondary refiners may soon find large stocks of unsaleable antimonial lead on their hands. As yet, the recyclers of spent batteries do not have the technology to extract the antimony and produce oxide, a much more saleable product.

On the positive side, expansion in the use of flame retardants, as well as greater usage in industries such as rubber, plastics and ceramics, could bring about higher rates of growth in demand for antimony oxide. Also, government legislation continues to play a role in expanding the demand for flame retardants.

ANTIMONY METAL PRICES



Source: METALS WEEK

Flameproofing regulations now apply in the United States to children's sleepwear, automobile upholstery, bedding products, carpet fibres and underlays, plus numerous other textile items. Government legislation in Europe in this regard is also becoming more common.

With antimony stocks likely to remain in oversupply for the foreseeable future, any sustained recovery in prices is unlikely. In fact, antimony metal prices could display fresh price weakness. On the other hand, ore and oxide prices might firm up somewhat if there should be an improvement in the generally depressed world economy. Prices are also affected by the continuing unpredictability of Chinese antimony supplies.

Prices

The United States domestic price for antimony metal (RMM brand), as quoted in *Metals Week*, for 99.5 per cent antimony in carload lots, fob Laredo, Texas, remained unchanged throughout 1977 at $1.75 a pound. The price of Lone Star brand antimony metal, 99.8 per cent antimony, in carload lots, fob Laredo, Texas, also remained unchanged throughout the year at $2.10 a pound. On the other hand, the New York dealer price for foreign antimony metal displayed an almost steadily declining trend in 1977. Early in January the dealer price for 99.5 to 99.6 per cent antimony metal, cif port, for 5-short-ton lots, as quoted in *Metals Week*, was $1.45 to $1.50 a pound. The price peaked at $1.43 to $1.60 in February, declined to a low of $1.00 in October and closed in December at $1.10 to $1.15 a pound.

The European free market metal price, 99.6 per cent antimony, cif Europe, as quoted in *Metal Bulletin*, opened the year at $U.S. 3 000 to $U.S. 3 085 a tonne and then rose to a high for the year of $U.S. 3 085 to $U.S. 3 150 late in January. Thereafter, the price trend was generally declining until late in September, when a low for the year of $2 000 to $2 050 a tonne was reached. During the last quarter of 1977 the price increased somewhat, and at the end of December it was $U.S. 2 140 to $U.S. 2 180 a tonne.

Antimony ore prices in the United States market, as quoted in *Metals Week*, remained unchanged at $23.50 to $25.00 a short ton unit (stu) for 60 per cent lump ore, from the beginning of January 1977 until late August when the price was reduced to $16.20 to $18.20. The lower price remained in effect until the end of the year.

Tariffs

Canada

Item No.		British Preferential	General Preferential	Most Favoured Nation	General
33000-1	Antimony, or regulus of, not ground, pulverized or otherwise manufactured	free	free	free	free
33502-1	Antimony oxides	free	free	12½%	25%

United States

TSUS No.		Non-communist countries	Communist countries except Yugoslavia
601.03	Antimony ore	free	free
632.02	Antimony metal, unwrought; waste and scrap[1]	1¢ per lb	2¢ per lb

European Economic Community (EEC)

Brussels Tariff Nomenclature No.		Autonomous	Conventional
26.01	Antimony ore	free	free
81.04	I. Antimony, unwrought; waste and scrap[2]	8%	
	II. Other antimony	10%	8%

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa; Tariff Schedules of the United States, Annotated (1978) TC Publication 843; Official Journal of the European Communities, volume 20, No. L289, November 1977.
[1]Duty on antimony waste and scrap temporarily suspended. [2]Where no conventional duty is quoted, duty shall normally be chargeable at the rate of the autonomous duty.

Asbestos

G.O. VAGT

Shipments of asbestos in 1977 remained at essentially the same level as in 1976, mainly on the strength of shipments to developing countries. There was no growth in demand in the industrialized countries as a result of depressed world economic conditions.

The Quebec government announced that it will become directly involved in the asbestos industry by purchasing from General Dynamics Corporation, of St. Louis, Missouri, its 54.6 per cent holding in Asbestos Corporation Limited, the second largest asbestos producer in Canada.

Canadian production (shipments)

Canadian production of asbestos fibre in 1977 was 1 543 000 tonnes* valued at $564 130 000, compared with 1 536 091 tonnes valued at $452 208 338 in 1976. Approximately 82 per cent of total production is from Quebec, 6 per cent each from British Columbia and Yukon Territory, 5 per cent from Newfoundland and less than 1 per cent from Ontario.

Canada exported nearly 92 per cent of its total production of asbestos fibre to more than 80 countries. Exports totalled 1 415 218 tonnes in 1977 with nearly 75 per cent of the total distributed among the following 10 countries: United States, 36.2; West Germany, 8.8; Japan, 8.7; United Kingdom, 6.0; Australia, 4.3; Spain, 3.0; France, 2.7; Mexico, 2.1; Belgium and Luxembourg, 1.6. This quantity provides the noted approximate percentage of total asbestos imports: United States, 95 per cent; European Economic Community, 55 per cent; Japan, 40 per cent; eastern Europe, 7 per cent and others 54 per cent.

The value of Canadian exports of manufactured asbestos products in 1977 was $25 301 000 compared with $14 874 000 in 1976, according to Statistics Canada. The value of imports of manufactured asbestos products was $24 324 000 in 1977 compared with $23 496 000 in 1976.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Canadian developments

A bill to create a Quebec Crown Corporation Société nationale de l'amiante (SNA) was given first reading on November 29, 1977 in the Quebec National Assembly. Authorized capitalization of SNA will be $250 million to implement the government's direct participation in the asbestos mining industry. A planned $250 million will be set aside for purchase of Asbestos Corporation Limited (ACL) and for the following goals: to transform into finished products from 10 per cent to 12 per cent of the fibre produced in Quebec; to start new product research and development; to undertake joint ventures with other asbestos mining and manufacturing companies; and to evaluate new mining projects. Currently, only about 3 per cent of the asbestos output from Quebec is transformed into finished products. An asbestos office, under jurisdiction of the Quebec Department of Natural Resources (Le Bureau de l'Amiante du Quebec), will plan the transition to establish an active role for SNA in the industry, prepare necessary laws and regulations to apply the asbestos policy and will also negotiate development intentions with present producers.

The Quebec government's stated reasons for the proposed takeover were: ACL has a relatively large proportion of the world export markets; the company has good-quality fibre; it has adequate reserves and is not vertically integrated. As well, ACL has a satisfactory profit record, and its shares trade freely on the stock market. The company employs over 2000 people in Quebec and about 150 at its final milling facility in West Germany.

Developments at the asbestos producing mines in Canada are highlighted in Table 2. Canadian Johns-Manville Company, Limited continued its $77 million, five-year investment program designed to ensure optimum annual production of over 600 000 tonnes of fibre a year over the next 25 years.

Asbestos Corporation Limited closed its Normandie open-pit mine after 24 years of operation. The King-Beaver open-pit mine and ore preparation plant were reactivated, and beneficiated ore was transported

11 kilometres (km) to the Normandie mill. The King-Beaver underground operation continued to supply nonbeneficiated ore to the British Canadian plant. In Ungava the Asbestos Hill mine, at Putuniq, attained production targets. An underground experimental mining program commenced, and a decision on a full underground operation must await completion of this work.

Bell Asbestos Mines, Ltd. completed a $10 million mill modernization program started in 1973 and will invest $3.7 million in order to increase by approximately 30 per cent its annual output of fibre.

Lake Asbestos of Quebec, Ltd. completed installations to improve dust control at its Black Lake mine and also completed an additional modernization and air purification program at its National Division in Robertsonville, near Thetford Mines.

Cassiar Asbestos Corporation Limited continued

Table 1. Canada, asbestos production and trade, 1976 and 1977

	1976		1977^p	
	(tonnes)	($)	(tonnes)	($)
Production (shipments)				
By type				
Crude, groups 1, 2 and other milled	27	60 000	. .	. .
Group 3, spinning	30 291	33 498 000	. .	. .
Group 4, shingle	460 031	228 092 000	. .	. .
Group 5, paper	190 681	65 384 000	. .	. .
Group 6, stucco	253 164	57 821 000	. .	. .
Group 7, refuse	601 874	67 352 000	. .	. .
Group 8, sand	23	1 000	. .	. .
Total	1 536 091	452 208 000[1]	543 000	564 130 000[1]
By province				
Quebec	1 246 312	339 129 883	1 261 000	430 830 000
British Columbia	70 444	40 727 296	96 000	59 940 000
Yukon	103 431	35 310 723	102 000	37 180 000
Newfoundland	89 017	34 445 154	71 000	35 000 000
Ontario	26 887	2 595 282	13 000	1 180 000
Total	1 536 091	452 208 338	1 543 000	564 130 000
Exports				
Crude				
United States	22	15 000	1	3 000
France	9	19 000	—	—
United Kingdom	49	22 000	—	—
Japan	3	6 000	—	—
Total	83	62 000	1	3 000
Milled fibre (groups 3, 4 and 5)				
United States	130 218	62 953 000	123 341	73 257 000
West Germany	99 457	42 836 000	90 625	54 562 000
Australia	42 802	20 659 000	53 449	30 714 000
United Kingdom	53 514	30 086 000	40 917	26 527 000
Spain	28 260	15 004 000	35 292	21 642 000
Japan	44 994	18 539 000	35 326	18 012 000
Mexico	22 415	12 019 000	24 490	14 795 000
Italy	21 130	12 022 000	23 252	14 721 000
France	35 705	18 978 000	23 310	13 783 000
India	17 457	9 500 000	16 183	9 907 000
Brazil	12 115	6 777 000	14 560	8 742 000
Belgium and Luxembourg	29 220	15 860 000	14 241	8 610 000
Other countries	171 207	84 950 000	210 666	125 094 000
Total	708 494	350 183 000	705 652	420 366 000

Table 1. (cont'd)

	1976		1977^{p}	
	(tonnes)	($)	(tonnes)	($)
Shorts (groups 6, 7, 8 and 9)				
United States	426 243	62 301 000	389 628	64 909 000
Japan	100 473	20 472 000	87 893	20 405 000
United Kingdom	41 453	5 971 000	43 440	7 486 000
West Germany	35 361	6 396 000	33 851	6 733 000
Netherlands	34 472	4 784 000	27 451	4 389 000
South Korea	12 047	3 016 000	9 649	2 716 000
France	20 560	2 586 000	15 457	2 493 000
Thailand	8 594	1 972 000	7 677	2 119 000
Belgium and Luxembourg	7 134	1 589 000	8 858	1 994 000
Australia	5 975	1 045 000	7 912	1 682 000
Spain	7 568	1 589 000	6 459	1 589 000
Brazil	6 752	1 015 000	8 941	1 353 000
Argentina	7 431	1 382 000	6 815	1 270 000
Mexico	6 666	1 289 000	5 079	1 176 000
Switzerland	1 358	296 000	3 140	919 000
Other countries	47 393	9 946 000	47 315	11 682 000
Total	769 480	125 649 000	709 565	132 915 000
Grand total crude, milled fibres and shorts	1 478 057	475 894 000	1 415 218	553 284 000
Manufactured products				
Asbestos cloth, dryer felts, sheets				
United States		2 136 000		1 085 000
United Kingdom		30 000		88 000
Thailand		11 000		32 000
New Zealand		–		17 000
Venezuela		–		9 000
Philippines		–		4 000
Other countries		246 000		7 000
Total		2 423 000		1 242 000
Brake linings and clutch facings				
United States		1 352 000		2 811 000
Ecuador		149 000		146 000
Australia		7 000		124 000
France		70 000		50 000
Thailand		10 000		33 000
Guatemala		14 000		21 000
Uruguay		–		16 000
Honduras		8 000		15 000
Syria		9 000		13 000
Other countries		121 000		108 000
Total		1 740 000		3 337 000

Table 1. (concl'd)

	1976		1977p	
	(tonnes)	($)	(tonnes)	($)
Asbestos and asbestos cement building materials				
United States		4 934 000		12 049 000
United Kingdom		145 000		748 000
Netherlands		303 000		606 000
Singapore		4 000		342 000
Spain		625 000		271 000
Australia		34 000		138 000
Iran		621 000		109 000
Kuwait		–		103 000
Cuba		15 000		103 000
Other countries		1 386 000		541 000
Total		8 067 000		15 010 000
Asbestos basic products, nes				
United States		2 438 000		5 505 000
Switzerland		35 000		117 000
Netherland Antilles		–		28 000
Finland		4 000		16 000
Surinam		–		14 000
Jamaica		2 000		8 000
United Kingdom		20 000		8 000
Other countries		145 000		16 000
Total		2 644 000		5 712 000
Total exports, Asbestos manufactured		14 874 000		25 301 000
Imports				
Asbestos, unmanufactured	6 002	2 966 000	4 112	2 035 000
Asbestos, manufactured				
Cloth, dryer felts, sheets, woven or felted		2 842 000		3 949 000
Packing		1 599 000		2 087 000
Brake linings		4 513 000		4 612 000
Clutch facings		751 000		1 305 000
Asbestos-cement shingles and siding		143 000		88 000
Asbestos-cement board and sheets		337 000		525 000
Asbestos building materials, nes		7 336 000		5 933 000
Asbestos basic products, nes		3 009 000		3 790 000
Total asbestos, manufactured		20 530 000		22 289 000
Total asbestos, unmanufactured and manufactured		23 496 000		24 324 000

Source: Statistics Canada.
[1] Value of containers not included.
[p] Preliminary; – Nil; nes Not elsewhere specified; . . Not available.

work on a new mill air system and vacuum cleaning system, and completed employee-related construction projects. The Clinton Creek mine, Yukon Territory, will close during mid 1978 because ore reserves will be exhausted. Tenders were called from West Coast shipping and barging firms to transport fibre to Vancouver from Stewart, British Columbia. The all-Canada route is considered to be less expensive than the current major route through Skagway, Alaska.

At Carey-Canadian Mines Ltd. and at Advocate Mines Limited, major emphasis was placed on modernization and environmental control programs.

United Asbestos Inc. in Midlothian township, Ontario ceased operations in March, at which time it was in default of $45.6 million. The mill is designed to process 3 600 tonnes of ore a day and produce 90 000 tonnes of asbestos fibre a year. Estimated ore reserves are 27 million tonnes with an average fibre content of 7.5 per cent.

Prospective producers

Brinco Limited continued discussions with ASARCO Incorporated and other prospective partners that could lead to the development of the "A" asbestos deposit of Abitibi Asbestos Mining Company Limited. This property is located 84 kilometres (km) north of Amos, Quebec. Capital costs to bring the project into production are now estimated to be over $400 million based on an annual output of approximately 200 000 tonnes of fibre. Ore reserves in the "A" deposit are estimated at 100 million tonnes averaging 3.5 per cent asbestos fibre.

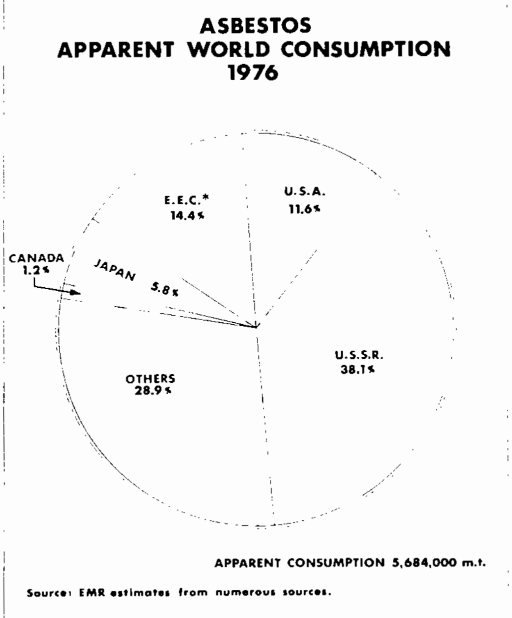
Rio Algom Limited continued economic evaluation of the deposit owned by McAdam Mining Corporation Limited. This property is situated approximately 32 km east of Chibougamau, Quebec. McAdam and Campbell Chibougamau Mines Ltd. are jointly exploring an asbestos property in the same region, about 24 km east of Chibougamau.

Cassiar continued the evaluation of its Kutcho Creek property near Dease Lake in northern British Columbia.

World production, and developments in major markets

Total world production of asbestos in 1977 was an estimated 5.2 million tonnes based on the inclusion of Russian grades approximately equivalent to Canadian grades. Chrysotile accounted for about 90 per cent of world production and the remaining production consisted of about 6 per cent crocidolite (blue asbestos) and 3 per cent amosite. Less than 1 per cent of other types of asbestos, including tremolite and anthophyllite, was produced, mainly in the United States.

The diagrams show a breakdown of 1976 world production and world consumption by country. Discrepancies occur in the data available from the U.S.S.R. and also in the interpretation of this data, resulting in problems of statistical correlation. Most of the annual output from the U.S.S.R. is consumed domestically, although about 600 000 tonnes are exported mainly to eastern European countries, Japan, France, West Germany and India.



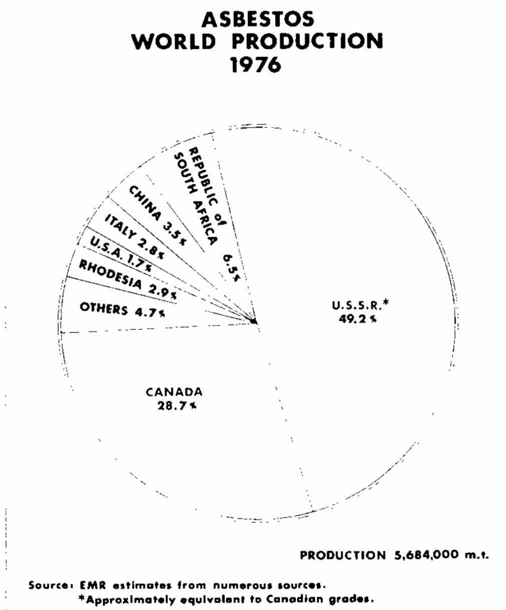


Table 2. Canadian asbestos producers and prospective producers, 1977

	Mine Location	Mill Capacity		Remarks
		(tonnes)		
		ore/day	fibre/year	
Producers				
1. Advocate Mines Limited	Baie Verte, Nfld.	6 800	80 000	Open pit. Produces Groups 4 and 6.
2. Carey-Canadian Mines Ltd.	East Broughton, Que.	5 000	210 000	Open pit. Mainly produces Groups 6 and 7.
3. Asbestos Corporation Limited				World's major independent asbestos producer.
Asbestos Hill mine	Putuniq, Que.	5 400	90 000	Annual rated capacity 272 000 tonnes concentrate. Final processing of fibre in West Germany.
British Canadian mine	Black Lake, Que.	11 200		Open pit, two milling plants.
King-Beaver mine	Thetford Mines, Que.		210 000	Underground and open pit.
Normandie mine	Black Lake, Que.	6 800		Reserves exhausted. Mill processes K-B open pit ore.
4. Bell Asbestos Mines, Ltd.	Thetford Mines, Que.	2 700	55 000	Underground.
5. Lake Asbestos of Quebec, Ltd.	Black Lake, Que.	8 200		Open pit.
National Mines Division	Thetford Mines, Que.	3 200	235 000	Open pit.
6. Canadian Johns-Manville Company, Limited				
Jeffrey mine	Asbestos, Que.	30 000	645 000	Open pit (western world's largest known asbestos deposit).
7. Hedman Mines Limited	Matheson, Ont.	300	–	Open pit.
8. United Asbestos Inc.	Matachewan, Ont.	3 600	100 000	Ceased operations in March.
9. Cassiar Asbestos Corporation Limited				
Cassiar mine	Cassiar, B.C.	3 000	100 000+	Open pit.
Clinton mine	Clinton Creek, Yukon	3 600	100 000+	Open pit. Will close in 1978.
Prospective producers				
10. Abitibi Asbestos Mining Company Limited	Amos, Quebec	11 800		Feasibility study underway.
11. McAdam Mining Corporation Limited	Chibougamau, Quebec	4 500		Feasibility study underway.
12. Cassiar Asbestos Corporation Limited	Dease Lake, B.C.			Possible future development.

Sources: Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa. The Quebec Asbestos Mining Association, Quebec.
– Not available.

Asbestos reserves in the U.S.S.R. are known to be very large and are probably greater than those in Canada. The three major producing areas in the U.S.S.R. are: the Bazhenovo deposits of the Uralasbest Combine in the Central Urals, near Sverdlovsk, where there is capacity of about 1.7 million tonnes a year of fibre; the Kustanayas Combine in the Dzhetygara district of Northwest Kazakhstan, along the eastern flanks of the southern Urals, where there is capacity of about 600 000 tonnes a year; and Aktovrak, Tuva district to the west of Lake Baikal, with a reported capacity of 200 000 tonnes a year. Progress continues at the new Kiembay deposit in the southern Urals where several Council for Mutual Economic Assistance (COMECON) countries are assisting in the completion of the project designed to produce 550 000 tonnes a year of asbestos. The Comecon countries are expected to receive most of the output from this new project. Construction and expansion programs are also underway at the two combines in the Urals.

The Republic of South Africa has the only commercial deposit of amosite and is also a major producer of crocidolite and chrysotile. Approximately 30 per cent of this country's total asbestos production of about 360 000 tonnes is chrysotile. Cutbacks in production of amosite and crocidolite were decided on at year-end as a result of depressed world demand.

Official figures for asbestos output have not been available from Rhodesia since the country's Unilateral Declaration of Independence in November, 1965 and subsequent imposition of U.N. trade sanctions. Rhodesia was the third largest producer of asbestos in the western world, after Canada and Republic of South Africa, and the country undoubtedly remains a world ranking producer with an estimated output of 200 000 tonnes a year.

Most United States production of approximately 100 000 tonnes a year is from California and Vermont. Significant changes in levels of production are not expected. The United States produces approximately 17 per cent of its asbestos needs and imports 83 per cent, 95 per cent of which is chrysotile from Canada.

Woodsreef Mines Limited, N.S.W., Australia, continued to produce fibre in 1977; however, technical, financial and environmental control problems did not allow the company to attain its goal of 100 000 tonnes of fibre a year. The continued drop in the value of Canadian currency, in which western world asbestos prices are quoted, contributed to Woodsreef's insecure financial position.

In Greece, the Hellenic Industrial Development Bank will finance a new $U.S.68 million asbestos processing plant at Kozani. The plant, with capacity of 100 000 tonnes of fibre a year, is scheduled to begin operations in 1980. The expected life of the mine is 20 years, based on presently defined reserves, and about 75 per cent of the production is expected to be for export markets.

Johns-Manville Corporation, with the Gulf International Corporation group of Kuwait and the Sudanese government, continued their evaluation of asbestos deposits in the Sudan. A feasibility study will evaluate the possibility of constructing a plant to produce 100 000 tonnes of fibre a year.

Asbestos output in Turkey increased, mainly as a result of new milling expansion. Other asbestos projects in various stages of development are underway in Brazil, Mexico, Bolivia, Colombia and New Zealand.

Fibre groups, uses and technology

To evaluate the quality of asbestos fibre there are five basic properties that must be considered: fibre length distribution, fibre bundle diameter distribution, harshness, tensile strength and surface activity. Other properties governing quality are iron content, colour and dust content. The major standard on a length basis is that developed by the industry in Quebec, whereby asbestos is classified and priced by groups from the longest fibre, corresponding to No.1, to the shortest, No.9. Because there are more than 3 000 uses for asbestos, it is more appropriate to classify the groups in categories and describe the major purposes the fibres serve than to list the products in which they are used.

Long fibres, Crudes Nos.1 and 2 and Group 3: used in the textile industry, as electrical insulation, as a filtration medium and as reinforcing fillers in asbestos-cement products where great strength is required.

Medium-length fibres, Groups 4,5,6: reinforcing fillers in asbestos-cement products, friction materials such as brake linings and clutch facings, paper and pipe coverings.

Short fibres, Groups 7,8,9: reinforcing fillers in plastics, floor tile, asphalt, and in paints and oil-well muds.

In the United States, by far Canada's major market, about 71 per cent of asbestos is used in the construction industry in the form of roofing and flooring products and asbestos-cement pipes and sheets. A breakdown of United States asbestos demand is as follows: roofing products, 34 per cent; asbestos-cement pipes, 19 per cent; flooring products, 15 per cent; friction materials, 8 per cent; paper products, 4 per cent; asbestos-cement sheets, 3 per cent; plastics, 2 per cent; coatings and compounds, 2 per cent; insulation, 1 per cent; textiles, 1 per cent; and others, 9 per cent.

Stricter environmental control proposals in the asbestos industry and stricter legislation regarding the use of certain asbestos products continued in the industrialized countries. The United States Occupational Safety and Health Administration (OSHA) proposed a limit on worker exposure to 0.5 fibres a cubic centimetre (cm^3) of air, from the current 2.0 fibres a cm^3; however, hearings were not scheduled. OSHA announced a new policy which would classify all carcinogenic substances to one of four categories. Asbestos has been defined to the Category I class of known carcinogens, and rules would reduce worker exposure to the "lowest level feasible." Public hearings on this issue will continue into 1978. The use of asbestos was banned in certain minor end-use products; these were spackling compounds and wall patching tapes as well as imitation logs and ashes for gas-burning fireplaces.

In Canada, the Department of Fisheries and the Environment established new asbestos emission regulations to become effective December 31, 1978. Regulations will allow a maximum of 2 fibres greater than 5 microns in length a cm^3 to be emitted to the air from dry rock storage and surrounding crushing, drying and milling operations. Monitoring at individual plants begins immediately to identify problem areas.

In-plant emission standards are a provincial concern and these are being enforced in Ontario (2 fibres a cm^3) and in British Columbia (5 fibres a cm^3). Regulations will become effective in Quebec, Newfoundland and the Yukon Territory in 1978.

Certain consumer products containing free asbestos fibre have been banned since 1975, and the federal departments of Health and Welfare and Consumer and Corporate Affairs continue to review applicable products.

A Phase I study by Sorès Inc., Montreal, to evaluate opportunities for further processing of asbestos fibre in Quebec was completed. Fourteen products falling into the textile, paper, asbestos-cement, friction materials and filler groups were evaluated. Five products of the 14 were selected for a detailed analysis of opportunities that will be reviewed in a Phase II study to be completed in 1978. The elected products were: molded friction material, asbestos-cement pipe, asbestos-cement finished sheets, flooring felts and papers.

The Institute of Occupational and Environmental Health, founded in 1966 and supported by the Quebec Asbestos Mining Association, approved additional research projects to further study of the biological effects of asbestos. Over $5 million in grants have been paid by the Institute, and results of the scientific research have been widely published.

The University of Sherbrooke began a research program that will call for investments of approximately $5 million over the next five years. Research will be mainly placed on the development of new asbestos products and on new uses from waste materials. Socio-economic studies and medical studies will also have priority.

A Soviet asbestos delegation consisting of five senior planning and mine operating officials visited three mining and milling operations in Quebec and one in British Columbia. The Russians were primarily interested in mine planning and ore handling, improvements in milling technology, automatic controls and fibre quality control. A Canadian delegation will visit Moscow and the major asbestos mining regions in the Central and Southern Urals in May, 1978.

Table 3. Canada, asbestos production and exports, 1960, 1965, 1970, 1975, 1976 and 1977

	Crude	Milled	Shorts	Total
		(tonnes)		
Production[1]				
1960	229	438 336	576 011	1 014 646
1965	148	598 377	660 840	1 259 365
1970	6 579	668 629	832 210	1 507 418
1975	5	480 579	575 083	1 055 667
1976	27	681 003	855 061	1 536 091
1977[p]	. .	. .	. .	1 543 000
Exports				
1960	219	415 539	553 563	969 321
1965	112	572 231	624 600	1 196 943
1970	91	747 814	669 509	1 417 414
1975	183	568 683[r]	511 434[r]	1 080 300[r]
1976	83	708 494	769 480	1 478 057
1977[p]	1	705 652	709 565	1 415 218

Source: Statistics Canada.
[1] Producers' shipments.
[p] Preliminary; . . Not available; [r] Revised.

Outlook

Depressed world economic conditions have contributed to an outlook of slight pessimism in the short run.

Considering the health-environmental concerns and the trend toward mature markets in some industrialized countries, western world growth in asbestos demand may only be in the range of 1.5 per cent — 2 per cent during the next several years. Slow growth, or lack of growth in some industrialized countries, is expected to be offset by increased demand for asbestos in developing countries. Adverse publicity and what the industry terms an "anti-asbestos lobby", along with several pending class action suits emanating in the United States, are prompting some consumers to seek asbestos substitutes where these are possible. Also, these and other factors, including bans on the use of certain consumer products, have resulted in a short term trend away from asbestos product related research and development.

Mining companies and asbestos-based product manufacturers are greatly improving environmental conditions and are expected to meet presently defined regulations as these become effective. Environmental health studies are ongoing in the industrialized countries, and these studies will contribute to the factual data necessary for establishing well-founded regulations governing environmental control and product use.

If glass fibres can be made alkali-compatible these could replace, or partially replace, asbestos in some asbestos-cement products. No satisfactory cost-competitive substitutes are available for asbestos in many applications, particularly for friction materials.

Prices

Quebec producers raised prices an average of about 14 per cent in January 1977, and an average of approximately 8.5 per cent in July. The prices for some grades remained the same, but for other grades price decreases were initiated. Price increases on January 1, 1978 were approximately 5 per cent; however, adjustments again varied considerably depending on grade. Cassiar Asbestos Corporation Limited increased fibre prices approximately 15 per cent in July 1977, and about 5 per cent in January 1978.

Canadian asbestos prices quoted in "Asbestos"[1]

	Jan. 1, 1978
Quebec, fob mines	($ a short ton)
Crude No. 2	2 165.00
Group	
No. 3 (spinning fibre)	965.00-1 501.00
No. 4 (asbestos-cement fibre)	642.00- 945.00
No. 5 (paper fibre)	323.00- 501.00
No. 6 (waste, stucco, plaster)	307.00- 311.00
No. 7 (refuse, shorts)	107.00- 213.00
	July 1, 1977
	($ a short ton)
Cassiar, fob North Vancouver, B.C.	
Canadian group	
No. 3 (nonferrous spinning fibre)	
AAA grade	2 000.00
AA grade	1 600.00
A grade	1 050.00
AC grade	913.00
No. 4 AK grade (single fibre asbestos — cement)	770.00
No. 4 CP grade	730.00
No. 4 AS grade	670.00
No. 4 CT grade	650.00
No. 5 AX grade	580.00
No. 5 CY grade	420.00
No. 5 AY grade	420.00

[1] *Asbestos* is published monthly by Stover Publishing Company.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
		(%)	(%)	(%)	(%)
31210-1	Asbestos, crude	free	free	25	free
31215-1	Asbestos, yarns, wholly or in part of asbestos, for use in manufacture of clutch facings and brake linings	7½	7½	25	5
31225-1	Asbestos felt, rubber impregnated for use in manufacturing floor coverings	free	free	25	free
31200-1	Asbestos, in any form other than crude, and all manufactures thereof, nop	15	22½	25	8
31205-1	Asbestos in any form other than crude, and all manufactures thereof, when made from crude asbestos of British Commonwealth origin, nop	free	12½	25	free
31220-1	Asbestos woven fabric, wholly or in part of asbestos for use in manufacture of clutch facings and brake linings	12½	12½	30	8

United States

Item No.		
518.11	Asbestos, not manufactured, crude, fibres, stucco, sand and refuse containing not more than 15 per cent by weight of foreign matter	free
		(% ad valorem)
518.21	Asbestos, yarn, slivers, rovings, wick, rope cord cloth, tape and tubing	4
518.51	Asbestos articles not specifically provided for	4.5
	Articles in part of asbestos and hydraulic cement	(¢ per lb)
518.41	Pipes and tubes and fittings thereof	0.15
518.44	Other	0.1

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa; Tariff Schedule of the United States, Annotated (1978) TC Publication 843.

Barite and Celestite

G.O. VAGT

Production of barite in 1977 was 116 950 tonnes* valued at $2.3 million. This represents an increase of approximately 17 per cent compared with the 1976 production of 100 266 tonnes. Imports of barium carbonate, one of the most important barium chemicals derived from barite, amounted to 1 654 tonnes valued at $433 000 in 1977.

Barite ($BaSO_4$) is a valuable industrial mineral because of its high specific gravity (4.5), low abrasiveness, chemical stability and lack of magnetic and toxic effects. Its dominant use is in drilling of oil and gas wells as a weighting agent in the muds that serve to counteract high pressures confined by the substrata.

Barite is found in many countries of the world and is the raw material from which nearly all other barium compounds are derived. Witherite ($BaCO_3$) was formerly of importance but it occurred in relatively large quantities only in the north of England. The United States, the principal producer of barite with about 26 per cent of the total production, is followed by Ireland and Peru, both with about 6 per cent of the total, and by Mexico and West Germany, both with about 5 per cent, according to United States Bureau of Mines. Canada is ninth in world production and exports approximately 60 per cent of its output, mainly as crude barite, to grinding plants in the United States.

Production and occurrences in Canada

Barite is found in a variety of geological environments: as the principal mineral in veins along with fluorite, calcite and quartz; as a gangue mineral in some lead-zinc-silver deposits; and as irregular replacement deposits in sedimentary rocks. Pure barite is white and is most common in veins; impure barite may be near white, grey, brown or light red. Barite was produced only from operations in Nova Scotia, Ontario and British Columbia in 1977.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

At the Walton, N.S. mine, operated by Dresser Minerals of Dresser Industries, Inc., most of the production was obtained from low-grade stockpiles, waste dumps and the tailings pond. Limited quantities of ore were mined from underground workings, although mud and water inflows have not been effectively controlled. Severe flooding in March 1978, is expected to result in complete closure of the operation later in the year. Most of the production in 1977 was shipped in crude form to southwestern United States and the remainder was transferred to an affiliated company for use in offshore oil drilling in eastern Canada.

There was only one barite producer in British Columbia in 1977. Mountain Minerals Co. Ltd. mined barite underground from vein deposits near Parson and Brisco in the eastern part of the province, and recovered crude barite from the tailings at the Mineral King mine near Invermere. The crude barite was shipped to the company's plant at Lethbridge, Alberta, for grinding. Mountain Minerals is evaluating a barite property located north of Cranbrook, near Skookumchuk, B.C. Baroid of Canada, Ltd. discontinued its barite recovery operation, near Spillimacheen, south of Golden. Tailings from an abandoned lead-zinc mine were fed as a slurry to separation tables, and the barite concentrate was dewatered and shipped by rail for further processing in a grinding plant at Onoway, Alberta.

Extender Minerals of Canada Limited operated the only barite mine in Ontario. Extender's mine is located near Matachewan, where barite is mined from a vein deposit by open-pit methods, with all beneficiation being done on the site.

The higher demand for barite in the United States market accounted for Canada's expansion of exports in 1977 and resulted largely from increased oil-well drilling activity in that country.

There are many occurrences of barite across Canada. Of note are those at Buchans, Newfoundland where there is an estimated 0.5 million tonnes of barite in tailings; in Nova Scotia near Brookfield on the mainland and east of Lake Ainslie on Cape Breton Island; in northern Ontario, in Yarrow, Penhorwood and Langmuir townships, and on McKellar Island in Lake Superior; at mile 397 of the Alaska Highway in northern British Columbia, and north of mile 548 on the highway. The Lake Ainslie deposit on Cape Breton Island contains about 2.7 million tonnes of ore grading 44 per cent barite and 17 per cent fluorspar. Feasibility studies to date have not developed an efficient commercial-scale separation method for this deposit.

Barite deposits in the MacMillan Pass region of the eastern part of the Yukon Territory continued to be evaluated. Yukon Barite Company Ltd. expects to produce from 20 000 to 30 000 tonnes of barite a year from the TEA property located near the Canol road, about 200 kilometres northeast of Ross River. The property is under option from Welcome North Mines Ltd.

Uses, consumption and trade

The dominant use for barite is as a weighting agent in oil and gas well drilling muds where its specific gravity assists in counteracting high pressure in oil and gas reservoirs. Principal specifications are usually a minimum specific gravity of 4.20, a particle size of at least 95 per cent minus 325 mesh, and a maximum water-soluble solids content of 250 ppm.

In 1976, consumption of barite in Canada was an estimated 58 066 tonnes, with over 90 per cent of this utilized in the oil well-drilling industry.

Barite is used in paint as a special filler or "extender pigment". This is a vital constituent that provides bulk, improves consistency of texture, surface characteristics and application properties, and controls prime pigment settling and the viscosity of paints. Specifications for barite used in the paint industry call for 95 per cent $BaSO_4$, particle size at least minus 200 mesh, and a high degree of whiteness or light reflectance. Final "wet milled" and "floated" products result in smooth microcrystalline surfaces that prevent agglomeration, thus allowing easy dispersal in water as well as in oil-soluble binders. When barite is used in highly pigmented distemper or latex paints, a degree of light scattering is attributed to the barite, therefore allowing it to function as a pigment.

The glass industry uses barite to increase the workability of glass, to act as a flux, assist decolouration and increase the brilliance or lustre of the product. Specifications call for a minimum of 98 per cent $BaSO_4$, not more than 0.15 per cent Fe_2O_3, and a particle size range of 40 to 140 mesh.

Table 1. Canada, barite production, trade and consumption, 1976-77

	1976		1977^p	
	(tonnes)	($)	(tonnes)	($)
Production (mine shipments)	100 266	1 852 254	116 950	2 325 000
Imports				
United States	18 097	1 370 000	5 979	747 000
Total	18 097	1 370 000	5 979	747 000
Exports				
United States	60 297	1 168 000	65 509	1 345 000
Venezuela	–	–	3 912	80 000
Total	60 297	1 168 000	69 421	1 425 000
	1975		1976	
Consumption[1]				
Well drilling	36 044^e		54 767^e	
Paints and varnish	2 175		2 140^e	
Glass and glass products[2]	867		169	
Rubber goods	48		86^e	
Other[3]	1 095		904	
Total	40 229		58 066	

Sources: Statistics Canada; Department of Energy, Mines and Resources, Ottawa.
[1]Available data reported by consumers with estimates by Mineral Policy Sector. [2]Includes glass fibre and glass wool. [3]Other includes bearings and brake linings, ceramics, chemicals and plastics.
^{p}Preliminary; – Nil; ^{e}Estimated.

The specifications vary for natural barite used as a filler in rubber goods, but the main factors are whiteness and particle size range.

The balance of Canada's barite was used in the manufacture of ceramic products, chemicals, plastics and brake linings. Barite may become an important ingredient in heavy concrete used as a radiation shield.

There is, as yet, no barium chemicals industiy in Canada. Some important barium chemicals include the nitrate, acetate, oxide, hydroxide and stearate compounds, all derived from barium carbonate. Two other important compounds are chemical or precipitated barium sulphate, referred to in the trade as blanc fixe; and lithopone, a chemically precipitated mixture of 70 per cent barium sulphate and 30 per cent zinc sulphide. Lithopone, a white pigment, is still in demand for certain purposes such as undercoatings, filling pastes, emulsion paints and wallpaper coatings. Lithopone, however, has largely been replaced by titanium dioxide pigments in most uses.

Specifications of barite for the barium chemicals industry call for 95 per cent $BaSO_4$, and not more than 2 per cent Fe_2O_3.

Table 2. Canada, barite production, trade and consumption, 1960, 1965, 1970, 1975, 1976 and 1977

	Production[1]	Imports	Exports	Consumption[2]
	(tonnes)			
1960	142 560	1 833	122 445	22 000
1965	184 181	3 344	167 858	19 700
1970	133 584	6 827	90 305	50 100
1975	81 356	4 479	45 606	40 229
1976	100 266	18 097	60 297	58 066
1977^p	116 950	5 979	69 421	. .

Sources: Statistics Canada; Department of Energy, Mines and Resources, Ottawa.
[1]Mine shipments. [2]Includes estimates by the Mineral Policy Sector.
^{p}Preliminary; . . Not available.

World review

There is worldwide production and considerable international trade in barite, even though transportation costs in some cases may be greater than the cost of the lump material. World production of barite in 1977 was an estimated 5.4 million tonnes, according to the United States Bureau of Mines. An estimated 75 per cent of this quantity was consumed in oil well-drilling operations and most barite was supplied by oil-field service companies closely interrelated with the drilling companies. Dependence on the oil industry as a principal market means that regional demand for barite is subject to considerable fluctuations as the tempo of oil and gas exploration varies in time and in geographic location. However, world demand is fairly stable and is most economically served by production from many countries. The viability of any deposit is dominantly infuenced by transportation costs to markets.

The United States is by far the world's largest producer of barite and production reached an all-time high in 1977. About 30 mines produced an estimated 1.4 million tonnes, derived mostly from Nevada, Arkansas and Missouri. Annual imports of barite to the United States during 1976 and 1977 were 820 000 and 871 000 tonnes, respectively. Following the United States, which accounted for 26.1 per cent of the total world production, were: Ireland, 6.2; Peru, 6.2; Mexico, 5.2; West Germany, 4.9; Italy, 3.4; France, 3.0; Morocco, 2.5; Canada, 2.2; Greece, 1.3; Yugoslavia, 1.2; other market economy countries, 18.5; and central economy countries, except Yugoslavia, 19.3.

The United States, the principal consumer of barite, used an estimated 2.3 million tonnes in 1977. Imports into the United States for the years 1973 to 1976, inclusive, came from: Peru, 31 per cent; Ireland, 24 per cent; Mexico, 15 per cent and other, 30 per cent. Of the total 1976 consumption of barite in the United States, approximately 90 per cent was used in oil- and gas-well drilling. The pattern of consumption of ground barite (excluding the barium chemicals industry) in the United States is similar to that in Canada.

In the United States, most major barite producers are carrying out extensive exploration and development programs to assure a continuing supply of barite. New plants were completed in Nevada and Texas.

In Ireland, Milchem, Inc., continued development work in County Cork, where barite production is expected to be used by the paint and chemical industry in Britain. Output from Imco Drilling Services' mine in Ben Bulben Co. is being ground in Norway for drilling in the North Sea. Most barite production from Ireland is utilized either in the United States, the North Sea, or in new areas off the coast of Ireland and Wales in the Celtic Sea and the Irish Sea.

Outlook

The high level of worldwide oil exploration activity resulting from higher crude oil and natural gas prices during the past four years assures a continuing strong demand for barite during the next several years. World barite production may be expected to meet requirements because geologic factors suggest that there is good potential for discovery and development of deposits near most regions where there is drilling activity. Continued restrictions on exports of barite from Mexico, or other possible disruptions to trade, could result in more barite exploration activity in the United States and Canada.

Exploration for new barite deposits in Canada and feasibility studies presently underway could bring about

Table 3. World mine production of barite, 1975-77 and reserves, 1977

	Mine production (000 tonnes)			Reserves (000 tonnes)
	1975	1976	1977[e]	1977
United States	1 196	1 119	1 405	59 000
Ireland	295	323	336	5 000
Peru	230[e]	331	336	4 000
Mexico	300	270	281	4 000
West Germany	247	262	263	6 000
Italy	213	179	181	4 000
France	92	150	159	4 000
Morocco	120	131	136	5 000
Canada	81	100	117	4 000
Greece	105	61	68	4 000
Yugoslavia	61	61	64	3 000
Other free world countries	999	974	998	50 000
Communist countries (except Yugoslavia)	928	1 024	1 043	30 000
World totals	4 867	4 985	5 387	182 000

Sources: United States Bureau of Mines, Mineral Commodity Summaries, January 1978 and United States Bureau of Mines, Mineral Trade Notes, January 1978. For Canada, Statistics Canada.

[e] Estimated.

changes in the production pattern and the quantity of output in the near future. With continued oil- and gas-well drilling activity in the Mackenzie Delta, Arctic regions, and off the east coast, a growing market for barite in these areas may be expected. The continued increase in drilling activity in Canada, largely accounted for by the development of new areas offering potential for relatively large oil and natural gas discoveries in Alberta and British Columbia, suggests that Canadian requirements for barite will be maintained.

In the future, larger quantities of barite may be recovered from mine dumps and tailings ponds in Canada and abroad. Also, an increasingly important source of barite may be as a co-product from the mining of iron, base-metal, fluorspar and rare-earth ores.

The relatively low cost and technical advantages of barite for the drilling-mud market indicate that other materials will not likely be substituted on a large scale in this major application. For example: iron ore is more abrasive, and undesirable to handle because of colour; celestite ($SrSO_4$) is more expensive and has a lower specific gravity, and galena (PbS) is too expensive. *Fer-O-Bar,* a semi-synthetic product derived from the calcination of pyritic ores, is now available in commercial quantities and may prove to be a successful substitute for drilling-grade barite in some markets.

Prices

United States prices of barite as reported in "Engineering and Mining Journal" of December, 1977.

	($ per short ton)
Unground	
Chemical and glass grade:	
Hand picked, 95% $BaSO_4$ not over 1% Fe	46.50 — 55.00
Magnetic or Flotation, 96-98% $BaSO_4$ not over 0.5% Fe	60.00 — 70.00
Imported drilling mud grade, specific gravity 4.20 — 4.30, cif	
Gulf ports	19.00 — 28.00
Canada	19.00
Ground	
Water, 95% $BaSO_4$ 325 mesh, 50-lb bags	60.00 — 80.00
Dry ground drilling mud grade, 83-93% $BaSO_4$ 3-12% Fe, specific gravity 4.20-4.30	71.00 — 78 00
Imported	
4.20-4.30 specific gravity	31.00

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
		(%)	(%)	(%)	(%)
49205-1	Drilling mud and additives	free	free	free	free
68300-1	Barites	free	10	25	free
92842-1	Barium carbonate	10	15	25	10
92818-1	Barium oxide, hydroxide peroxide	10	15	25	10
93207-5	Lithopone	free	12½	25	free

United States

Item No.		
472.02	Barium carbonate, natural, crude	free
472.04	Barium carbonate, natural, ground	6% ad valorem
		($ per lt)
472.10	Barium sulphate, natural, crude	1.27
472.12	Barium sulphate, natural, ground	3.25
		(¢ per lb)
472.14	Barium sulphate, precipitated (blanc fixe)	0.3
473.72	Lithopone, containing under 30% zinc sulphide	0.43
473.74	Lithopone, containing 30% or more zinc sulphide	0.43 + 3.5% ad valorem

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division; Tariff Schedules of the United States, Annotated (1978) TC Publication 843.

CELESTITE

Celestite ($SrSO_4$), the main source of strontium, is used to produce commercial strontium compounds, principally strontium carbonate and strontium nitrate. In the sulphate form it is used in the zinc flotation process. Strontium carbonate is used in glass faceplates in colour television sets, where it improves the absorption of X-rays emitted by picture tubes operated at high voltages. An increasing use for this compound is in the manufacture of ferrites, a material required in the production of ceramic permanent magnets used in small electric motors.

Kaiser Celestite Mining Limited, a subsidiary of Kaiser Aluminum & Chemical Canada Investment Limited, closed its celestite mining operation at Loch Lomand, Cape Breton Island, N.S. and its strontium products plant at Point Edward, N.S. in 1976 and auctioned the plant equipment in 1977. Mining of celestite at Loch Lomand commenced in 1970 and the chemical plant began operating in 1971.

Efforts to find a purchaser or a joint venture partner were unsuccessful. Closure of the operation resulted from the slow growth in markets for strontium products and also from technical problems involving the chemical plant.

In the United States current producers of strontium compounds obtain most raw material needs from Mexico and Spain. Similarly, Japanese consumers presently have relatively secure sources of supply.

Prices

United States prices as reported in "Chemical Marketing Reporter", December 1977.

Strontium carbonate	($ per short ton)
glass grade, bags	
carlot, truckload, works	360.00 — 415.00
Strontium nitrate	($ per 100 pounds)
bags, carlot, works	24.00

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
92839	Strontium nitrate effective July 1, 1974 to June 30, 1984	free	free	free	free

United States

Item No.		(% ad valorem)
Strontium Metal		
632.46	Unwrought, waste and scrap	5
632.68	Alloys of strontium	7.5
473.19	Strontium chromate pigments	5
Strontium Compounds		
421.70	Carbonate (not precipitated)	free
421.72	Carbonate (precipitated)	6
421.74	Nitrate	6
421.76	Oxide	6
421.82	Mineral (celestite)	free
421.84	Sulphate	5
421.86	Other	5

Sources: For Canada, The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division. For United States, Tariff Schedules of the United States, Annotated (1978) TC Publication 843.

Bentonite

G.O. VAGT

Bentonite is a clay composed mainly of the mineral montmorillonite, a member of the smectite group of clay minerals. The term "smectite", as a group name, is growing in acceptance, and this usage eliminates confusing terminology that includes "montmorillonite" as both mineral species and group names. Montmorillonite is a hydrated aluminum silicate with weakly-attached cations of sodium and calcium, which impart different properties to bentonite depending on amounts and proportions present. One method of classifying bentonite is based on its swelling capacity when wet. With sodium as the dominant or abundant exchangeable ion, swelling from 15 to 20 times the original dry volume will occur, and when added to water, gel-like masses result. Sodium bentonite also possesses a high dry-bonding strength, especially at high temperatures, a feature important in the manufacture of some ceramic products.

Montmorillonite clays have ion-exchange properties; and, by adsorption, absorption and chemical activity, bentonite can collect many types of inorganic and organic compounds, sometimes selectively. In general, the nonswelling or calcium bentonites exhibit the more pronounced adsorptive characteristics. While naturally occurring clays may exhibit adsorptive or bleaching properties, their efficiencies are commonly improved by acid leaching or, as the process is generally termed, activation.

Another clay, "fuller's earth", also contains mainly smectite-group clay minerals and is very similar to nonswelling bentonite. These clays have natural bleaching and absorbent properties and were originally used by fullers to remove dirt and oil from wool. The terminology is confusing, and bentonite and fuller's earth may or may not be separated in world trade and production figures by country.

Bentonites may originate from smectitic clays formed from igneous rocks other than volcanic ash, tuff or glass, or from rocks of sedimentary or uncertain origin. The deposits occur in relatively flat-lying beds of various chemical compositions and impurities; the latter consisting of quartz, chlorite, biotite, feldspar, pyroxenes, zircon and various other minerals. Natural clay may be creamy white, grey, blue, green or brown; and, in places, beds of a distinctly different colour are adjacent. Fresh, moist surfaces are waxy in appearance; on drying, the colour lightens, and the clay has a distinctive cracked or crumbly texture.

Production and occurrences in Canada

Canadian bentonite occurrences are confined to Cretaceous and Tertiary rocks at many localities in Manitoba, Saskatchewan, Alberta and British Columbia. Although clay beds occur in rocks older than Cretaceous, none of these in Canada have been identified as bentonite.

Two companies presently mine and process bentonite in Canada, and a third company prepared for production in 1978. Statistics on total production and exports are not available for publication.

In Alberta, Dresser Minerals Division of Dresser Industries, Inc. recovers swelling bentonite from the Edmonton Formation of Upper Cretaceous age. The deposits are in the Battle River Valley, 14 kilometres (km) south of Rosalind, the site of the company's processing plant. The bentonite is mined selectively from relatively shallow paddocks or pits in the dry summer months. Some natural drying may be done by spreading and harrowing material before trucking it to the plant for drying, pulverizing and bagging. Bentonite of intermediate swelling quality from Alberta is used mainly as a foundry clay, as feed pelletizing material, as a drilling-mud additive, as a fire-retardant additive to water and as a sealer for farm reservoirs. Baroid of Canada, Ltd. mined bentonite until 1976 from the Edmonton formation at a deposit located 14 miles northwest of Onoway using methods similar to those used by Dresser.

In Manitoba, Pembina Mountain Clays Ltd. mines nonswelling bentonite from the Upper Cretaceous Vermilion River Formation, 30 km northwest of Morden, which is 130 km southwest of Winnipeg. Some bentonite is dried and pulverized in a plant at Morden, but the bulk of production is railed from Morden to the companies activation plant at Winnipeg where it is leached, washed, filtered, dried, pulverized and bagged. The main use is for decolourizing and purifying mineral and vegetable oils, animal fats and tallows. Highly sorptive properties also make this bentonite suitable for pet litter and floor sweeping compounds.

Avonlea Mineral Industries Ltd. started construction of a $1.4 million bentonite processing plant in Wilcox, Saskatchewan, approximately 30 kilometres south of Regina. The plant, to be completed about mid-1978, will have a capacity of approximately 50 000 tonnes* a year. Raw material will be transported a distance of approximately 14 kilometres. Major uses of the final product will be for iron ore pelletizing.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Uses, consumption and trade

Bentonite has many uses, but it generally constitutes only a small part of the final product.

Select swelling bentonite has found widespread and rapidly growing uses as a binder in the pelletizing of iron ore concentrates. About 18 pounds is used in every long ton of concentrate to provide pellets with sufficient "green" strength to withstand handling during the drying and firing stages. The amount of bentonite required varies with the mineralogy and particle size of the concentrate. Over 70 per cent of the reported total consumption of bentonite in 1976 was used in pelletizing iron ore concentrates.

Special muds used in oil- and gas-well drilling contain about 10 per cent swelling bentonite, which is used principally to prevent the loss of drilling fluid into

Table 1. Canada, bentonite imports and consumption, 1976 and 1977

	1976		1977[p]	
	(tonnes)	($)	(tonnes)	($)
Imports				
Bentonite				
United States	274 095	5 288 000	324 813	7 214 000
Greece	—	—	33 182	659 000
Total	274 095	5 288 000	357 995	7 873 000
Activated clays and earths				
United States	9 066	2 684 000	8 607	3 025 000
Greece	83 095	2 082 000	111 081	2 179 000
France	294	134 000	363	481 000
Other countries	41	20 000	81	65 000
Total	92 496	4 920 000	120 132	5 750 000
Fuller's earth				
United States	571	36 000	2 356	122 000
Consumption[1] (available data)		1974	1975	1976[p]
			(tonnes)	
Pelletizing iron ore		199 904	202 401	241 604
Foundries		75 547	59 439	61 209[e]
Well drilling		25 292	18 967	22 820
Fertilizer stock and poultry feed		757	1 387	1 389
Paint and varnish		642	290	183
Chemicals		39	36	65
Other products[2]		1 518	1 749	1 612
Total		303 699	284 269	328 882

Source: Statistics Canada.
[1]Does not include activated clays and earths. Breakdown by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa. [2]Explosives, frits and enamels, refractory brick and cements, ceramic products, petroleum refining, pulp and paper and other miscellaneous minor uses.
[p]Preliminary; — Nil: [e]Estimate.

permeable zones by forming a mud cake on the wall of the drillhole. Of equal importance, swelling bentonite acts as a suspension agent to carry drill cuttings in water-based muds to the surface. Synthetic bentonite (sodium-exchanged calcium bentonites) may also be used in special muds, depending upon the cost and availability of natural swelling bentonites.

Swelling bentonite serves as a binder in moulding sands used by iron and steel foundries. Nonswelling bentonite is also used as a binder in some low-temperature foundries.

Swelling bentonite is used as a binder in the pelletizing of base metal concentrates and stock feeds. It is used in small quantities as a plasticizer in abrasive and ceramic mixes and as a filler in paints, paper, rubber, pesticides, cosmetics, medicinal products, and cleaning and polishing compounds. Engineering applications are: in grout for sealing subsurface water-bearing zones, dams and reservoirs; as additives to cements, mortars and concretes to suppress bleeding of the mixing water; as a compacting agent for gravels and soils; and as a ground stabilizing medium for excavations when used in a bentonite-water suspension. Bentonite slurry is also effective in fighting forest fires.

Some nonswelling bentonite is used in pelletizing stock feed, as a carrier and diluent for pesticides, and as a cleaning powder for animals.

Table 2. Canada, bentonite imports[1] and consumption[2], 1960, 1965, 1970, 1975, 1976 and 1977[p]

	Imports		Consumption
	(tonnes)	($)	(tonnes)
1960	. .	1 590 441	58 850
1965	174 334	2 310 566	123 610
1970	351 066	5 590 000	262 804
1975	287 886	9 388 000	284 269
1976	367 162	10 244 000	328 882
1977[p]	480 483	13 745 000	. .

Source: Statistics Canada.
[1]Includes bentonite, fuller's earth and activated clays and earths. [2]Includes only fuller's earth and bentonite.
[p]Preliminary; . . Not available.

Activated bentonite is used in decolouring mineral and vegetable oils, animal fats, waxes, beverages and syrups. It is also used in some countries as a catalyst in the refining of fluid hydrocarbons.

Consumption of bentonite in Canada has increased substantially in the last decade, largely because of increased consumption as a binder in iron concentrate pelletizing as more of these plants have been constructed. Consumption of bentonite in well drilling in the oil and gas industry is subject to considerable fluctuation that is not necessarily directly related to the footage drilled. Factors such as age and degree of compaction of the rock formations encountered, as well as the severity of subsurface geopressures and temperatures that vary from region to region, are also important determinants. Iron and steel foundries require bentonite as a binder for moulding sands, and consumption for this use is continuing to rise. Quantities of activated clays and fuller's earth are imported mainly from Greece and the United States, and some activated bentonite from Manitoba is exported to the United States.

Bentonite production in the United States is mainly from extensive deposits in Wyoming where the name was derived from the Cretaceous Fort Benton Formation. These Cretaceous deposits are the world's most outstanding swelling bentonite occurrences, and the specifications and standards for bentonite used in industry are based on these high-quality clays. Although there are numerous occurrences of bentonite in many countries, it is mined in only a few. As a result of the high quality of Wyoming bentonite, this material is transported over such long distances that transportation costs commonly exceed the value of the product at the mine, in some cases by several times. However, in recent years, Wyoming producers have lost some markets for iron ore pelletizing in eastern Canada to Greek bentonite producers. The cost spread between rail and ocean transportation is the principal reason for this change. Canada is the main importer from the United States, which also ships some bentonite to Australia and western Europe.

Nonswelling bentonite, fuller's earth and bleaching clays are produced in numerous states, the major ones being Florida, Georgia, Mississippi and Texas.

Prices

United States bentonite prices quoted in Chemical Marketing Reporter, December 26, 1977

	($)
Bentonite, domestic, 200 mesh, bags, carlots, fob mines, per short ton	26.00
Bentonite, imported Italian White, high gel, bags, 5-ton lot ex-warehouse, per lb.	No prices[1]

[1]In Chemical Marketing Reporter, November 28, 1977 a price of $.1688 per lb was quoted.

Outlook

Most of Canada's bentonite consumption is in pelletizing iron ore concentrates. Wyoming bentonite continued to be the most suitable material for this purpose; however, some imports of Wyoming bentonite will be replaced by Saskatchewan bentonite with the start-up of production in 1978 by Avonlea Mineral

Industries Ltd. The slowdown in import growth since 1970 is a result of a more stable consumption pattern resulting from the completion of new pellet plants. Sidbec-Normines Inc. at Port Cartier, P.Q., started a 6-million-tonne-a-year iron ore pellet plant to process concentrate from its Fire Lake property. The project should reach maximum capacity in the near future, and it is anticipated that this plant will result in a net increase in bentonite consumption over the next few years. Countering this expansion, some small companies are expected to cease operations before 1980. This will contribute to a slower net growth in industry output. No changes in production and consumption patterns in industries other than ore pelletizing are foreseen; however, there is a trend toward the use of low-solids mud systems, utilizing organic polymers. Also, in land-based regions characterized by deep, high temperature drilling, there is an increasing use of oil-based muds.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
29500-1	Clays, not further manufactured than ground	free	free	free	free
93803-2	Activated clay	10%	15%	25%	10%
20600-1	Fuller's earth, in bulk	free	free	free	—

United States

Item No.		
		(¢ per long ton)
521.61	Bentonite	40
521.51	Fuller's earth not beneficiated	25
521.54	Wholly or partly beneficiated	50
		(¢ per lb)
521.87	Clays, artificially activated with acid or other material	0.05 +6% ad valorem

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. Tariff Schedules of the United States, Annotated (1978), T.C. Publication 843.

Bismuth

J.G. GEORGE

Bismuth is obtained in Canada in the processing of some lead-zinc, lead-zinc-copper and copper ores. The more important sources are the lead-zinc-copper ores mined in New Brunswick and the lead-zinc ores mined in southeastern British Columbia. Smaller amounts are sometimes recovered from ores mined in Ontario and Quebec.

Bismuth production in Canada in 1977, based on bismuth recovered from domestic ores and concentrates plus the recoverable bismuth content of bullion and concentrates exported, was 140 000 kilograms (kg) valued at $1 971 000. This represents an 8 per cent increase in production from the level of 129 578 kg in 1976. Inventory of metallic bismuth held by consumers as of December 31, 1976 totalled 4 747 kg compared with 4 162 kg in stock as at December 31, 1975.

In 1977 world mine production of bismuth as estimated by the United States Bureau of Mines, excluding United States production, was about 4.28 million kg, an increase of almost 2.5 per cent from the 4.18 million kg produced in 1976. Australia and Japan were the two leading producers, followed by Peru, Bolivia and Mexico. The United States, which is a substantial producer from its own and imported ores, does not publish production statistics because one company, ASARCO Incorporated, accounts for almost all of the country's primary refined metal output.

Domestic sources

The Smelting Division of Brunswick Mining and Smelting Corporation Limited produces bismuth metal and alloys at its plant at Belledune, about 40 kilometres (km) northwest of Bathurst, New Brunswick. Production of bismuth in 1977 was in the form of various grades of bismuth-lead alloys containing 178 000 kg of bismuth compared with 132 450 kg of bismuth contained in similar alloys produced in 1976. The Kroll-Betterton process is used to treat the desilverized lead bullion and produce a bismuth-lead-calcium-magnesium dross. The dross is then refined pyrometallurgically with chlorine to produce bismuth metal or alloy.

The other primary bismuth metal producer is Cominco Ltd. at its lead-zinc plant in Trail, British Columbia. Cominco derives most of its output from lead concentrates produced at its Sullivan lead-zinc mine at Kimberley. Other sources include lead concentrates from other company mines and from domestic and foreign custom shippers. Lead bullion produced from the smelting of these concentrates contains about 0.05 per cent bismuth. Bismuth is recovered as 99.99+ per cent metal from the treatment of residues resulting from the electrolytic refining of the lead bullion. Production in 1977 totalled 77 439 kg compared with 118 723 kg in 1976. (A substantial part of this production is derived from imported materials.) Bismuth for use in research and the electronics industry is further processed at Cominco's nearby high-purity plant to give it a purity of up to 99.9999 per cent.

Late in 1977 Brunswick Tin Mines Limited entered into a Joint Venture Agreement with Billiton Exploration Canada Limited, a subsidiary of Billiton International Metals, which is controlled by Royal-Dutch Shell of Holland. It is a joint venture to evaluate and, if feasible, develop and exploit Brunswick Tin's tungsten-bismuth-molybdenum property about 64 km north of St. Andrews in Charlotte County, New Brunswick. Billiton undertook to carry out a feasibility study at its own expense. This study was expected to be completed about mid-1978. Reserves in the North Zone are estimated at 13.7 million tonnes* and in the Fire Tower Zone at 23.7 million tonnes. Average grade of the two zones combined is 0.24 per cent tungsten oxide, 0.08 per cent bismuth and 0.13 per cent molybdenite. The major hindrance to development in the past has been the complex metallurgy of the orebody, but with the successful completion of metallurgical testing of the ores in late 1975 at the Department of Energy, Mines and Resources in Ottawa the company is confident that the property can be brought into production in the near future. At a proposed milling rate of 1 350 tonnes a day,

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

bismuth production could be in the range of 250 000 to 300 000 kg a year.

In 1976 improvements were made in mill procedures and equipment at the concentrator of Terra Mining and Exploration Limited near Port Radium on the east shore of Great Bear Lake, Northwest Territories. These changes resulted in a better recovery of bismuth that is contained in the silver-copper-bismuth ore being mined. Formerly, the bismuth content of the ore was either lost in the tailings or treated as a penalty item in concentrate settlements because of its low grade. Further metallurgical tests in 1977 confirmed that a high recovery of bismuth could be attained in concentrates that also contained cobalt and nickel arsenides. However, marketing difficulties were encountered as a result of the high arsenic content of these concentrates. Accordingly, research is now underway to evaluate leaching processes capable of treating all concentrates produced and recovering the various metals in some saleable form.

World developments

In 1977 the world bismuth industry continued the dismal performance it had in the previous two years. With stocks continuing to build up, supplies of the metal have remained plentiful. Meanwhile, bismuth demand and prices have been on the decline, partly because of a significant drop in consumption by the pharmaceutical industry in France which is reported to account for up to one-third of the free world's consumption of bismuth.

In the United States consumption of bismuth in 1977 was down less than 1 per cent from 1976, with pharmaceuticals showing the largest drop — 34 750 kg. Bismuth production also declined slightly in 1977, with the single primary metal producing plant operating well below capacity. The General Services Administration did not sell any bismuth from the nation's strategic and critical materials stockpile. The new goal of 349 720 kg established by the U.S. Federal Preparedness Agency late in 1976 remained unchanged. At the end of 1977 the stockpile contained 944 061 kg. The 594 341 kg surplus of bismuth may not, however, be disposed of without congressional approval. The disposal policy of

Table 1. Canada, bismuth production and consumption, 1976 and 1977

	1976		1977p	
	(kilograms)	($)	(kilograms)	($)
Production, all forms[1]				
New Brunswick	108 937	1 776 253	135 000	1 895 000
British Columbia	20 261	226 462	5 000	76 000
Quebec	336	5 473	—	—
Ontario	44	710	—	—
Total	129 578	2 008 898	140 000	1 971 000

	1976	1977
	(kilograms)	(kilograms)
Consumption, refined metal (available data)		
Fusible alloys	3 543	2 299
Other uses	17 562	22 716
Total	21 105	25 015

Source: Statistics Canada.
[1]Refined bismuth metal from Canadian ores, plus recoverable bismuth content of bullion and concentrates exported.
pPreliminary; — Nil.

Table 2. Canada, bismuth production and consumption, 1965, 1970, 1975-77

	Production all forms[1]	Consumption[2]
	(kilograms)	
1965	194 482	21 899
1970	267 774	11 135
1975	156 605	29 267
1976	129 578	21 105
1977p	140 000	25 015

Source: Statistics Canada.
[1]Refined bismuth metal from Canadian ores, plus recoverable bismuth content of bullion and concentrates exported. [2]Refined bismuth metal reported by consumers.
pPreliminary.

the United States administration has yet to be determined.

In Australia, the major bismuth producer, Peko-Wallsend Ltd., operated two ore sources in 1977, the Juno and Warrego mines, from which bismuth concentrates were derived. Because of the exhaustion of ore reserves, the Peko mine and concentrator were closed down about mid-1976 and the Juno mine ceased operations in mid-1977. The copper-gold-bismuth orebody of the Gecko mine is being developed for production. At mid-1977 reserves at the Warrego and Gecko mines were reported to total 7.5 million tonnes grading 2.5 per cent copper, 0.24 per cent bismuth and 4.2 grams of gold a tonne on a weighted average basis. The company's Tennant Creek copper smelter and bismuth plant remain closed while metallurgical studies are being made of technical changes proposed to make the smelter more efficient and to produce a saleable bismuth metal product. It will be late 1978 or early 1979 before the plant is back in production at its annual rated capacity of 1 200 tonnes of crude bismuth bullion, provided copper markets are sufficiently improved.

Bolivia is one of the few countries where the bismuth content of some ores is high enough for them to be mined primarily to obtain bismuth. Traditionally a major supplier of bismuth, most of Bolivia's output is produced by the Quechisla group of mines, which are operated by the state-owned Corporacion Minera de Bolivia (COMIBOL). These mines are located in the Tasna mining district in southern Bolivia, and some of the deposits grade up to 40 per cent bismuth; other deposits are located at Baracoles in the North Group and at Esmoraca. COMIBOL also operates Bolivia's sole bismuth metal refinery at Quechisla with an annual capacity of 650 tonnes of 99.99 per cent bismuth. COMIBOL also operates the country's sole bismuth smelter at Telamayu about 100 km north of Quechisla in Potosi Department. Bolivia's bismuth production in 1977 was up slightly from that of 1976 but is being cut back in 1978 because of the declining price and demand for the metal.

Peru continued to be one of the world's largest producers of bismuth. Refined bismuth metal was produced as a byproduct of lead at the La Oroya smelting and refinery complex of Empresa Minera del Peru (Centromin).

In Japan, Sumitomo Metal Mining Co. Ltd. planned to discontinue bismuth production early in 1978 at its Kunitomi plant, which some years ago was producing at a peak annual rate of 25 000 kg of bismuth. However, Sumitomo also intends to build a bismuth reduction plant at Niihama and which is expected to come on stream about mid-1978.

Table 3. World mine production of bismuth, 1975-77

	1975	1976^p	1977^e
		(kilograms)	
Australia	853 661	861 826^e	907 185
Japan	671 317	680 842	680 389
Peru	614 164	635 029	635 029
Bolivia	611 443[1]	611 896	635 029
Mexico[2]	444 974	580 598	612 350
People's Republic of China	249 476	249 476	. .
Canada	156 605	129 578	140 000
Republic of Korea	112 944	120 202	127 006
Romania	81 647	81 647	. .
Yugoslavia	55 338	78 018	. .
France	55 792	59 874	. .
U.S.S.R.	58 967	58 967	. .
Other countries	33 566	29 937	544 311
Total[3]	3 999 894	4 177 890	4 281 299

Sources: Statistics Canada and Department of Energy, Mines and Resources for Canada. For other countries for 1975 and 1976, United States Department of the Interior, Preprint from the 1976 Bureau of Mines Minerals Yearbook. For other countries for 1977, the United States Department of the Interior, U.S. Bureau of Mines Mineral Commodity Summaries 1978.
[1]Production by Corporacion Minera de Bolivia (COMIBOL) plus exports by medium and small mines. [2]Bismuth content of refined metal, bullion, and alloys produced indigenously, plus recoverable bismuth content of domestic ores and concentrates exported for processing. [3]Total for listed figures only; it excludes United States production, which is not available for publication, as well as that of some other smaller producing countries.
^{p}Preliminary; ^{e}Estimated; . . Data not available, but estimate included in figure for "Other countries."

In March 1978, members of the Bismuth Institute held a closed meeting in Lima, Peru. The Institute was incorporated in 1973, and the six sponsoring members* are the world's major producers. The principal objectives of the Institute are an increased use of bismuth in its current applications and the development of new uses for the metal, its alloys and compounds. Statistics are kept on consumption and production of bismuth. The Institute's headquarters are in La Paz, Bolivia, but it maintains an information centre in Brussels, Belgium.

Uses

A major use of bismuth is in pharmaceuticals, cosmetics, and industrial and laboratory chemicals, including catalytic compounds. Various bismuth compounds, salts and mixtures are used in pharmaceuticals for indigestion remedies, antacids, burn and wound dressings. The consumption of bismuth for indigestion remedies is on the decline since France made such compounds a prescription drug item. France is the leading consumer in this category. Insoluble salts of bismuth are given to patients before X-ray examination of the digestive tract. Cosmetics containing bismuth oxychloride, which imparts a "pearlescent" glow to eye shadow, lipstick, nail polish and powders, comprise one of the larger end-use markets of bismuth, but consumption in this market depends on changing fashion trends and is declining.

Another important outlet for the metal is fusible or low-melting point alloys for fire-protection devices, electrical fuses, fusible plugs and solders. Many of these alloys contain 50 per cent or more bismuth, with the chief additive metals being cadmium, lead and tin. In safety applications, the dependability of the melting temperatures of the various bismuth alloy compositions is of utmost importance. Pure bismuth metal expands 3.3 per cent on changing from a molten to a solid state. Nonshrinking, low-melting-point bismuth alloys are used in the holding of jet engine airfoil blades during the machining of the root sections. Bismuth-tin alloys are sprayed on patterns to make moulds in the plastic industry.

The metal is also used as an important additive to improve the machinability of aluminum alloys, malleable irons and steel alloys, and, with indium, forms a low-melting alloy used in the ophthalmic industry for holding lenses. The United States Atomic Energy Commission used bismuth in many nuclear research applications because of the metal's low thermal neutron absorption rate.

Bismuth is used in catalysts in the production of acrylonitrile for acrylic fibres and plastics. This use suffered some decline in the 1960s but technological improvements in the process have led to increased demand in the 1970s. The rubber industry also uses a bismuth compound to accelerate the vulcanization process.

*Cerro de Pasco Corporation, Peru; Corporacion Minera de Bolivia (COMIBOL); Mining & Chemical Products Limited, United Kingdom; Salsigne S.A., France; Sidech S.A., Belgium; and Peko-Wallsend Ltd., Australia. Industrial Minera Mexico S.A. later became a member of the Institute.

Table 4. United States consumption of bismuth by principal uses, 1976 and 1977

	1976	1977[1]
	(kilograms, bismuth content)	
Pharmaceuticals[2]	631 248	596 498
Fusible alloys	235 255	276 071
Metallurgical additives	206 811	198 950
Other alloys	9 191	8 426
Experimental uses	3 972	—
Other uses	6 946	5 443[e]
Total	1 093 423	1 085 388

Source: United States Department of the Interior, Bureau of Mines, Minteral Industry Surveys, "Bismuth in the Fourth Quarter 1977."
[1]Estimated 100 per cent coverage based on reports from respondents that consumed 90 per cent of the total bismuth metal in 1976. [2]Includes industrial and laboratory chemicals.
[e]Estimated; — Nil.

Outlook

The major western world economies are still recovering from the 1974-75 recession and the outlook for 1978 is one of continued sluggish growth. Price reductions, somewhat poorer demand and more than adequate supplies characterized the bismuth market in 1977, and little improvement in this situation is expected in 1978 or the first half of 1979. Moreover, there are no new markets or uses for bismuth on the horizon.

Bismuth is mainly a byproduct of the copper and lead industries. The depressed market conditions for copper since late 1974 have kept and will keep bismuth output from this source restricted through 1978 and possibly well into 1979.

The United States Bureau of Mines has forecast that demand for bismuth should increase at an annual rate of 1 per cent through 1985 and at a rate of 0.7 per cent from 1985 to 2000. These forecasts used 1973 as a base.

Prices

The Canadian price, as quoted by Cominco Ltd., for 99.994+ per cent pure bismuth was $7.50 a pound from January 1, 1977 until late July when it was dropped to $5.00 a pound. About mid-October the price was reduced to $4.50 a pound at which level it remained until year-end. The United States domestic producer price for 99.99 per cent pure bismuth, as quoted in *Metals Week,* was U.S. $7.50 a pound at the beginning of January. Late in June it declined to $5.00 a pound and about mid-September it was reduced to $4.50 a pound at which level it remained until year-end.

Dealer prices on the New York Market opened the year at $4.65 to $4.80 a pound, peaked in March at $6.00 to $6.25 a pound, then declined during the rest of the year, reaching a low of $2.70 to $2.80 a pound late in December.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
33100-1	Bismuth ores and concentrates	free	free	free	free
35106-1	Bismuth metal, not including alloys, in lumps, powders, ingots or blocks	free	free	25%	free

United States

		Non-communist Countries
601.66	Bismuth ores and concentrates	free
632.10	Bismuth metal, unwrought; waste and scrap	free
632.64	Alloys of bismuth, containing by weight not less than 30% lead	free
632.66	Other alloys of bismuth	9% Ad valorem
633.00	Bismuth metal, wrought	9% Ad valorem

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa; Tariff Schedules of the United States Annotated (1978) TC Publication 843.

Cadmium

D.H. BROWN

Although cadmium is a relatively rare element in the earth's crust, it occurs most commonly as the sulphide, greenockite (CdS) which is found associated with zinc sulphide ores, particularly sphalerite [(Zn, Fe)S]. The presence of cadmium during sphalerite development results in the formation of greenockite crystals on the surface and between the sphalerite crystals. To a very small degree cadmium also displaces zinc within the sphalerite crystal structure. The intimate association of cadmium with zinc minerals continues even during separation of multi-mineral ores into concentrates, such that small amounts of zinc reporting to lead and copper concentrates will be accompanied by a proportionate amount of cadmium. There are no known commercial orebodies of cadmium and, accordingly, reserves at any time are a function of zinc reserves, and specifically the cadmium content of those reserves. Cadmium recoveries are generally estimated to be 70 to 90 per cent from ore to concentrate and 45 to 80 per cent from concentrate to metal, or 31.5 to 72 per cent overall.

Cadmium metal is recovered as a byproduct of zinc smelting and refining and, since secondary sources are considered negligible in terms of total supply, cadmium production or supply is therefore strictly a function of zinc metal production, which bears little or no relationship to the demand for cadmium. Because cadmium represents only 2 to 3 per cent of zinc plant revenues, its supply is virtually inelastic to price fluctuations.

Generally, cadmium is initially separated in fumes collected during the roasting of zinc-bearing ores and concentrates, and in precipitates obtained during the purification of zinc sulphate solution resulting from the sulphuric acid leaching of calcine, which is the product of roasting. In Canadian zinc plants, which are all electrolytic, cadmium metal is recovered either by the electrolytic process whereby the cadmium-bearing precipitate is redissolved in sulphuric acid and plated out in electrolytic cells, or by a purification process in which cadmium-bearing precipitates are releached in sulphuric acid, then filtrated and purified. The purified solution is then cemented with zinc dust to produce cadmium sponge which, in turn, is filtered, briquetted, melted and cast. At primary zinc distillation plants cadmium is reduced and vaporized with zinc in a retort or furnace. The vapour is condensed and cadmium (BP*776°C) is separated from zinc (BP 905°C) by fractional distillation.

In Canada, metal production increased to 1 375 tonnes in 1977 from 1 342 tonnes in 1976; however, shipments declined sharply from the prior year. Producers domestic shipments declined to 90 tonnes in 1977 from 123 tonnes in 1976 and exports fell to 870 tonnes in 1977 from 1 556 tonnes in 1976. The United States and the United Kingdom continued to be Canada's major export markets, accounting for 93 per cent of total exports, with the balance being shipped to the Netherlands, Belgium and West Germany.

The General Services Administration in the United States did not buy or sell any cadmium for the strategic stockpile in 1977 and the stockpile goal of 11 204 tonnes remained in a deficit position of 8 333 tonnes throughout the year.

Production of cadmium in the western world as reported by the World Bureau of Metal Statistics is estimated to have increased to 14 102 tonnes in 1977 compared to 13 181 tonnes in 1976.

Canadian production

Canadian mine production in 1977 as reported by Statistics Canada was 1 199 tonnes compared with 1 314 tonnes in 1976. These figures represent the metallic cadmium recovered at domestic zinc refineries from Canadian ores, plus the recoverable content of ores and concentrates exported. The Canadian mines listed in Table 4 produced approximately 3 809.1 tonnes of cadmium in zinc concentrates in 1977, compared with 3 391 tonnes in 1976. The difference between data reported by Statistics Canada and that shown in Table 4 stems from the fact that many mining companies are

*Boiling point.

not paid for their cadmium in zinc concentrate and thus they did not report its content in their shipments of concentrate. For the same reason, most mines do not assay for cadmium on a regular basis, and accordingly many of the entries listed in Table 4 are estimated composite assays of annual production.

Table 1. Canadian primary cadmium statistics, 1975-77

	1975	1976	1977^p
	(tonnes)		
Mine production[1]	3 492	3 391	3 809
Metal production	1 142	1 342	1 375
Metal capacity	1 705	1 705	1 705
Metal shipments:			
Domestic	105	123	90
Exports	638	1 556	870

Sources: Statistics Canada; *Operators List No. 3,* 1975-1977, Department of Energy, Mines and Resources; and estimates by Mineral Policy Sector, Department of Energy, Mines and Resources.
[1]Cadmium content of zinc concentrate production as shown in Table 4.
^{p} Preliminary.

Metallic cadmium is recovered as a byproduct at the electrolytic zinc plants of Cominco Ltd. at Trail, British Columbia; Hudson Bay Mining and Smelting Co., Limited at Flin Flon, Manitoba; Canadian Electrolytic Zinc Limited at Valleyfield, Quebec; and Texasgulf Canada Ltd. near Timmins, Ontario. Cadmium metal production by these companies in 1977 increased to 1 375 tonnes, equivalent to 2.71 kilograms (kg) cadmium per tonne of zinc metal produced, compared with 1 342 tonnes in 1976 equivalent to 2.84 kg cadmium per tonne of zinc metal produced.

Canadian consumption

A survey of cadmium consumers in Canada as shown in Table 3 by Statistics Canada indicates that usage in cadmium plating applications declined in 1976 from 1975 but overall usage increased due to growth in chemicals, pigments and alloys. Total end-usage accounted for by this survey amounted to 53.8 tonnes in 1976 compared with 38.2 tonnes in 1975. Unfortunately, the tonnage represented in this survey is not reconcilable with domestic shipments of metal by producers, which amounted to 123.4 tonnes in 1976 and 104.9 tonnes in 1975. Accordingly, the survey cannot be considered to be a reliable estimate of total consumption in Canada.

Uses

Cadmium is a soft, ductile, silver-white electropositive metal with a valence of two. It is used mainly for electroplating iron and steel products to protect them against oxidation. A cadmium coating, like a zinc coating, protects those metals lower in the electromotive series by physical enclosure and by sacrificial corrosion. Cadmium is usually preferred to zinc as a coating because it is more ductile, is slightly more resistant to common atmospheric corrosion, can be applied more uniformly in recesses of intricately shaped parts, and can be electro-deposited with less electric current per unit of area covered. It is also preferred for its more aesthetic appearance. However, because it is more costly and much less plentiful than zinc, it is not as widely used. Improvements in zinc electroplating techniques in recent years have tended to reduce the consumption of cadmium in plating but it still remains the largest use for cadmium. Cadmium-plated parts are used in automobiles, household appliances, aircraft, radios, television sets and electrical equipment.

Table 2. Canada, cadmium metal capacity, 1977

Company and Location	Annual Capacity
	(tonnes)
Canadian Electrolytic Zinc Limited, Valleyfield, Quebec	544
Cominco Ltd., Trail, British Columbia	544
Hudson Bay Mining and Smelting Co. Ltd., Flin Flon, Manitoba	163
Texasgulf Canada Ltd., Timmins, Ontario	454
Total Canada	1 705

Source: Operators List No. 3, *Metallurgical Works in Canada, Nonferrous and Precious Metals,* January 1977, Department of Energy, Mines and Resources, Ottawa.

The second-largest use according to the Statistics Canada survey is in the manufacture of pigments and chemicals. Cadmium sulphides give yellow-to-orange colours and cadmium sulphoselenides give pink-to-red and maroon. Cadmium stearates act as stabilizers in the production of polyvinyl chloride plastics, and cadmium phosphors are used for tubes in both black-and-white and colour television sets. Unique photochemical properties have also created uses for cadmium in such areas as smoke alarm systems and solar energy cells.

Cadmium is a valuable alloying metal and has applications in cadmium-silver solders and in cadmium-tin-lead-bismuth fusible or low-melting-point alloys for automatic sprinkler systems, fire-detection apparatus, and valve seats for high-pressure gas containers. Low-cadmium copper (about 1 per cent cadmium) is used in trolley and telephone wires because of the improved tensile strength imparted by cadmium. Low-cadmium copper is also now employed in automobile radiator finstock, replacing the low-silver copper formerly used. Another growing application is in the production of nickel-cadmium storage batteries. These batteries are considerably more expensive than the standard lead-acid battery, but have a longer life and higher peak power output, are smaller, and are superior in low-temperature operation. They are especially suitable for use in airplanes, satellites and missiles, and ground equipment for polar regions, as well as in portable items such as battery-operated shavers, toothbrushes, drills and hand saws.

Table 3. Canada, cadmium production, exports and consumption, 1976 and 1977

	1976		1977[p]	
	(kilograms)	($)	(kilograms)	($)
Production				
All forms[1]				
Ontario	733 859	4 246 943	622 000	4 375 000
British Columbia	356 424	2 062 675	322 000	2 260 000
Quebec	91 706	530 715	194 000	1 361 000
Manitoba	57 548	333 036	25 000	175 000
New Brunswick	2 534	14 666	18 000	127 000
Saskatchewan	15 024	86 945	11 000	80 000
Newfoundland	53 795	311 320	5 000	32 000
Yukon	2 284	13 220	2 000	11 000
Northwest Territories	549	3 179	—	—
Total	1 313 723	7 602 699	1 999 000	8 421 000
Refined[2]	1 342 269		1 374 675	
Exports				
Cadmium metal				
United States	1 057 305	5 823 000	408 224	2 558 000
United Kingdom	382 190	2 089 000	404 127	2 392 000
Netherlands	84 712	366 000	47 325	258 000
Belgium and Luxembourg	30 005	177 000	10 002	61 000
West Germany	. . .	1 000	1	. . .
Other countries	1 560	11 000	—	—
Total	1 555 772	8 467 000	869 679	5 269 000

	1975	1976
	(kilograms)	(kilograms)
Consumption		
Cadmium metal[3]		
Plating	27 624	26 142
Solders	2 505	3 398
Other uses[4]	8 080	24 275
Total	38 209	53 815

Source: Statistics Canada.
[1]Production of refined cadmium from domestic ores, plus recoverable cadmium content of ores and concentrates exported. [2]Refined metal from all sources and cadmium sponge. [3]Available data reported by consumers. [4]Mainly chemicals, pigments and alloys other than solder.
[p]Preliminary; — Nil; . . . Less than $1 000 or one kilogram.

Table 4. Principal cadmium producing mines in Canada, 1977 and (1976)

Company name	Daily Mill Capacity	Grade of Zinc Concentrates: Cadmium	Zinc	Lead	Copper	Silver	Zinc Concentrate produced	Cadmium Content
	(tonnes ore)	%	%	%	%	(grams/tonne)	(tonnes)	(kg)
Newfoundland								
ASARCO Incorporated,	1 150	0.22	55.81	3.11	0.61	139.9	26 232	57 710.4
Buchans	(1 150)	(0.22)	(55.60)	(3.29)	(0.68)	(162.9)	(29 134)	(64 096.0)
Newfoundland Zinc Mines	1 350	0.376	62.6	. .	. .	. .	71 292	268 057.9
Limited,	(1 350)	(0.17)	(62.0)	(. .)	(. .)	(. .)	(61 213)	(104 063.3)
Daniel's Harbour								
New Brunswick								
Brunswick Mining and Smelting	8 950	0.09	51.91	2.08	0.28	87.4	354 135	318 721.5
Corporation Limited,	(8 950)	(0.08)	(52.04)	(. .)	(. .)	(. .)	(231 839)	(185 471.2)
Bathurst								
Heath Steele Mines Limited,	3 650	0.09	47.78	1.73	0.88	101.8	69 181	62 262.9
Newcastle	(3 650)	(0.09)	(48.34)	(1.83)	(0.75)	(122.7)	(72 422)	(65 181.0)
Nigadoo River Mines Limited[e],	1 050	0.65	45.3	. .	. .	. .	5 960	38 740.0
Bathurst	(1 050)	(0.65)	(45.3)	(2.41)	(1.09)	(167.3)	(8 970)	(58 304.5)
Quebec								
Falconbridge Copper Limited,	1 400	0.11	52.59	—	0.76	0.6	22 152	24 367.2
Lake Dufault Division,	(1 400)	(0.11)	(52.65)	(. .)	(. .)	(. .)	(23 523)	(29 924.2)
Noranda								
Lemoine Mines Limited,	350	0.27	. .	. .	. .	. .	17 140	46 278
Lemoine Mine,	(350)	(0.28)	(53.22)	(. .)	(. .)	(. .)	(13 067)	(36 588)
Chibougamau								
Louvem Mining Company Inc.,	900	0.17	53.14	. .	. .	. .	30 334	51 567.8
Louvicourt	(. .)	(. .)	(. .)	(. .)	(. .)	(. .)	(. .)	(. .)
Mattagami Lake Mines Limited,	3 500	0.12	53.33	—	0.39	50.1	108 518	130 221.6
Matagami	(3 500)	(0.12)	(52.7)	(0.12)	(0.47)	(47.0)	(140 513)	(168 615.6)

Orchan Mines Limited, Orchan and Garon Lake mines, Matagami	1 700 (1 700)	0.11 (0.15)	51.53 (51.64)	— (. .)	0.50 (. .)	— (. .)	54 787 (48 064)	60 265.7 (72 096.0)
Ontario								
Falconbridge Copper Limited, Sturgeon Lake Joint Venture, Sturgeon Lake	1 100 (1 100)	0.13 (0.13)	53.22 (52.29)	. . (. .)	. . (. .)	. . (. .)	57 805 (46 019)	75 146.5 (59 824.9)
Mattabi Mines Limited, Sturgeon Lake	2 700 (2 700)	0.14 (0.14)	54.88 (54.36)	0.29 (. .)	0.20 (. .)	49.4 (. .)	127 707 (126 185)	178 789.8 (176 659.0)
Noranda Mines Limited, Geco Division, Manitouwadge	4 550 (4 550)	0.38 (0.37)	51.93 (52.07)	— (. .)	0.98 (0.82)	60.3 (64.9)	60 309 (56 584)	229 174.2 (209 360.8)
Selco Mining Corporation Limited, South Bay Division, Uchi Lake	500 (450)	0.234 (0.234)	53.62 (53.66)	— (. .)	0.37 (. .)	54.3 (. .)	27 442 (29 181)	64 214.3 (68 285.4)
Texasgulf Canada Ltd., Kidd Creek	9 050 (9 050)	0.25 (0.25)	52.59 (51.98)	0.47 (0.52)	0.6 (0.48)	143 (136.5)	395 782 (429 099)	989 455.0 (1 070 579.7)
Willroy Mines Limited[e], Manitouwadge Division, Manitouwadge	1 450 (1 450)	0.17 (0.17)	51.58 (51.58)	. . (. .)	. . (0.46)	. . (. .)	3 685 (20 482)	6 264.5 (35 001.8)
Manitoba and Saskatchewan								
Hudson Bay Mining and Smelting Co. Limited, Flin Flon	7 700 (7 700)	0.12 (0.12)	47.8 (47.7)	1.1 (0.7)	0.77 (0.74)	65.1 (54.9)	63 764 (50 039)	76 516.8 (60 046.7)
Sherritt Gordon Mines Limited, Fox mine, Lynn Lake	2 700 (2 700)	0.13 (0.13)	51.10 (49.41)	. . (. .)	0.98 (0.90)	. . (. .)	22 051 (17 354)	28 666.3 (22 559.6)
Ruttan Lake, Ruttan Lake	9 090 (9 050)	0.15 (0.15)	50.63 (50.56)	— (. .)	1.22 (1.22)	— (. .)	70 244 (83 523)	105 366.0 (125 285.3)

Table 4. (cont'd)

Company name	Daily Mill Capacity	Grade of Zinc Concentrates: Cadmium	Zinc	Lead	Copper	Silver	Zinc Concentrate produced	Cadmium Content
	(tonnes ore)	%	%	%	%	(grams/tonne)	(tonnes)	(kg)
British Columbia								
Cominco Ltd.,	9 050	0.13	48.6	5.7	. .	85.7	150 420	195 546.0
Sullivan mine,	(9 050)	(0.13)	(48.1)	(5.8)	(. .)	(78.9)	(150 648)	(195 844.6)
Kimberley								
H.B. mine,	1 100	0.42	54.2	1.7	. .	27.4	22 561	94 756.2
Salmo	(1 100)	(0.44)	(48.1)	(5.8)	(. .)	(27.4)	(23 261)	(102 350.1)
Silvana Mines Inc.,	100	0.383	49.47	. .	. .	2 009.9	1 405	5 381.2
Silmonac mine,	(100)	(0.37)	(49.54)	(. .)	(. .)	(2 122.6)	(1 240)	(4 588.6)
Sandon								
Northair Mines Ltd.,								
Alta Lake,	250	0.315	53.9	2.55		526.3	2 347	7 393.1
Brandywine area	(250)	(0.2)	(48.5)	(4.3)	(. .)	(644.2)	(846)	(1 692.0)
Teck Corporation Limited,	100	0.29	32.5	1.6	. .	2 180.6	245	710.5
Beaverdell mine,	(100)	(0.39)	(39.1)	(1.5)	(. .)	(1 579.9)	(298)	(1 163.9)
Beaverdell								
Western Mines Limited,	1 000	0.23	52.67	0.86	0.56	176.9	31 247	71 868.1
Lynx and Myra Falls	(1 000)	(0.23)	(52.85)	(0.85)	(0.64)	(187.2)	(32 299)	(72 801.4)
Yukon Territory								
Cyprus Anvil Mining	9 050	0.06	50.29	1.72	0.85	31.3	220 831	132 498.6
Corporation,	(9 050)	(0.06)	(51.36)	(1.59)	(. .)	(. .)	(114 868)	(68 921.3)
Faro								
United Keno Hill Mines Limited,	450	0.67	. .	. .	. .	. .	454	3 041.8
Elsa	(450)	(0.67)	(48.0)	(. .)	(. .)	(. .)	(586)	(3 926.3)

Northwest Territories								
Pine Point Mines Limited,	9 050	0.10	56.66	2.13	. .	. .	264 801	264 801.0
Pine Point	(9 050)	(0.10)	(57.37)	(1.92)	(. .)	(. .)	(295 711)	(295 714.4)
Nanisivik Mines Ltd.	1 350	0.19	57.6	. .	. .	230	116 500	221 350.0
Baffin Island	(1 350)	(0.18)	(49.0)	(5.0)	(. .)	(. .)	(14 756)	(26 559.9)

Source: Annual survey of mines, Minerals and Metals Division, Department of Energy, Mines and Resources, Ottawa.
— Nil; . . Not available; [e]Estimated.

Table 5. Canada, cadmium production, exports and domestic shipments, 1960, 1965, 1970, 1975, 1976 and 1977

	Production		Exports Cadmium Metal	Producers' Domestic Shipments
	All Forms[1]	Refined[2]		
	(kilograms)			
1960	1 069 343	1 015 140	932 737	333 844
1965	796 474	812 152	618 993	206 891
1970	1 954 055	836 745	702 630	157 307
1975	1 191 674	1 142 502	637 797	104 898
1976	1 313 723	1 342 269	1 555 772	123 389
1977[p]	1 199 000	1 374 675	869 679	89 586

Source: Statistics Canada.
[1]Production of refined cadmium from domestic ores, plus recoverable cadmium content of ores and concentrates exported. [2]Refined metal from all sources and cadmium sponge.
[p]Preliminary.

Prices

Typically, zinc plants pay for 60 per cent of the cadmium in zinc concentrates above a base level of 0.2 per cent cadmium, equivalent to two kg of cadmium per tonne of zinc concentrate. Depending upon market conditions for cadmium and zinc concentrate, these payment terms can range from zero to 70 per cent of the full cadmium content.

In Canada, *The Northern Miner* publishes the announced sales price for cadmium, but does not publish a monthly average, and on this basis the prices shown in Table 6 represent the price in effect at month-end.

Primary cadmium metal producers, including Canadian producers, normally sell metal at individual prices established by each firm. Almost all Canadian metal production is exported to the United States and the European Economic Community (EEC). North American prices, which are quoted on a delivered basis, are best represented by the "U.S. Producer" quotations published by *Metals Week* in New York.

Table 6. Cadmium metal prices, 1977

	Northern Miner	Metals Week		Metals Bulletin	
Month	Cominco	U.S. Producer	New York Dealer	Common-wealth	Sticks, free market
	($Cdn/lb)	($U.S./lb)		($U.S./lb)	
January	3.00	3.000	2.450-2.850	3.000	2.567-2.644
February	3.00	3.000	2.650-2.900	3.000	2.691-2.741
March	3.00	3.000	2.800-2.950	3.000	2.847-2.899
April	3.00	3.000	2.500-2.850	3.000	2.653-2.725
May	3.00	3.000	2.550-2.700	3.000	2.548-2.639
June	3.00	3.000	2.300-2.350	3.000	2.347-2.437
July	3.00	3.000	2.300-2.450	3.000	2.280-2.352
August	3.00	3.000	2.000-2.400	3.000	2.054-2.160
September	3.00	3.000	2.000-2.300	3.000	1.890-1.968
October	3.00	3.000	1.950-2.200	3.000	1.810-1.860
November	3.00	3.000	1.900-2.100	3.000	1.851-1.902
December	2.50	2.544	1.850-2.050	3.000	1.779-1.828
Average 1977	2.958	2.962	2.271-2.508	3.000	2.276-2.346

Sources: *Northern Miner, Metals Week, Metal Bulletin.*

European prices, which are quoted on a cif* port-of-discharge basis, with inland freight negotiable and dependent upon market conditions, are best represented by the "Commonwealth (cif)" quotations published by the *Metal Bulletin* in London. In the United States, domestic producers are the price leaders and Canadian producer price policy appears to adopt the U.S. basis. In the EEC, the "European Reference Price", cif/ex-works, also quoted by the *Metal Bulletin,* has formed the basis for some metal sales, as it represents the range of prices at which cadmium is sold by European producers, as determined by a regular survey conducted by the publication. Producer prices are very sensitive to dealer prices and tend to follow them closely, despite the fact that it is very difficult to determine the quantity of metal that the dealers trade represents. The primary dealer quotations are the "N.Y. Dealer" quotations published by *Metals Week* and the "sticks, free market" cif quotations published by the *Metal Bulletin.* All prices mentioned above represent cadmium metal having a minimum purity of 99.95 per cent, and are set out in Table 6 which lists the monthly average during 1977, except for the "N.Y. Dealer" quotations which are the range of weekly averages during the month.

*Cost insurance freight.

Tariffs

Canada

Item No.		British Preferential	GSP[1]	GATT[2]	General
32900-1	Cadmium in ores and concentrates	free	free	free	free
35102-1	Cadmium metal, not including alloys in lumps, powders, ingots or blocks	free	free	free	25%

United States

TSUS No.		GSP	GATT
601.66	Cadmium in ores and concentrates	free	free
632.14	Cadmium metal, unwrought, waste and scrap	free	free
632.84	Cadmium alloys, unwrought	9%	9%
633.00	Cadmium metal, wrought	free	9%

European Economic Community

Brussels Tariff Nomenclature Number		GSP	GATT
26.01	Cadmium in ores and concentrates	free	free
81.04	Cadmium metal: unwrought, waste and scrap	4%	4%
	Other	6%	6%

Japan

Brussels Tariff Nomenclature Number		GSP	GATT
26.01	Cadmium in ores and concentrates	free	free
81.04	Cadmium metal: unwrought, waste and scrap, powders, flakes	free	8%
	Other	free	12%

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa; Tariff Schedules of the United States Annotated (TSUS); Official Journal of the European Communities, Common Customs Tariff; Customs Tariff Schedules of Japan.
[1]GSP — Generalized System of Preferences, extended to most developing countries. [2]GATT — General Agreement on Tariffs and Trade.

Calcium

D. PEARSON

Calcium occurs in dolomites and limestone, and is the fifth most abundant element in the earth's crust. Metallic calcium was first prepared by Sir Henry Davy in 1808 by electrolysis of fused calcium salts. Calcium is silvery white in colour, extremely soft and ductile and highly reactive. This metal has a low tensile strength. The principal source of calcium today is from high-calcium limestone deposits.

The process now used exclusively to recover metallic calcium is the aluminothermic reduction of lime in a non-continuous process. There are only three producers of metallic calcium in the non-communist world: Chromasco Limited in Canada, Planet-Wattohm S.A., a subsidiary of Compagnie de Mokta, in France; and Charles Pfizer and Co. Inc. in the United States. Canada continued to be a leading international producer and supplier of calcium metal in 1977. Production and consumption of calcium amount to approximately 950 tonnes* a year in the non-communist world. Calcium metal is also produced in the U.S.S.R., which exports small quantities to Western Europe and the United States.

Canadian industry

Chromasco Limited produces calcium metal at its metallurgical plant at Haley, near Renfrew, Ontario. It utilizes the same vacuum retort process which is used to produce its principal product, magnesium. Other products from the Haley operation, in addition to magnesium and calcium metals, are magnesium and calcium alloys, and barium, strontium and thorium metals. To make calcium, high-purity quicklime (CaO)

*The term "tonne" refers to the metric ton of 2,204.62 pounds avoirdupois.

Table 1. Canada, calcium production and exports, 1976-77

	1976		1977p	
	(kilograms)	($)	(kilograms)	($)
Production (metal)[1]	513 964	1 432 505	566 000	2 022 000
Exports (metal)				
United States	261 723	675 000	227 567	800 000
India	11 929	55 000	—	—
West Germany	11 340	42 000	31 842	109 000
United Kingdom	4 717	22 000	7 575	57 000
South Africa	7 257	26 000	272	4 000
Other countries	1 044	2 000	1 497	7 000
Total	298 010	822 000	268 753	977 000

Source: Statistics Canada.
[1] Producers' shipments of calcium metal, and calcium used in production of calcium alloys.
— Nil; p Preliminary.

and commercially pure aluminum are briquetted and then charged into horizontal electric retorts. Under vacuum, the aluminum reduces the quicklime to form a calcium vapour. This calcium vapour crystallizes between 680° and 740°C in the water-cooled condenser section of the retort. The initial product, known as "crowns", contains about 98 per cent calcium. Higher purities are obtained by subsequent refining operations.

Chromasco makes four main grades of calcium: Grade 1, chemical standard, 99.7 per cent calcium, with up to 0.2 per cent magnesium and minor amounts of other elements; Grade 2, nuclear quality, 99.4 per cent calcium, with a maximum magnesium content of 0.5 per cent; Grade 3, battery grade, 98.5 per cent calcium, with a maximum of 0.5 per cent magnesium, 0.15 per cent nitrogen maximum, and 0.45 per cent aluminum maximum; Grade 4, commercial crowns, 98.0 per cent calcium, 0.5 to 1.5 per cent magnesium, 0.15 per cent nitrogen maximum, 0.45 per cent aluminum maximum.

Canadian production of metallic calcium in 1977 was 566 000 kilograms (kg). This is an increase of 10 per cent above that of 1976. As will be seen in Table 2, production of calcium over the period 1970 to 1977 increased by an average of almost 26 per cent a year. During the same period, exports of calcium increased steadily to an all-time high of 339 060 kg in 1974.

Table 2. Canada, calcium production and exports, 1960, 1965, 1970, 1975, 1976 and 1977

	Production[1]	Exports
	(kilograms)	
1960	61 145	33 929[e]
1965	72 318	67 267
1970	201 194	78 970
1975	428 288	309 758
1976	513 964	298 010
1977[p]	566 000	268 753

Source: Statistics Canada.
[1]Producers' shipments of calcium metal and calcium metal used in production of calcium alloys.
[p]Preliminary; [e]Estimated.

Exports in 1977 were 268 753 kg, of which 227 567 kg were imported by the United States. The U.S. Department of the Interior reported that the new lead-calcium storage battery continued to consume the major portion of that country's calcium metal supply in 1977. It is therefore inferred that the tremendous growth in calcium production has been linked to this development.

Uses

Metallic calcium is a powerful reducing agent and this property is used in the preparation of many of the less common metals which resist reduction by normal reductants such as carbon, hydrogen and natural gas. Some of these metals are columbium, tantalum, titanium, thorium, uranium, vanadium and zirconium. Calcium is used extensively to remove bismuth, antimony and arsenic from lead. A great number of organocalcium compounds are produced and these find uses as special lubricants, corrosion inhibitors and detergents. Calcium is also an alloying agent in magnesium, aluminum, lead, lithium and silicon. Ferrosilicon alloys containing calcium, or in combination with magnesium or aluminum are widely used in the steel industry to control grain size, inhibit carbide formation, improve ductility and reduce internal flaws.

Outlook

Demand for calcium in both the ferrous and nonferrous industries, as well as for the other uses mentioned above, should remain at about the same level as in 1977. There are strong indications that the use of "maintenance-free" automotive batteries will replace the lead-acid type now used predominantly in the automobile market. These batteries, containing about 0.1 per cent calcium, are lighter and substantially higher in conductivity, and require no addition of water during the life of the battery.

Prices

According to *Metals Week*, December 30, 1977, in United States currency:

	(¢/lb)
Calcium metal, 5-ton lots, full crowns	149.00
Calcium silicon, 32% calcium	51.00

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
		(% ad. val.)			
92805-1	Calcium metal	10	15	25	10

United States

Item No.		Non-communist countries	Communist countries except Yugoslavia
		(% ad val.)	
632-16	Calcium	7.5	25
633-00	Other base metals, wrought	9	45

Duty on waste and scrap temporarily suspended.

Sources: For Canada, the Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1978) T.C. Publication 843.

Cement

D.H. STONEHOUSE

Portland cement is produced by burning, usually in a rotary kiln, an accurately proportioned, finely ground mixture of limestone, silica, alumina and iron oxide. Kiln discharge, in the shape of rough spheres, is a fused, chemically complex mixture of calcium silicates and aluminates, termed clinker, which is mixed with gypsum, 4 to 5 per cent by weight, and ground to a fine powder to form portland cement. By close control of the raw mix, the burning conditions and of the use of additives in the clinker-grinding procedure, finished cements displaying various desirable properties can be produced.

The three basic types of portland cement: Normal Portland, High-Early-Strength Portland, and Sulphate-Resisting Portland, are produced by most Canadian cement manufacturers. Moderate Portland Cement and Low-Heat-of-Hydration Portland Cement, designed for use in concrete to be poured in large masses, such as in dam construction, are manufactured by several companies in Canada. Masonry cement (generic name) includes such proprietary names as Mortar Cement, Mortar Mix (unsanded), Mason's Cement, Brick Cement and Masonry Cement. The latter, produced by portland cement manufacturers, is a mixture of portland cement, finely ground high-calcium limestone (35 to 65 per cent by weight) and a plasticizer. The other products do not necessarily consist of portland cement and limestone, and may include a mixture of portland cement and hydrated lime and/or other plasticizers.

Cement has little use alone but, when combined with water, sand, gravel, crushed stone or other aggregates in proper proportions, acts as a binder, cementing the materials together as concrete. Concrete has become a widely used and readily adaptable building material which can be poured on site in large engineering construction projects, or used in the form of delicate precast panels or heavy, prestressed columns and beams in building construction.

Concrete research has generally been relative to strength determination, durability, placement and curing. Currently, great emphasis is being placed on researching the use of superplasticizers in concrete. Superplasticizers, a group of admixtures described chemically as naphthalene or melanine sulphonate polymers, have been found to provide greatly increased workability over short time spans or to provide high strength by permitting lower water-cement ratios.

Specifications

Portland cement used in Canada should conform to the specifications of CSA Standard A5 — 1971 published by the Canadian Standards Association. This standard covers the five main types or portland cement. Masonry cement produced in Canada should conform to the CSA Standard A8 — 1970.

The cement types manufactured in Canada, but not covered by the CSA standards, generally meet the appropriate specifications of the American Society for Testing and Materials (ASTM).

Cembureau, The European Cement Association, has published *Cement Standards of the World — Portland Cement and its Derivatives,* in which standards are compared. Cembureau's *World Cement Directory* lists production capacities by country and by company.

Regulations governing the design and application of these and other associated materials of construction are generally covered by CSA Standarts or by those of The American Concrete Institute.

Although individual companies continue to conduct research relative to cement production, much experimentation concerning the use of cement and concrete is done through the Portland Cement Association (PCA), an industry-supported, nonprofit organization whose purpose is to improve and extend the uses of cement and concrete through scientific research and engineering fieldwork. The Association is active in all parts of Canada, and can offer detailed information on concrete use, design and construction, from regional offices of The Canadian Portland Cement Association.

Summary

Cement is one of a number of industrial mineral commodities produced in Canada in direct support of the construction industry. Others are clays, lime, sand and gravel, stone, asbestos and gypsum. The construction industry is the largest single employer in Canada and one that is immediately affected by changes in the country's economic climate.

In Canada, construction is categorized broadly as building construction and engineering construction, and the values of each type, discounted by inflationary factors, provide a basis for comparison of annual construction in place. Historically, building construction has represented about 60 per cent of the total value of construction, and one element within this general category — residential construction — has normally accounted for 30 per cent of total value, or one-half of building construction. In current dollars, construction is credited with about 17 per cent of gross national expenditure. In 1977 capital and repair expenditure on construction was $35.7 billion, up about 7.8 per cent over expenditures in 1976.

The Anti-Inflation Board, constituted late in 1975, continued to produce mixed reactions during its second

Table 1. Canada, cement production and trade, 1976-77

	1976		1977p	
	(tonnes*)	($)	(tonnes)	($)
Production[1]				
By province				
Ontario	3 730 502	127 171 333	3 666 000	129 306 000
Quebec	2 624 800	94 868 687	3 019 000	110 654 000
Alberta	1 073 039	54 212 351	1 052 000	53 929 000
British Columbia	845 762	39 001 814	944 000	44 013 000
Manitoba	508 645	24 831 004	587 000	29 776 000
Saskatchewan	333 937	17 587 155	337 000	17 790 000
New Brunswick	. .	10 123 974	. .	10 367 000
Nova Scotia	. .	8 064 408	. .	8 257 000
Newfoundland	. .	5 250 927	. .	4 581 000
Total	9 624 320	318 111 653	10 099 000	408 673 000
By type				
Portland	9 268 220	. .	9 735 436	. .
Masonry[2]	356 100	. .	363 564	. .
Total	9 624 320	381 111 653	10 099 000	408 673 000
Exports				
Portland cement				
United States	920 020	23 921 000	1 273 711	40 355 000
Other countries	104	6 000	963	57 000
Total	920 124	23 927 000	1 274 674	40 412 000
Cement and concrete basic products				
United States	. .	14 930 000	. .	17 317 000
Other countries	. .	654 000	. .	521 000
Total	. .	15 584 000	. .	17 838 000
Imports				
Portland cement, white				
United States	25 299	1 373 000	21 078	1 406 000
Japan	565	25 000	656	37 000
Belgium and Luxembourg	569	29 000	487	33 000
Spain	—	—	14	1 000
Total	26 433	1 427 000	22 235	1 477 000

Table 1. (concl'd)

	1976		1977^p	
	(tonnes)*	($)	(tonnes)	($)
Cement, nes[3]				
United States	286 980	13 323 000	234 130	13 147 000
United Kingdom	988	45 000	306	34 000
Japan	—	—	911	31 000
Belgium and Luxembourg	—	—	144	14 000
West Germany	177	13 000	51	12 000
Other countries	101	12 000	41	19 000
Total	288 246	13 393 000	235 583	13 257 000
Total cement imports	314 679	14 820 000	257 818	14 734 000
Refractory cement and mortars				
United States	. .	6 048 000	. .	7 793 000
United Kingdom	. .	56 000	. .	152 000
Austria	. .	111 000	. .	113 000
Belgium-Luxembourg	. .	—	. .	109 000
Ireland	. .	33 000	. .	106 000
Other countries	. .	74 000	. .	115 000
Total	. .	6 322 000	. .	8 388 000
Cement and concrete basic products, nes				
United States	. .	2 261 000	. .	1 525 000
West Germany	. .	34 000	. .	48 000
France	. .	1 000	. .	40 000
United Kingdom	. .	69 000	. .	15 000
Belgium and Luxembourg	—	—	. .	14 000
Other countries	. .	2 000	. .	11 000
Total	. .	2 367 000	. .	1 653 000
Cement clinker				
United States	14 365	376 000	5 715	197 000

Source: Statistics Canada.
*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.
[1]Producers' shipments, plus quantities used by producers. [2] Includes small amounts of other cement. [3] Includes grey portland, masonry, acid proof, aluminous and other specialty types of cement.
^{p}Preliminary; nes Not elsewhere specified; . . Not available; — Nil.

year of operation. Unquestionably, wage and price increases were moderated, but an atmosphere of uncertainty prevailed throughout the business community and in many instances corporate decisions to forego, or at least defer, construction of new or expanded facilities were influenced by that uncertainty.

Although buoyancy was evident in western Canada, particularly in Alberta, slower growth in the non-residential building sector and in engineering construction was experienced throughout the country. Spending constraints by governments have reduced capital works expenditures on such projects as schools, hospitals, and highways. Because of this, governments at all levels have been cited as contributing to the depressed condition of the construction industry. Housing starts in 1977 were 245 724, following a record of 273 203 in 1976. The construction industry experienced an extremely high rate of unemployment, which indicates an underutilization of capacity. Many bankruptcies resulted during 1977.

The outlook for 1978 is far from encouraging. Industrial, commercial and institutional building are expected to show further declines, residential housing construction is expected to show little variation and engineering construction should achieve a slight increase in activity. A continued decline in total volume is forecast.

Many labour contracts in the construction industry

Table 2. Canada, cement production, shipments, trade and consumption, 1973-77

	Production	Shipments[1]	Exports[2]	Imports[2]	Apparent Consumption[3]
			(tonnes)		
1973	10 052 902	10 214 214	1 278 764	116 715	9 052 165
1974	10 640 001	10 553 233	1 148 393	251 300	9 656 140
1975	9 740 502	9 719 959	996 579	421 202	9 144 582
1976	9 898 024	9 803 020	920 124	314 679	9 197 575
1977[p]	9 933 137	10 047 573	1 274 674	257 818	9 030 717

Source: Statistics Canada, Cat. No. 44-001.
[1]Producers' shipments, plus quantities used by producers. [2]Does not include cement clinker, but does include exports from other than producer plants. [3]Producers' shipments plus imports, less exports.
[p]Preliminary.

will be negotiable in 1978 and without the restraint of the Anti-Inflation Board, demands could be severe, especially if the consumer price index reaches double figures.

In a supply role to a volatile industry, the cement industry, in turn, must be capable of adjusting and remaining competitive. Markets and raw material adequacy generally have influenced the selection of new cement plant sites. However, environmental considerations, labour situations and energy sources are becoming important factors in planning industry expansion and in keeping some plants operative. A coal-burning capability will probably become increasingly attractive as oil and gas become more expensive. The cement manufacturing industry uses an average of 5.5 million Btu's to produce a tonne* of product and is considered to be one of a number of energy-intensive industries. In fairness, the real product is concrete and the energy consumed over the entire life cycle of concrete structures can compare favourably with the amount consumed over the life cycle of structures built with other materials. The cement industry in Canada has voluntarily set an energy conservation goal — a reduction by 1980 of 12 per cent in unit energy consumption, with 1974 as the base year.

Markets for cement tend to be regional because transportation costs represent much of the laid-down price to the consumer and only rarely, as in the case of special cements or in periods of regional shortage, are shipments made beyond normal distribution boundaries. Production, therefore is determined by the regional construction activity and by interpretation of construction intentions.

An export market for Canadian cement developed in the northeastern and southeastern United States during the early 1970s because of a production deficiency in those regions. Canadian production became influenced, at least regionally, by construction activity and intentions in that country. The lack of production capability was brought on by plant closures forced by the application of environmental legislation, and by the industry's lack of appeal to attract capital investment for either the erection of new plants or the modernization of existing ones.

During 1977, production capacity of the cement industry in the United States was about 84 million tonnes a year, a net gain of 1.5 million tonnes over 1976. Shipments were up nearly 10 per cent in 1977, but were still substantially below the record level of 78.4 million tonnes set in 1973. The increase is credited to greater activity in the residential construction sector. Although the industry is recovering from the setbacks of the early 1970s, it is unlikely that any new or expanded capacity in the United States through the next two or three years will do more than meet demand.

In addition to spot sales of cement and clinker in the United States from Canadian plants, at least three contracts to supply major amounts of clinker to U.S. cement companies exist. Whether this will develop into a trend in the face of high energy costs and changing priorities in the utilization of fossil fuels remains to be seen. The opportunity to import energy in the form of cement clinker, while also avoiding the environmental problems associated with kiln operations, could become attractive.

Despite poor performance in construction in many parts of the country, the Canadian cement industry in total maintained a high level of production activity. Both production and shipments were marginally increased in 1977, mainly as a result of aggressive marketing of portland cement and cement clinker in the United States.

At the end of 1977 the industry's total theoretical capacity was just under 15 million tonnes a year, reflecting a net reduction of 102 000 tonnes a year compared with 1976. Canada Cement Lafarge Ltd.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoidupois.

essentially completed an expansion program at the Brookfield, Nova Scotia plant which began with the installation of a second kiln. During the year a new finish grinding mill and new clinker storage facilities were added. Cement-producing capacity in the Atlantic region now represents 6.5 per cent of the Canadian total.

In Ontario, St. Marys Cement Limited increased the production rate of its Bowmanville plant by about 45 000 tonnes a year by improving the efficiency of the grinding stages. The company's St. Marys plant experienced start-up difficulties with the new 680 000-tonne-a-year dry-process kiln. Two of the older kilns will be maintained, mainly for production of "specials".

In February, St. Lawrence Cement Company announced purchase of the Hudson, New York plant of Universal Atlas Cement, a division of United States Steel Corporation, for $8.2 million. St. Lawrence plans to fully integrate and modernize the Hudson plant when both the Quebec and United States markets show improvement. In the meantime, production from the company's Joliette, Quebec plant, in excess of that required for domestic sales, will be exported for distribution from Hudson.

Lake Ontario Cement Limited has supplied clinker from its Picton, Ontario plant to the Essexville, Michigan plant of Martin Marietta Corporation under contract since April 1976. In March 1977, the Essexville plant was purchased by Aetna Cement Corporation, a wholly-owned subsidiary of Lake Ontario, for $7 million, assuring Lake Ontario of continued high utilization of clinker output from Picton.

Canada Cement Lafarge Ltd. terminated its 50-50 joint venture with Lone Star Industries, Inc. of Connecticut, in Citadel Cement Corporation of Atlanta, Georgia. Under the agreement each shareholder was to obtain assets and assume liabilities equal to one-half the net worth of the joint venture as of March 31, 1977. Citadel is now operated as a wholly-owned subsidiary of Canada Cement Lafarge, operating two plants in the United States, one at Demopolis, Alabama and one at Birmingham, Alabama.

Inland Cement Industries Limited continued the $60 million expansion program which will increase the annual capacity of its Edmonton, Alberta plant to over 1 million tonnes by 1980. Two 37 000-tonne silos were added during 1977. Among the new facilities planned is a dry-process kiln which should provide considerable energy savings. A 4 500-horsepower grinding mill and expanded cement storage facilities will also be provided. A recent announcement by the company indicates the intention to convert the Edmonton plant

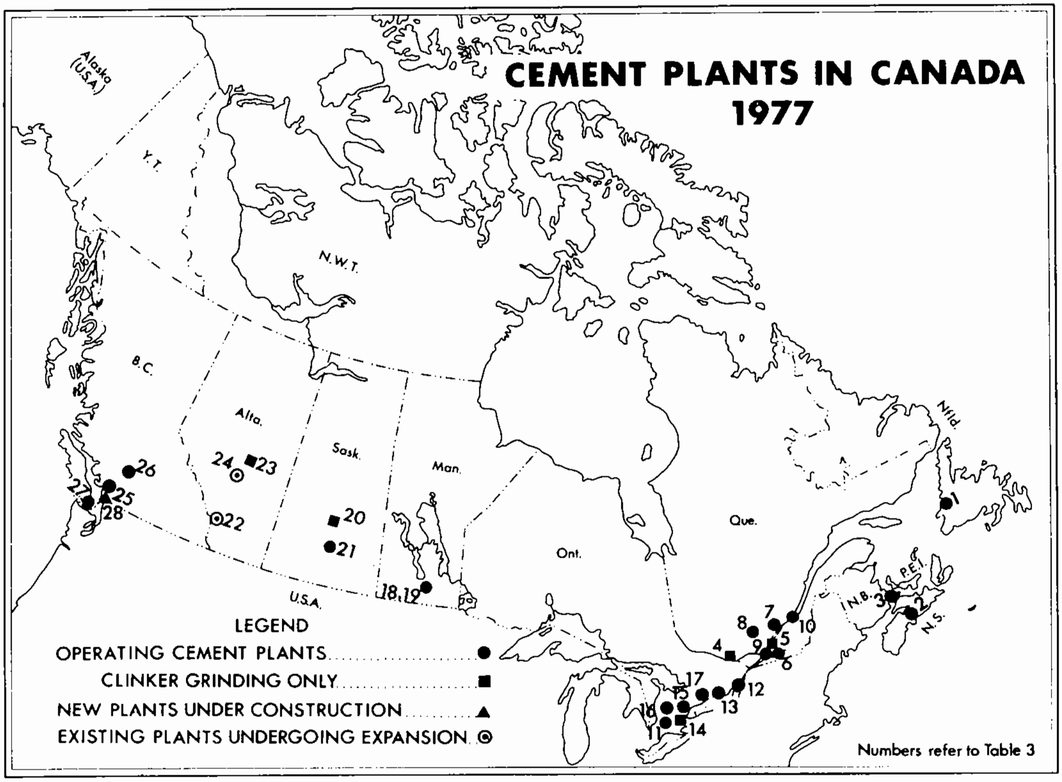


Table 3. Cement plants — approximate annual capacities, end of 1977

(Numbers refer to numbers on map on previous page)

	Company	Plant Location	Process	Fuel	Capacity
					(tonnes a year)
Atlantic Region					
1	North Star Cement Limited	Corner Brook, Nfld.	dry	oil	159 000
2	Canada Cement Lafarge Ltd.	Brookfield, N.S.	dry	oil,coal	474 000
3	Canada Cement Lafarge Ltd.	Havelock, N.B.	dry	oil,coal	327 000
	Total Atlantic Region				960 000
Quebec					
4	Canada Cement Lafarge Ltd.	Hull[1]			
5	Canada Cement Lafarge Ltd.	Montreal East[1]			
6	Canada Cement Lafarge Ltd.	St. Constant	dry	oil,gas,coal	953 000
7	Ciment Quebec Inc.	St. Basile	wet	oil	345 000
8	Independent Cement Inc.	Joliette[2]	dry	oil	1 089 000
9	Miron Company Ltd.	St. Michel[3]	dry	oil	953 000
10	St. Lawrence Cement Company	Villeneuve	wet	oil	714 000
	Total Quebec Region				4 054 000
Ontario					
11	Canada Cement Lafarge Ltd.	Woodstock	wet	gas	540 000
12	Canada Cement Lafarge Ltd.	Bath	dry	oil,gas	998 000
13	Lake Ontario Cement Limited	Picton	dry	gas,coal	1 515 000
14	Medusa Products Company of Canada Limited	Paris[1]			
15	St. Lawrence Cement Company	Clarkson	635 000 wet 953 000 dry	oil,coal	1 588 000
16	St. Marys Cement Limited	Bowmanville	wet	coal	680 000
17	St. Marys Cement Limited	St. Marys	dry	gas	935 000
	Total Ontario Region				6 256 000
Manitoba					
18	Canada Cement Lafarge Ltd.	Winnipeg	wet	oil,gas	572 000
19	Inland Cement Industries Limited	Winnipeg[3]	wet	oil,gas	295 000
Saskatchewan					
20	Canada Cement Lafarge Ltd.	Floral[1]			
21	Inland Cement Industries Limited	Regina[3]	dry	gas	204 000
Alberta					
22	Canada Cement Lafarge Ltd.	Exshaw[5]	dry	gas	726 000
23	Canada Cement Lafarge Ltd.	Edmonton[1]			
24	Inland Cement Industries Limited	Edmonton[3,4]	wet	gas	570 000
	Total Prairie Region				2 367 000
British Columbia					
25	Canada Cement Lafarge Ltd.	Lulu Island	wet	oil,gas	558 000
26	Canada Cement Lafarge Ltd.	Kamloops	dry	gas	190 000
27	Ocean Cement Limited	Bamberton[3]	wet	oil	500 000
28	Ocean Cement Limited	Tilbury Island[3,6]	dry	oil,gas	998 000
	Total British Columbia Region				1 248 000
	Total Capacity				14 885 000

Source: Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
[1]Grinding plants only. [2] Controlled by St. Lawrence Cement Company. [3]Controlled by Genstar. [4] Expansion program underway. [5] Expansion program planned. [6]Not included in totals — under construction.

from gas to coal at a cost of $10 to $12 million. Inland is a subsidiary of Genstar Limited, which bought Star-Key Mines Ltd., a 5 000- to 10 000-tonne-a-year coal producer some 12 kilometres northeast of Edmonton.

Canada Cement Lafarge Ltd. plans a $70-million expansion at its Exshaw, Alberta plant. The project will involve the construction of a 600 000-tonne kiln and related facilities which should be operational by 1980.

Ocean Cement Limited continued construction of its new facility on Tilbury Island (Vancouver), B.C., with 1978 as a completion target date.

Canadian industry and developments

Atlantic region. There are three cement-manufacturing plants in the Atlantic provinces serving the markets in the immediate area by road, rail, and water transportation routes. The plants represent 6.5 per cent of Canadian cement production capacity in a region having 9.5 per cent of the total population of Canada.

A plant at Corner Brook, Newfoundland, established in 1951, is operated by North Star Cement Limited. Limestone and shale, raw materials for the dry process being used, are quarried in the immediate area and gypsum is purchased from Flintkote Holdings Limited, which quarries gypsum at Flat Bay, about 95 kilometres (km) south of Corner Brook. Shipments of portland cement are made, mainly by rail and truck to provincial markets. Output depends directly on construction activity.

Large deposits of high-calcium limestone in the Port au Port area of western Newfoundland, from which Dominion Steel and Coal Corporation Limited (now Sidbec-Dosco Limited) obtained stone for the Sydney, Nova Scotia steel plant for many years, has attracted the attention of large cement producers in recent years. Obviously, a buoyant and stable export market for cement and clinker would be necessary to support additional capacity in this region.

Nova Scotia's only cement manufacturing facility, a two-kiln, dry-process plant incorporating the most modern analytical and control devices, was established in 1965 by Canada Cement Company, Limited (now Canada Cement Lafarge Ltd.) at Brookfield. Limestone at the plant site is chemically very close to a natural cement rock; but variations in lime, alumina and iron content necessitate the addition of iron oxide, coal ash and high-calcium limestone, all of which are available nearby. Gypsum is purchased from the Milford quarry of National Gypsum (Canada) Ltd., about 40 km south of Brookfield. Portland cement is marketed in bulk or package under the brand name *Maritime* cement. During 1975, work began on a $25 million expansion program, which, with the installation of a second kiln and new grinding and storage facilities, doubled the plant's capacity to 474 000 tonnes by 1977.

Canada Cement Lafarge Ltd. also operates a cement-manufacturing plant at Havelock, New Brunswick. This plant was built in 1951 and expanded in 1966 by the addition of a second kiln. The company increased plant capacity with the addition of heavier grinding equipment and larger storage facilities in 1974, and now has a capacity of 327 000 tonnes a year. During 1977 an electrostatic precipitator unit was installed.

Quebec. In the Province of Quebec five companies operate a total of seven cement-manufacturing plants. Regionally, the companies producing cement in Quebec compete for the construction markets in the Montreal and Quebec City areas as well as for markets in more remote regions such as James Bay, where the hydroelectric project continued throughout 1977. A major water-treatment plant at Rivière-des-Prairies is expected to require about 300 000 tonnes of cement. Fewer projects in the institutional, commercial and industrial sectors tended to offset the effects of large engineering construction in 1977. Exports of portland

Table 4. Canada, cement plants, kilns and approximate capacity utilization, 1973-77

	Plants	Kilns	Approximate Capacity (tonnes a year)	Portland Cement Production (tonnes) (1)	Cement Clinker imported by U.S. from Canada (tonnes) (2)	Total (1) & (2)	Approximate capacity utilization (%)
1973	24	58	14 268 000	10 052 902	1 243 400	11 296 302	79
1974	24	58	14 404 000	10 640 001	789 758	11 429 759	79
1975	24	57	15 064 000	9 740 502	658 954	10 399 456	69
1976	22	51	14 987 000	9 898 024	645 377	10 543 401	70
1977	22	49	14 885 000	9 933 137	775 145	10 708 332	72

Sources: For Canada: Statistics Canada; company data. For the United States: U.S. Bureau of Mines, Division of Non-metallic Minerals; company data.

Table 5. Canada, distribution of domestic cement sales[1] from producers' plants, 1973-77

	1973	1974	1975	1976	1977
Quebec					
Portland	2 288 228	2 486 495	2 509 057	2 006 578	1 991 607
Masonry	76 726	79 206	81 191	87 379	89 899
Total	2 364 954	2 565 701	2 590 248	2 093 957	2 081 506
Ontario					
Portland	3 400 986	3 459 307	3 089 953	3 051 287	2 920 972
Masonry	208 558	207 845	186 296	194 355	182 809
Total	3 609 544	3 667 152	3 276 249	3 245 642	3 103 781
Other Provinces					
Portland	2 847 275	3 070 564	2 966 838	3 383 503	3 369 219
Masonry	55 885	61 017	60 318	65 495	70 709
Total	2 903 160	3 131 581	3 027 156	3 448 998	3 439 928
Total Domestic					
Portland	8 536 491	9 016 367	8 565 849	8 441 368	8 281 798
Masonry	341 170	348 069	327 805	347 229	343 417
Total	8 877 661	9 364 436	8 893 654	8 788 597	8 625 215
Exports					
Portland	1 112 249	864 665	660 864	734 421	1 071 889
Masonry	28 621	27 483	19 610	24 053	24 887
Total	1 140 870	892 148	680 474	758 474	1 096 776
Clinker[2]	1 243 400	789 758	658 954	645 377	775 195
Total Sales					
Portland	9 648 740	9 881 032	9 226 714	9 175 789	9 353 687
Masonry	369 790	375 552	347 415	371 282	368 304
Total Cement	10 018 530	10 256 584	9 574 129	9 547 071	9 721 991
Total Clinker	1 243 400	789 758	658 954	645 377	775 195

Source: Statistics Canada.
[1]Does not include amounts used at producers' plant sites. [2] United States Bureau of Mines, Division of Non-Metallic Minerals.

cement to the United States from the province of Quebec increased greatly during the year.

The Montreal East plant of Canada Cement Lafarge Ltd. at Pointe-aux-Trembles has been operated as part of the Canada Cement complex since it was acquired in 1909. Material from the adjacent quarry approximates a natural raw mix which requires only minor amounts of sand, iron oxide and high-calcium limestone for corrective purposes. Its location a mile from docking facilities on the St. Lawrence River affords access to water transportation. Rehabilitation of the Montreal East plant began in 1976. Plans to replace seven old, wet-process kilns with two dry-process, preheater-equipped kilns was to result in an effective total capacity at completion of the project of about 454 000 tonnes a year. Through 1977 the plant served only as a grinding plant because market conditions slowed the conversion project.

Canada Cement Lafarge's plant at St. Constant, south of Montreal, is modern, technically efficient and, with a capacity of over 950 000 tonnes a year, is currently supplying product to fill the company's sales contracts in the Quebec region. The company's Hull operation, on the site where cement was first produced in Canada, was closed as a producing facility at the end of 1975. The plant has been partially dismantled and is currently serving as a distribution terminal with grinding capability.

Miron Company Ltd. operates a dry-process plant at St-Michel. The company also supplies concrete and other building materials to the construction industry, and maintains a contracting division. During 1973

Genstar Limited of Montreal acquired the majority of Miron shares. Genstar, through its cement division, operates Inland Cement Industries Limited in Winnipeg, Regina and Edmonton, and Ocean Cement Limited in Bamberton, B.C.

St. Lawrence Cement Company has a plant at Villeneuve, near Quebec City, capable of manufacturing about 700 000 tonnes of cement a year. Limestone and shale are available at the site; iron oxide and gypsum are brought in. Finished products include normal portland cement, medium-heat-of-hydration cement and masonry cement. Shipments are made in bulk or in bags by truck, rail and ship. During 1976 St. Lawrence acquired the Joliette cement plant of Independent Cement Inc., together with its construction, ready-mix and crushed-stone divisions. Early in 1977 St. Lawrence purchased Universal Atlas Cement's Hudson, New York, plant to be used initially as a distribution terminal and eventually modernized to a fully integrated cement producer.

Ciment Quebec Inc. was established in 1952 at St-Basile, 60 km west of Quebec City, as a single-kiln operation. Two additional kilns were installed to boost production capacity to about 345 000 tonnes a year.

Ontario. Four companies operate a total of six cement-manufacturing plants in the Ontario region, serving industrial and urban growth areas in southern Ontario and shipping to points in Quebec and northern Ontario as well as the United States. One other company operates a clinker-grinding plant.

The industrialized, population-intense region surrounding Lakes Ontario and Erie continues to grow and, in so doing, provides markets for cement for the many engineering, commercial, industrial and residential building projects there, which continue to increase in number. The Ontario cement producers represent 42 per cent of total Canadian production capacity in a province occupied by about 36 per cent of the total Canadian population. Steady growth is indicated by continued investment in additional capacity.

Table 6. Canada, mineral raw materials[1] used by the cement industry

Commodity	1975	1976^p
	(tonnes)	
Limestone	12 951 410	12 359 522
Shale	693 862	850 386
Clay	814 411	804 921
Gypsum	454 159	468 004
Sand	295 300	250 014
Iron oxide	100 469	106 409

Source: Statistics Canada.
[1] Includes purchased materials produced from own operations.
^{p} Preliminary.

Lake Ontario Cement Limited is one of Canada's largest cement exporters. The plant is located at Picton, where favourable raw materials are situated adjacent to deep water, permitting comparatively inexpensive bulk shipments to Great Lakes and St. Lawrence Seaway ports. Shipments were at an all-time high in 1977, mainly because of sales through Aetna Cement Corporation, a newly formed subsidiary of Lake Ontario Cement, which purchased a cement-grinding plant at Essexville, Michigan. The Essexville plant had previously been supplied with clinker from Picton under a three-year contract. The company's plant expansion program was completed in 1975 with the addition of a new preheater kiln which doubled the plant capacity.

Canada Cement Lafarge Ltd. brought its 1-million-tonne-a-year Bath, Ontario plant on stream late in 1973 at a cost of $50 million, and subsequently phased out its Belleville plant, one of the original operations grouped to form Canada Cement Company in 1909. Limestone for the new plant is quarried on site from the Trenton-Black River formation, Potsdam sandstone is obtained from Pittsburgh, about 65 kilometres east of Bath, and iron oxide mill scale comes from Hamilton.

The company operates a plant at Woodstock, Ontario capable of producing about 540 000 tonnes a year from a two-kiln, wet process. The plant was constructed in 1956 to serve the developing area of southwestern Ontario. Clay overburden from the limestone quarry is suitable for manufacturing masonry cement, high-early-strength cement and normal portland cement.

St. Lawrence Cement Company built its Clarkson, Ontario plant in 1957 and, with the expansion to 1.58 million tonnes a year in 1968, it became Canada's largest producing plant. The plant now combines a wet and a dry process.

Limestone for the plant is brought by boat from Ogden Point, 160 km east of Toronto on the north shore of Lake Ontario. An overhead, covered conveyor is used to transport stone from the lake carriers to the plant. Gypsum is trucked from producers in southwestern Ontario. The market area for finished cement product is mainly the Toronto-Hamilton strip and southern Ontario, served by rail and truck deliveries. Large quantities of clinker are exported to United States points. The company sold its assets in Wyandotte Chemical Corporation, Michigan in compliance with a U.S. Federal Trade Commission divesture order issued in early 1973.

St. Marys Cement Limited operates two plants in Ontario. A new and highly automated plant, built at Bowmanville during 1967 and 1968, was expanded during 1973 with the addition of a second kiln to increase capacity to ship product via truck and rail to the major marketing area of Metropolitan Toronto. The original plant at St. Marys was constructed in 1912 to serve the Toronto area. It has been expanded and modernized over the years and, with the installation of a new 680 000-tonne-a-year kiln and four-stage suspension preheater in 1976, production capacity was doubled. During 1977, as the new system assumed more of the total production commitment, three of the older kilns were retired, while two were maintained for production of special cements.

Medusa Products Company of Canada, Limited, Paris, Ontario, grinds a white clinker imported from the Medusa plant at York, Pennsylvania. The white cement is sold mainly in Ontario.

Federal White Cement began construction of a new plant at Woodstock, under the guidance of Lafarge Consultants Ltd. Limestone will be purchased from Canada Cement's Woodstock plant and capacity is designed to be about 100 000 tonnes a year with start up scheduled for 1979.

Prairie region. Two companies, Canada Cement Lafarge Ltd. and Inland Cement Industries Limited, operate a total of five clinker-producing plants in the Prairie region along with two clinker-grinding plants. The region accounts for 15.9 per cent of Canadian cement-producing capacity exclusive of the grinding plants and during 1977 produced at about 80 per cent of that capacity.

Canada Cement Lafarge Ltd. operates a cement-manufacturing plant at Fort Whyte, near Winnipeg, Manitoba. The original facility has been enlarged and rebuilt several times and is today a highly efficient plant capable of producing about 570 000 tonnes of cement a year. High-calcium limestone is obtained from the company's quarry at Steep Rock on the shore of Lake Manitoba, gypsum from Windermere, B.C., silica from Beausejour and clay from Fort Whyte. Products include portland cement, sulphate-resisting cement, oil-well cement and masonry cement for a market area extending from the United States border to the most northerly populated areas, and eastward halfway across northern Ontario.

At Exshaw, Alberta a cement plant has been operated by the Canada Cement group since 1910. A modernization and expansion program, completed in 1975 with the installation of a new kiln, included the development of a new quarry and the relocation of several roads and structures in Exshaw. A further expansion at Exshaw, announced in 1977, will involve construction of a new 600 000-tonne-a-year kiln, together with related facilities. Total cost is estimated at $70 million.

Production capacity is now 726 000 tonnes a year. Finished cement is shipped by rail and truck, mainly to consumers in Alberta and western Saskatchewan. Large quantities of clinker are shipped to the company's grinding, storage and distributing plant at Edmonton, Alberta. A facility at Floral, near Saskatoon, Saskatchewan was built in 1964 as a distribution terminal and in 1966 was expanded to include clinker-grinding equipment. When the demand for cement warrants, the Floral establishment can be expanded further to become a fully integrated cement-manufacturing and distributing plant.

Table 7. Capacity changes during 1977, cement plants

Company	Plant location	Net capacity increase compared with end of 1976	Approximate cost	Remarks
		(tonnes a year)	($ millions)	
Atlantic Region				
Canada Cement Lafarge Ltd.	Brookfield, N.S.	238 000	25	Completion of 3-year project which doubled plant capacity.
Ontario Region				
St. Marys Cement Limited	Bowmanville	45 000	. .	Improved grinding stages.
	St. Marys	(335 000)	. .	Three older kilns removed from service.
British Columbia				
Ocean Cement Limited	Bamberton	(50 000)		Adjusted according to company data.
Net change 1977 from 1976		(102 000)		

Source: Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
. . Not available.

Inland Cement Industries Limited, a Genstar Limited subsidiary, operates three cement-manufacturing plants, one in Winnipeg, Manitoba; one in Regina, Saskatchewan and one in Edmonton, Alberta. The Winnipeg plant came on stream in 1965 to increase the company's total production capacity to over 900 000 tonnes a year. A limestone quarry at Mafeking, Manitoba, near the Manitoba-Saskatchewan border, supplies limestone to the Regina plant, while the Winnipeg plant is supplied from Steep Rock, Manitoba. The Edmonton plant is supplied from Cadomin, Alberta, by a 4 500-tonne unit train which provides an automated materials-handling system. Other raw materials are obtained close to the plant site. A $60 million expansion of the Edmonton plant began in 1976 with the addition of new environmental-control facilities. The program was reassessed and strengthened in 1977 and when completed in the early 1980s will result in a production capacity of over 1.3 million tonnes a year. A market area stretching east to the Lakehead and west to, and including, British Columbia is served by Inland's facilities.

Houg Cement, Limited, Edmonton was scheduled to produce cement from marl early in 1974 near Clyde, some 100 km northeast of Edmonton. Details are limited, but a $5 million expenditure for a 60 000-tonne-a-year plant has been reported. Local markets would consist principally of ready-mix operations.

Table 8. Planned capacity changes (as of early 1978)

Company	Plant location	Net capacity change compared with Table 3	Expected date of completion	Approximate cost	Remarks
		(tonnes a year)		($ millions)	
Quebec					
Canada Cement Lafarge Ltd.	Montreàl East	. .	. .	. .	Plans for plant conversion delayed because of present market conditions.
Ontario					
Federal White Cement	Woodstock	100 000	1979	. .	New plant to use stone from Canada Cement Lafarge's Woodstock quarry.
Prairie Region					
Canada Cement Lafarge Ltd.	Exshaw, Alta.	600 000	1980	70	Expansion to include one new kiln.
Inland Cement Industries Limited	Edmonton	758 000	1980	75	Original project reassessed and enlarged during 1977.
British Columbia					
Inland Cement Industries Limited	Vancouver	1 000 000	1978	90	New plant under construction on Tilbury Island.
	Bamberton	(500 000)	1978	. .	Clinker production to be phased out.
Total		1 958 000			

Source: Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
. . Not available.

Pacific region. Construction activity in British Columbia has been maintained at a high level despite labour difficulties and escalating costs. The optimistic outlook towards increased activity in construction was reflected in Genstar's decision to build a 680 000-tonne-a-year plant in the Vancouver area and amplified by the company's further commitment to increase the size of this plant to about 1 million tonnes even before construction had begun. The new plant will be located on Tilbury Island and will cost an estimated $90 million. Inland Cement Industries Limited and Ocean Cement Limited, are operated as a cement division of Genstar. Ocean Cement quarries limestone at Bamberton on Vancouver Island for cement manufacture and for use as an aggregate. The cement plant, with a capacity of about 550 000 tonnes a year, will be phased out upon the completion of the new facility on the mainland.

Canada Cement Lafarge Ltd. produces cement at Richmond, on Lulu Island near Vancouver, British Columbia, using limestone barged down the Strait of Georgia from a quarry at Vananda on Texada Island.

The plant was built in 1958, and later the capacity was doubled to the present 558 000 tonnes a year. A new plant with a capacity of over 190 000 tonnes a year began production in 1970 at Kamloops, British Columbia.

Markets and trade

Cement markets are regional in scope and are centred in developing urban areas where construction activity is concentrated, or in areas where mining or heavy engineering construction projects are being carried out. The normal market area of a given cement-producing plant depends on the amount of transportation cost that the selling price can absorb. A potential large volume of sales could warrant a secondary distribution terminal; water transportation to a distribution system could extend a plant's market area even farther. Because raw materials for cement manufacture are generally widespread, most countries can supply their own cement requirements if the market volume warrants a plant. Few countries rely entirely on imports for their cement needs. However, some countries rely heavily on export markets for their cement production in order to operate facilities economically.

Specialty cements such as white cement are transported greater distances than ordinary grey portland cement when the transportation costs do not represent as high a proportion of the landed price, and when quantities required are generally much smaller than for portland cement. Cement shortages in countries experiencing a buoyant surge in construction have led to exceptions to the norm and resulted in cement being shipped unusual distances.

Cement from plants in the United States and Canada is traded between the two countries where competition and tariffs permit. The 1973 situation which saw record amounts of both cement and clinker exported to the United States market was an anomaly created by the combined effects of a cement shortage in parts of the United States and an extremely buoyant construction industry. The sliding economy since that time has had an immediate and strong effect on United States construction activity and the cement industry in turn was forced to adjust to reduced demand for its product. Exports of portland cement from Canada to the United States were reduced by 10 per cent in 1974, another 14 per cent in 1975 and 6 per cent in 1976, as the predicted recovery in construction activity did not materialize as rapidly as was expected. During most of 1977, however, the United States economy experienced healthy growth, and cement exports from Canada surged to near-1973 levels, while by comparision, the Canadian economy stagnated, leaving domestic cement consumption lower than in 1976.

A typical feature of the cement-manufacturing industry is its diversification and vertical integration into related construction material industries. Many cement companies also supply ready-mix concrete, stone, aggregates and preformed concrete products such as slabs, bricks, and prestressed concrete units.

Outlook

Construction expenditures in 1978 will be between $37 and $38 billion which will result in a real growth of about 3 per cent. The labour scene could become disturbing as a number of contracts, which were in force prior to the advent of the Anti-Inflation Board (AIB) or were influenced by AIB rulings during the past two years, will be negotiable in 1978. Housing needs, along with favourable mortgage rates, will maintain the buoyancy of the residential building sector, and engineering construction relating to energy projects will result in greater expenditures in that field. Construction in Canada will continue to show an annual increase in value, but cement producers will have to compete with producers of all other building materials to obtain a share of the construction dollar. Not only is practical research in the use of cement-concrete needed, but effective advertising and public relations must be used to encourage acceptance of modular construction at a time when reasonably priced, attractive and convenient housing units are in short supply. In general, modest gains are expected in the near-term, with activity across the country expected to range from promising to cautious, a situation little changed from 1977.

The availability of other construction materials has at times played a major role in determining the amount of cement required for construction. Projects have been delayed because of shortages of steel, rebar, gypsum products and other items. Of particular concern in this regard will be sources of energy. The cement industry has long recognized the importance of fuel conservation, if for no other reason than that fuel costs have represented a major portion of its total operating costs and undoubtedly will continue to in-

Table 9. Canada, house construction, by province, 1976 and 1977

	Starts			Completions			Under Construction		
	1976	1977	% Diff.	1976	1977	% Diff.	1976	1977	% Diff.
Newfoundland	5 709	3 719	−35	5 850	4 292	−27	4 537	2 878	−37
Prince Edward Island	842	824	−2	989	652	−34	183	347	+90
Nova Scotia	7 470	7 495	+1	7 364	7 521	+2	7 307	6 479	−11
New Brunswick	6 772	4 308	−36	7 137	5 313	−26	3 873	2 709	−30
Total (Atlantic Provinces)	20 793	16 346	−21	21 340	17 778	−17	15 900	12 413	−22
Quebec	68 748	57 580	−16	54 301	61 979	+14	43 600	35 366	−19
Ontario	84 682	79 130	−7	80 302	80 717	+1	78 359	75 518	−4
Manitoba	9 339	9 410	+1	8 492	8 720	+3	5 820	6 479	+11
Saskatchewan	13 143	12 825	−2	11 046	11 485	+4	9 319	10 097	+8
Alberta	38 771	38 075	−2	25 858	37 879	+46	29 411	27 305	−7
Total (Prairie Provinces)	61 253	60 310	−2	45 396	58 084	+28	44 550	43 881	−2
British Columbia	37 727	32 358	−14	34 910	33 231	−5	21 877	18 421	−16
Total Canada	273 203	245 724	−10	236 249	251 789	+7	204 286	185 599	−9

Source: Statistics Canada.

crease. For example, in 1977 the cost of natural gas was 338 per cent higher per unit than in 1972, and 25 per cent increases are expected in 1978. A voluntary commitment by the Canadian industry to reduce unit fuel consumption by 9 to 12 per cent by 1980 (with 1974 as the base year) has been undertaken. The already-established trend to dry processing and the use of preheaters will continue for new plants, while the rehabilitation of older plants will continue to benefit from new technology. Rebuilding programs are costly, especially when they must be accomplished with no loss in production. The obvious incentives of cost savings and greater profits must be attractive enough to warrant the additional expense and effort. The expense of adapting older facilities to meet newly imposed environmental-control regulations can contribute to a decision in favour of a new plant — such decisions have forced a number of plant closures in the United States. Continued diversification and vertical integration by cement producers will eventually result in the write-off of some comparatively inefficient production capacity as the emphasis on a cement-concrete industry increases. Work stoppages have seriously delayed many construction projects. In general, labour relations in the construction industry have shown improvement, with a mature and rational approach to labour-management problems which, hopefully, will continue and thereby do much to reduce the cyclical aspects of the industry. The shortage of skilled labour could reach problem proportions for the construction industry; if not generally, then certainly in some regions, as more and larger projects are undertaken.

The cement industry in Canada is capable of meeting the immediate demands on it and is in a position to expand in anticipation of even greater demand, and to take advantage of foreign market openings should they be presented.

Cement manufacture is energy-intensive. It is obvious that research should be concentrated in this area, and specifically within the pyroprocessing sector, where over 80 per cent of the energy is consumed. Raw material grinding and finish grinding are also being studied to determine optimum particle size for energy consumed.

In terms of the energy content in concrete structures and the energy requirements to service and maintain them, they are not so energy-intensive as the more than 5 million Btu's per tonne of cement would at first indicate.

Table 10. Canada, production of concrete products, 1976-77

	1976	1977^p
Concrete bricks (number)	143 834 994	135 559 586
Concrete blocks (except chimney blocks)		
Gravel (number)	176 223 844	157 907 588
Other (number)	36 889 256	33 901 282
Concrete drain pipe, sewer pipe, water pipe and culvert tile (tonnes)	1 316 109	1 351 032
Other precast products (tonnes)	150 094	260 770
Concrete, ready-mix (cubic metres)	13 192 562	13 757 554

Source: Statistics Canada.
^{p} Preliminary.

World review

Because of the direct relationship between cement, concrete, and construction, the consumption of cement can be monitored as an indication of a country's rate of development.

World production of cement is estimated at 728 million tonnes, up from about 700 million tonnes in 1976 but still below estimates made a few years ago, and on which many capacity increases were considered timely. Excess capacity in some developed countries will not be fully utilized for some time. Developing countries, particularly oil-producing countries, continue to show increasing demand for cement and cement-manufacturing facilities. Involvement, through provision of design and technical expertise, of cement and construction corporations from developed countries in the building of cement production facilities in these countries has become quite common.

Conservation of energy and raw materials within the cement industry is of worldwide concern and provides a theme around which major developments in the industry have taken place. Of particular note is the emphasis on blended cements and the utilization of slag, ash and other byproducts. Even greater additions to production capacities than those witnessed during the past few years will be needed to meet demand in many developing countries.

The following summary is based on data published in *Rock Products* and/or *Pit and Quarry* magazines. Although major trends are evident in this data, the summary in no way represents total world activity in the cement industry.

North America. During 1977 about 3.7 million tonnes of new cement production capacity went into operation in the United States while plant shutdowns

Table 11. World production of cement, 1966, 1976 and 1977

	1966	1976^p	1977^e
	(thousand tonnes)		
U.S.S.R.	79 991	123 968	127 000
United States (including Puerto Rico)	68 522	67 581	74 000
Japan	38 265	68 712	64 000
Italy	22 417	36 323	42 000
People's Republic of China	11 000^e	35 000^e	40 000
West Germany	34 739	34 155	34 000
France	23 304	29 394	30 390
Spain	12 070	25 202	28 000
Poland	10 041	19 800	. .
India	11 051	18 499	. .
Brazil	6 046	16 857	. .
United Kingdom	16 775	15 300	16 000
Mexico	4 924	12 584	. .
Romania	5 886	12 548	. .
Turkey	3 865	12 346	. .
Republic of Korea	1 880	11 873	. .
East Germany	6 450	11 345	. .
Canada	8 102	9 624	10 099
Other countries	98 928	174 769	262 511
	464 256	735 880	728 000

Sources: Statistics Canada; U.S. Bureau of Mines, *Minerals Yearbook, 1968* for 1966; and U.S. Bureau of Mines, *Mineral Trade Notes,* Vol. 74, No. 11, November 1977.
^{p} Preliminary; ^{e} Estimated; . . Not available.

and facilities removed from service at still-operating plants reduced capacity by about 1.4 million tonnes. The net new capacity of 2.3 million tonnes was in the form of two essentially new plants which replaced existing plants at the same locations — Citadel Cement Corporation completed its new 680 000-tonne-a-year plant at Demopolis, Alabama, and South Dakota Cement Co. put on line a new suspension preheater plant at Rapid City, S.D. Major expansions were confined to two plants; Louisville Cement Co. at Speed, Indiana, and National Cement Company Inc. at Ragland, Alabama.

Indications are that there will be little net change in cement capacity during 1978. There will probably be two completely new plants at new locations.

The Cantex Corporation will complete a new $32 million, 453 000-tonne, dry-process plant at Austin, Texas. The preheater system is designed for the later addition of a coal-fired flash calciner, illustrating what could be two trends with future new installations — the use of flash calciners and the use of coal.

Lone Star Lafarge, Inc., a joint venture of Lone Star Industries, Inc. and Lafarge Fondu International of

Paris, France will start up a $10 million plant at Chesapeake, Virginia for the manufacture of calcium aluminate cements.

Three essentially new plants will replace or supplement existing operations during 1978. Coplay Cement Manufacturing Co. will spend $50 million on a modernization program at its Nazareth, Pennsylvania plant which will increase capacity by 900 000 tonnes a year. Lehigh Portland Cement Company will add 450 000 tonnes a year to the capacity of its Mason City, Iowa plant with a new kiln and a four-stage suspension preheater with a precalciner. Both the kiln and precalciner are to be coal-fired. The third such project is that of the Cement Division of Ideal Basic Industries, Inc. at its Knoxville, Tennessee plant where a 4-kiln wet process operation is being replaced by a suspension preheater kiln system with 25 per cent more capacity.

To 1980 and beyond, a number of plant expansions and improvements are scheduled. Three new plants at new locations, two new plants replacing facilities now in existence and three major expansions involving new kilns and mills are being constructed.

Table 12. Apparent consumption of cement by the leading producers, 1976

	Production[p]	Apparent Consumption	kg/capita
	(000 tonnes)		
U.S.S.R.	123 968	121 800	475
United States	67 581	63 652	293
Japan	68 712	64 522	572
Italy	36 323	35 870	638
People's Republic of China	35 000[e]	30 100	35
West Germany	34 155	32 594	528
France	29 394	28 712	542
Spain	25 202	21 292	596
Poland	19 800	19 608	570
India	18 499	18 623	30
Brazil	16 857	19 450	175
United Kingdom	15 300	15 581	278
Mexico	12 584	12 184	195
Romania	12 548	9 500	443
Turkey	12 346	11 579	289
Republic of Korea	11 873	9 080	250
East Germany	11 345	10 965	653
Canada	9 624	9 293	401
Other countries	174 769		
Total	735 880		

Sources: Statistics Canada; U.S. Bureau of Mines, *Mineral Trade Notes*, Vol. 74, No. 11, November 1977; *Cembureau Statistical Review, 1975, 1976.*
[p] Preliminary; [e] Estimated.

Central America. One new plant came on stream during 1977, while five are in various stages of completion. The new plant, in Mexico, has a rated capacity of 450 000 tonnes a year. New plants under construction will add 1.3 million tonnes a year to the region's total capacity over the next three years. This new capacity will be distributed as follows: Barbados, 230 000 tpy; Costa Rica, 550 000 tpy (2 plants); El Salvador, 240 000 tpy; and Panama, 300 000 tpy.

Table 13. Apparent consumption of cement by the leading consumers, 1976

	Consumption	Consumption per capita
	(000 tonnes)	(kg)
U.S.S.R.	121 800	475
Japan	64 522	572
United States	63 652	293
Italy	35 870	638
West Germany	32 594	528
People's Republic of China	30 100	35
France	28 712	542
Spain	21 292	596
Poland	19 608	570
Brazil	19 450	175
India	18 623	30
United Kingdom	15 581	278
Mexico	12 184	195
Turkey	11 579	289
East Germany	10 965	653
Czechoslovakia	10 000	670
Romania	9 500	443
Canada	9 293	401

Source: *Cembureau Statistical Review,* 1975, 1976.

Nearly 3 million tonnes a year will be added to production capacity in Central America when announced expansion plans are completed. Only one plant extension became operative during 1977, again in Mexico, where three other programs are still under way to yield an additional 1.2 million tpy. Other expansions for 1978 and beyond will be in the following countries: El Salvador, 330 000 tpy; Guatemala, 530 000 tpy; and Jamaica, 430 000 tpy.

South America. New capacity realized during 1977 in South America was evenly split between new projects and expanded plants, and totalled approximately 2.3 million tpy. One new plant was brought in in Brazil at 660 000 tpy and one in Ecuador at 495 000 tpy, while plant expansions were completed in Peru for 660 000 tpy and Venezuela (2) for 500 000 tpy.

New capacity under construction includes a 480 000

Table 14. Canada, value of construction by province, 1976-78

	1976[1]			1977[2]			1978[3]		
	Building Construction	Engineering Construction	Total	Building Construction	Engineering Construction	Total	Building Construction	Engineering Construction	Total
	(thousands of dollars)								
Newfoundland	420 507	312 521	733 028	375 388	217 918	593 306	407 064	261 837	668 901
Nova Scotia	545 195	328 845	874 040	495 512	412 490	908 002	542 131	441 534	983 665
New Brunswick	499 409	393 570	892 979	454 697	428 982	883 679	493 082	443 490	936 572
Prince Edward Island	65 723	34 789	100 512	85 017	38 780	123 797	91 473	48 104	139 577
Quebec	5 127 246	2 775 934	7 903 180	5 064 075	3 612 443	8 676 518	4 803 376	4 255 293	9 058 669
Ontario	6 783 354	3 282 600	10 065 954	6 947 157	3 528 352	10 475 509	7 423 049	3 637 628	11 060 677
Manitoba	782 397	505 218	1 287 615	848 174	537 800	1 385 974	938 134	527 501	1 465 635
Saskatchewan	909 271	512 319	1 421 590	971 352	586 032	1 557 384	997 035	677 322	1 674 357
Alberta	2 572 610	2 624 830	5 197 440	2 895 463	3 299 950	6 195 413	3 035 623	3 492 889	6 528 512
British Columbia, Yukon Territory and Northwest Territories	2 765 953	1 888 908	4 654 861	2 804 756	2 148 863	4 953 619	2 925 313	2 423 573	5 348 886
Canada	20 471 665	12 659 534	33 131 199	20 941 591	14 811 610	35 753 201	21 656 280	16 209 171	37 865 451

Source: Statistics Canada.
[1]Actual; [2]Preliminary; [3]Forecast.

tpy plant in Argentina, two plants in Colombia at 330 000 tpy each, one plant in Ecuador at 345 000 tpy, and two plants in Venezuela, one at 1 million tpy, one at 450 000 tpy. Expansions now under way in Argentina, Bolivia, Brazil, Columbia, Peru, Uruguay and Venezuela will increase South American cement-producing capacity by nearly 3.0 million tpy.

Europe. The cement industry underwent little change in many European countries during 1977 as existing production capacity appeared to be adequate for the next couple of years. A total of nearly 2.0 million tonnes a year was added in the form of new plant capacity, while a total of 4.0 million tonnes was added by plant expansions. New plants were put into operation in Italy, 360 000 tpy; in Luxembourg, 850 000 tpy; and in Spain, 630 000 tpy. Plant expansions were as follows: 225 000 tpy in France; 900 000 tpy in Ireland; 1 080 000 tpy in Italy, at four plants; 220 000 tpy in the United Kingdom; and 1 650 000 tpy in Yugoslavia.

New plants under construction include a 1 million tpy facility for Czechoslovakia, a 600 000 tpy kiln system for a company in France, and a 1 million tpy plant in Greece. Plant expansions will account for far more capacity increase than new plants. Expansions now under way include: 600 000 tpy in France; 1 440 000 tpy in Greece; 1 080 000 tpy in Portugal; 1 500 000 tpy in Sweden; 660 000 tpy in the United Kingdom and 1 650 000 tpy in Yugoslavia.

Africa. The relation between a country's physical and economic development and its cement-producing capacity and consumption is illustrated by the flurry of activity in many developing countries to establish new cement plants. Two new plants were started up in 1977; one in Libya at over 1 million tonnes a year, and one in Nigeria at 800 000 tpy. Plants under construction or planned for operation through 1981 will have a total capacity of over 19 million tpy. Algeria alone will add 4.5 million tpy, Egypt, nearly 4.0 million; Gabon, 330 000; Libya, 2.0 million; Morocco, 2.5 million; Nigeria, 500 000; Tanzania, 750 000; Tunisia, 2.0 million and West Africa, 2.6 million.

In contrast, completed plant expansions in two African countries totalled only about 1.5 million tpy in 1977, while expansions under way total about 2.0 million in the whole of Africa.

Asia. Although per capita consumption of cement in Asia remains low by comparision with other continents, the rate of increase in total cement consumption is greater than in other areas. Consumption in 1976 was nearly 9 per cent greater than in 1975. This compares with increases of 4 per cent in Africa, 3 per cent in Europe and 5 per cent in America, according to Cembureau data. Six countries brought on a total of eight new plants in 1977 for a combined increase in

Table 15. Value of construction in Canada, 1976-78

	1976[1]	1977[2]	1978[3]	Change 1977-78
	(millions of dollars)			(%)
Building construction				
Residential	12 669	12 951	13 584	4.9
Industrial	1 450	1 652	1 479	−10.5
Commercial	3 628	3 446	3 555	3.2
Institutional	1 595	1 663	1 719	3.4
Other building	1 130	1 230	1 319	7.2
Total	20 472	20 942	21 656	3.4
Engineering construction				
Marine	171	201	221	10.0
Highways, aerodromes	2 394	2 757	2 864	3.9
Waterworks, sewage systems	1 462	1 586	1 653	4.2
Dams, irrigation	124	139	159	14.4
Electric power	2 897	3 691	4 364	18.2
Railway, telephones	1 279	1 409	1 526	8.3
Gas and oil facilities	2 154	2 624	3 054	16.4
Other engineering	2 178	2 404	2 368	−1.5
Total	12 659	14 811	16 209	9.4
Total construction	33 131	35 753	37 865	5.9

Source: Statistics Canada.
[1]Actual; [2]Preliminary; [3]Forecast.

capacity of over 5 million tpy, while plant expansions in three countries totalled a little over 1 million. During 1978 and beyond, new plants currently under construction will add 20 million tonnes a year to Asian cement-producing capacity, about 7 million of which will come on stream in Saudi Arabia. During the same period some 10 million tonnes a year will be added through expansions to existing plants.

Oceania. Cement-producing capacity in Australia will be increased by nearly 700 000 tpy in 1978 with the addition of a new kiln, 4-stage cyclone preheater and ancillary equipment to an existing plant.

Tariffs

Canada

Item No.		British Preferential	Most - Favoured Nation	General	General Preferential
		(¢)	(¢)	(¢)	(¢)
29000-1	Portland and other hydraulic cement, nop; cement clinker per 100 lb	free	free	6	free
29005-1	White, nonstaining portland cement, per 100 lb	4	4	8	2⅔

United States

Item No.		(¢ per 100 lb incl. weight of container)	(%)
511.11	White, nonstaining portland cement	1	
511.14	Other cement and cement clinker	free	
511.21	Hydraulic cement concrete	free	
511.25	Other concrete mixed, per cu. yd.		7.5 ad val.

Sources: For Canada, the Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1978), TC Publication 843.
nop Not otherwise provided for.

Cesium

J.G. GEORGE

Cesium is a soft, silvery white, ductile metal with a melting point of 28.5°C, a boiling point of 705°C, a density of 1.87 grams per cubic centimetre at 20°C and an atomic weight of 132.91. It is the eighth-lightest metallic element, but the heaviest of the alkali metals. It is one of the three metals (the others are mercury and gallium) that are liquid at room temperature. Cesium is the most electropositive of the alkali metals, has the highest density, highest vapour pressure, lowest boiling point and lowest ionization potential. Because of these properties, cesium is used in preference to other alkali metals in such space-age applications as space propulsion and energy conversion.

Cesium emits electrons when exposed to visible light, ultra-violet light or infrared light. It is an efficient scavenger for traces of oxygen in highly evacuated containers. Precautions must be taken in handling, transporting and storing cesium metal because in air or water it is very reactive chemically, and when exposed to a combination of the two it reacts violently, liberating hydrogen. Cesium is usually packed under argon, or in vacuum in *Pyrex* glass vials, or in returnable shock-proof stainless steel cylinders. Cesium compounds are not as dangerous as the metal, but they must be handled carefully and shipped in closed containers. Their toxicity is usually low, but cesium fluoride is toxic and should be handled with care.

Occurrences and recovery

Cesium occurs in certain granites and granitic pegmatites, with granites having been estimated to contain an average of about one part per million of cesium. Cesium also occurs in brines and saline deposits. Although commercial quantities of cesium have been obtained from lepidolite and carnallite, the most important economic source of the metal is the rare mineral, pollucite. Pollucite is usually found in complex, generally well-zoned, pegmatite dykes that are rich in lithium minerals, especially lepidolite.

Pollucite, a mineral resembling quartz in lustre and transparency, is a hydrated silicate of aluminum and cesium ($H_2O \cdot 2Cs_2O \cdot 2Al_2O_3 \cdot 9SiO_2$) with the theoretically pure mineral containing 45 per cent cesium oxide (Cs_2O). Naturally-occurring pollucite usually contains from 6 to 32 per cent Cs_2O.

The largest known reserves of pullucite are: about 45 000 tonnes* in the Karibib area in Namibia (South-West Africa), some 135 000 tonnes in the Bikita district of Rhodesia, and 372 000 tonnes at the mine of Tantalum Mining Corporation of Canada Limited (Tanco) at Bernic Lake in southeastern Manitoba, Canada, about 177 kilometres (km) northeast of Winnipeg. A second Canadian occurrence is at the Valor property in Lacorne Township, northwestern Quebec, formerly owned by Massval Mines Limited. Mozambique also has pollucite deposits, but reserves and grade are not known. Other occurrences are found in the island of Elba and at Veratrask, Sweden. Occurrences in the United States are in Oxford County, Maine, and in the Black Hills near Custer, South Dakota. In recent years there has been no commercial production of cesium-bearing minerals in the United States, and the likelihood of any future domestic production of such minerals remains poor. Pollucite imported from Canada is, and will for some time continue to be, the main source of the United States production of cesium and its compounds. In fact, the world itself is currently dependent on the known deposits of pollucite in Canada and southern Africa for its cesium requirements.

The only known Canadian cesium-bearing deposit of economic importance is the one at Bernic Lake, Manitoba. Tanco, which operates the property, is owned 50.1 per cent by International Chemalloy Corporation; 24.9 per cent by Kawecki Berylco Industries, Inc.; with the remaining 25 per cent interest being held by the Manitoba Development Corporation (MDC), the investment agency of the Manitoba Government. The pollucite ore zones are separate from the company's tantalum and lithium orebodies (although these do contain low cesium values) which are contained in the

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

same deposit. The pollucite unit consists of three gently dipping, sheet-like bodies, the largest of which ranges up to 14 metres in thickness and lies in the southeast quadrant of the pegmatite. As of December 31, 1977 the company's cesium ore reserves consisted of 270 000 tonnes of pollucite averaging almost 23.9 per cent Cs_2O in the main zone, 47 000 tonnes averaging almost 23.9 per cent Cs_2O in one westerly zone and 55 000 tonnes of somewhat lower grade in the second westerly zone. These reserves are before allowances for dilution or pillars. The main zone is open to the south and could be extended by further drilling. In addition, there are large areas of the pegmatite body containing quantities of pollucite averaging 500 to 1 500 grams of Cs_2O a tonne which have not yet been assessed for ore reserves. Also, deeper drilling below the main pegmatite body has indicated a second sill approximately 30 metres below the main body which contains pollucite, tantalite, and spodumene mineralization.

Ores naturally rich in pollucite have been upgraded experimentally with some success, but satisfactory methods to concentrate pollucite economically from low-grade ores have not yet been developed. The United States Bureau of Mines has, however, developed experimentally a froth flotation process for concentrating pollucite ore. When applied to a low-grade cesium ore from Maine grading about 8 per cent Cs_2O, the ore was upgraded to over 21 per cent Cs_2O with a cesium recovery of almost 87 per cent. Commercial concentrates and direct-shipping ore usually grade in excess of 20 per cent Cs_2O.

Production and consumption

Little statistical data is available on the production and consumption of pollucite or cesium metal and compounds. Annual world mine production of pollucite ore was estimated at only 20 tonnes as recently as 1968. Since then, an increasing demand has resulted in a significantly greater output of pollucite. From late 1969, when Tanco's Bernic Lake mine began operations, until the end of 1975, shipments of pollucite ore totalled about 1 400 tonnes with an average Cs_2O content of almost 27 per cent. Of these total pollucite shipments, almost 86 per cent were exported to Russia, approximately 8 per cent to the United States, with the remainder going to the United Kingdom, West Germany and Japan. All of the company's shipments of pollucite made to the end of 1975 have been in the form of crushed ore. In 1976 the Bernic Lake mine did not make any shipments of pollucite ore and only a very minor quantity was shipped in 1977. Late in 1976 the Canadian government placed cesium in all forms, including ores, concentrates, chemical compounds, cesium metal and alloys containing cesium, on the Export Control List established under the Export and Import Permits Act. This legislation banned shipments of cesium in all the above-mentioned forms to all communist countries.

Until 1968, world consumption of cesium metal and compounds was probably less than ten tonnes a year. In the past few years there has been a major increase in consumption, mainly because of the increasing quantities of cesium compounds used in experimental magnetohydrodynamics (MHD) electrical power generators. The U.S.S.R. is probably the largest consumer of cesium in the world. It imported over 1 200 tonnes of pollucite from Canada between late 1969 and the end of 1975, which suggests an annual consumption in the range of about 52 000 kilograms (kg) of cesium metal equivalent, unless some of these imports were put into stockpile. The U.S.S.R. has for several years been doing extensive research in cesium-based MHD generation of electricity.

Uses

At present there are no large-scale commercial uses for cesium; the largest portion of consumption occurs in the field of research and development. The largest use is in thermionic power conversion units, ion propulsion and MHD electrical power generators. In MHD pilot plants, which make use of cesium's ionization potential, a fuel (coal, oil or gas) is burned, usually with preheated or oxygen-enriched air. The hot combustion gases, at temperatures as high as 2 760°C (5 000°F), are then seeded with an easily ionized element such as a cesium or potassium compound, or a mixed cesium-potassium compound, to increase electrical conductivity. The extremely hot ionized gases (plasma) are then accelerated through a high-velocity nozzle into a cooled chamber, usually called the MHD channel, which is surrounded by a magnetic field produced by a superconducting electromagnet. The gases, acting much like a rotating armature in a conventional generator, produce electricity which is bled off at high voltages by electrodes fixed to the inside walls of the channel. The electrodes are connected to inverters which convert the current from DC to AC. The amount of power generated depends mainly on the degree of ionization, the velocity of the plasma, and the magnetic field strength.

In an "open cycle" MHD power plant the gases exiting from the power generator are sufficiently hot (about 2 050°C) to heat water for a conventional steam turbine and thereby generate additional electricity. The exhaust gases then flow through heat exchangers, pass through cleaning equipment which recovers the expensive seed material and removes pollutants, including nitric oxide, and finally exit from a stack. Seed recoveries of up to 99.5 per cent have been reported. Sulphur dioxide emissions are greatly reduced, as sulphur in the coal combines with potassium vapour during the MHD cycle to form potassium sulphate. Research indicates that up to 99 per cent of the sulphur can be contained, depending on the amount of potassium compound used in the seeding material. The MHD process is thus suitable to the use of high-sulphur types of coal (up to about 4 per cent sulphur) as its basic feed. Another advantage is that MHD generators greatly reduce the mechanical unreliability from power generation, as virtually no moving parts are required. A major advantage of the combined MHD-turbine "open cycle" system is that it can operate at an efficiency of 50 to 60 per cent. Standard coal-fired power plants and conventional nuclear plants have efficiencies of about 40 and 32 per cent, respectively. While alternative materials such as rubidium, potassium and sodium may be used in the MHD process, present knowledge is that compounds containing both cesium and potassium appear to be the most efficient.

In thermionic converters the heat from nuclear reaction radiates to a surrounding metal (cathode) which emits large masses of electrons. The electrons travel through a space filled with a gas such as cesium vapour to an anode, which then has a potential with respect to the cathode, and electricity can flow through a circuit joining the anode and cathode. The most important factor limiting the efficiency of thermionic generators is the "space charge" effect. It is caused by the mutual repulsion of electrons wherein electrons in the space between the electrodes repel those emerging from the cathode and return them to the cathode. Ionized cesium gas is used to electrically neutralize the space charge. Nuclear heating is used in thermionic converters, as it can serve as the source for the high temperature (1 900°C) required.

In spacecraft, cesium is used in the ion-propelled engines. Vaporized cesium is ionized while passing through a heated porous tungsten disc. The cesium ions become positively charged and an electric field accelerates the positive ions to a velocity of some 483 000 km per hour. The high-velocity ions are neutralized by the injection of electrons and then exhausted through a nozzle to develop thrust. Since ion propulsion is essentially a low-thrust system, one of its potential uses lies either in the maintenance of orbiting space vehicles in their orbits, or in the movement of such vehicles from one orbit to another. An ion engine could be used to move a vehicle from earth orbit to Mars orbit, for example, but could not be used for takeoff from, or for landing on, either planet.

Other commercial applications for cesium include its use in photomultiplier tubes, vacuum tubes, scintillation counters, magnetometers, infrared lamps and pharmaceuticals, and as reagents in microanalysis. Another commercial outlet is in photoelectric cells, in which the photoemissive properties of cesium are utilized. An alloy of cesium and silver is used in the emitron or "electric eye" used in television. Cesium is used as an absorbent to remove impurities at carbon dioxide purification plants and acts as a catalyst in various hydrogeneration and polymerization processes. The metal may also act as a scavenger of gases and other impurities in chemical processing, and in both ferrous and nonferrous metallurgy.

In biological research, concentrated cesium chloride solutions are used for density gradient ultracentrifuge separation of DNA, viruses and other large molecules. This could become an important use for cesium. Cesium bromide is used in the manufacture of optical crystals. Cesium fluoride finds applications as a fluoridating agent in organic syntheses, and cesium hydroxide with rubidium hydroxide can be used in place of lithium hydroxide in alkaline storage batteries for operation at temperatures as low as -50°C. Cesium phosphate is used in the form of mixed crystals, with rubidium and/or ammonium salts, for piezoelectric purposes. Substitutes for cesium in some of its applications are potassium, magnesium oxide, and rubidium.

Outlook

So far, the market for cesium metal and compounds has been quite limited, since their high cost and scarcity, as well as the extreme reactivity of cesium metal, restrict their uses to applications where their unique properties are important. The greater availability of less-costly substitute materials such as potassium, magnesium oxide and rubidium, with properties similar to those of cesium, is also a factor limiting growth in consumption of cesium and its compounds.

Although accurate data are not available on world production and consumption of cesium and its compounds, currently known world reserves of pollucite ores are thought to be more than adequate to provide for expected world requirements of cesium and its compounds in the foreseeable future. Demand for cesium is expected to increase over the next several years, but requirements for research and development purposes could cause significant fluctuations in demand from year to year. Because of impending fuel shortages and increasing world demand for energy, the greatest potential for sharply increased consumption of cesium on a commercial basis appears to be in a technological break-through in the development of a power-generating process using cesium-containing compounds.

Late in 1974 it was reported that $150 million to $200 million had been spent worldwide on MHD research in the previous 15 years, with about 75 per cent of that amount having been spent in the U.S.S.R. Although the United States has spent much less money than the U.S.S.R. on MHD research, it is believed that the current energy crisis has revived support for greater research efforts in this field. Recent reports indicate that United States funding for MHD research in the fiscal year 1978 amounts to $70 million. The first commercial MHD plant is not expected to come on stream in the United States before 1990, whereas such a plant should be in commercial operation in the Soviet Union by 1980. MHD can be powered with any fossil fuel, but the greatest potential contribution toward solving today's energy crisis is that this new power-generating technique permits the use of abundantly available coal supplies and bypasses the scarcer oil and natural gas resources.

Grades, specifications and prices

Although cesium metal is produced in 99, 99.5, 99.9 and 99.97 per cent purities, the two main grades in which it is usually marketed are: standard, with a minimum cesium content of 99.5 per cent; and high purity, with a minimum cesium content of 99.9 per cent. Cesium salts are also available and include acetate, bromide, carbonate, chloride, chromate, fluoride, hydroxide, iodide, nitrate and sulphate. Cesium salts are similarly available in a high-purity grade of 99.9 per cent minimum purity. Cesium is also available in a series of oxides.

Recent nominal quotations for raw pollucite ore of good grade and quality vary between about 50¢ and 75¢ U.S. a pound of contained Cs_2O. Cesium salts sell for $25 to $U.S.40 a pound, depending on the type of salt, grade and quantity purchased. Cesium metal of 99+ per cent purity has been quoted at $100 to $375 a pound, depending on the quantity and grade purchased. Three United States companies that produce cesium chemicals are: Kawecki Berylco Industries, Inc., Kerr-McGee Corporation, and Great Western Inorganics, Inc. (formerly Rocky Mountain Research, Inc.).

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
92805-1*	Cesium	10%	15%	25%	10%
93819-1	Compounds of cesium	10%	15%	25%	10%

United States

Item No.		Non-communist countries	Communist countries, except Yugoslavia
601.66	Pollucite	Free	Free
415.10	Cesium	8.5% ad. val.	25% ad. val.
418.50	Cesium chloride	6.0% ad. val.	25% ad. val.
418.52	Other cesium compounds	5.0% ad. val.	25% ad. val.

Sources: For Canada, the Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1976), T.C. Publication 749.
*There are certain exceptions applicable to this tariff item. For further information regarding them, reference should be made to the above-mentioned Canadian Tariff manual or directly to the Department of National Revenue, Customs and Excise Branch, Ottawa.

Chromium

D.G. LAW-WEST

Canada is endowed with fairly large chromite deposits; however, none are economic at present. As a result, all of Canada's chromium requirements are met by imports. Since the closure of Union Carbide Canada Limited's ferrochromium plant in 1974, the only products made in Canada containing a high percentage of chromium are high-temperature alloys and chromium-magnesite refractories. Canadian imports of ferrochromium increased by 50 per cent in 1977, reflecting the improved market conditions and production performance in the Canadian specialty steel industry.

Canada

There are two principal areas of chromite mineralization in Canada; the Bird River area in Manitoba and the Eastern Townships in Quebec. The Bird River deposits are a continuous band of chromite mineralization, similar in type to the important chrome deposits in Rhodesia and the Republic of South Africa. However, most of the mineralization is low-grade — 10 to 20 per cent chromic oxide (Cr_2O_3) — and has a low chromium-to-iron ratio. This low ratio is undesirable, since it makes it difficult to beneficiate the ores to a marketable product. The Ontario Research Foundation has developed a process for upgrading the Bird River chromite to a marketable product, and partially as a result of this, the Manitoba Department of Mines, Resources and Environmental Management is currently conducting a re-evaluation of the Bird River deposits. Deposits in the Eastern Townships are discontinuous, or podiform, deposits. These deposits were exploited earlier in the century and during The Second World War. While these deposits are generally satisfactory in grade and composition, the tonnages are too small to be considered economical. The large number of claim owners in this area discourages major efforts to determine if there are larger deposits at depth.

Canadian consumption of chromite in 1977 was 30 299 tonnes* compared with 30 783 tonnes in 1976.

Canadian consumption of ferrochromium in 1977 was about 31 000 tonnes (gross weight) compared with 32 177 tonnes in 1976. The principal consumers of ferrochromium in Canada are: Atlas Steels Division of Rio Algom Limited, Colt Industries (Canada) Ltd., The Steel Company of Canada, Limited, The Algoma Steel Corporation, Limited and several iron and steel foundries. Atlas Steels, Canada's largest producer of stainless steel, is currently increasing the ingot capacity of its melt shop at Welland from 226 800 tonnes to 290 300 tonnes. This will result in greater ferrochromium consumption. The development of the argon-oxygen-decarburization (AOD) step will lead to an increased use of high-carbon ferrochromium in the production of stainless steel.

Canadian demand for ferrochrome is expected to rise to about 45 000 tonnes a year by 1980 and the bulk of these imports will most likely come from South Africa.

At present there is only one important consumer of chromium metal in Canada — the Deloro Stellite Division of Canadian Oxygen Limited, Belleville, Ontario.

Grades of ore

The only commercially important ore of chromium (Cr) is chromite. Chromite ores contain varying amounts of iron (Fe), magnesium (Mg) and aluminum (Al). The theoretical formula of pure chromite is $FeOCr_2O_3$ (68% Cr_2O_3; 32% FeO); however, in nature chromite is a combination of oxides of various elements having the general formula of (FeMg) O $(CrAlFe)_2O_3$. There are three principal grades of ore: metallurgical, refractory and chemical.

World developments

World production of chromite dropped marginally in 1977 to an estimated 8.4 million tonnes from 8.6 million tonnes in 1976. Rhodesia, the Republic of South Africa, Turkey and the U.S.S.R. remained the largest producers of metallurgical-grade ore; Philip-

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

pines remains the largest producer of refractory grade ore and the Republic of South Africa produces the most chemical-grade chromite.

The Republic of South Africa holds approximately 70 per cent of the world's chromite reserves and mine production during the year was estimated at 2.5 million tonnes of chromite ore.

South African rail rates increased by 23 per cent; this caused Transvaal chrome ore to be less attractive, as buyers must absorb any increase in rail costs as part of their contracts. In addition, any chromite moving through the port of Maputo, Mozambique faces demurrage charges as high as $10 a tonne for port handling delays. Ferrochrome producers have been hurt by higher power and rail rates as well. Power rates were increased by an average 40 per cent during the year.

In spite of these increasing costs South Africa has remained competitive in the world chromite and ferrochrome markets. In recent years there has been a notable increase in ferrochrome production; during 1977 the expansion of several existing plants and the

Table 1. Canada, chromium imports, 1976 and 1977

	1976		1977p	
	(tonnes)	($)	(tonnes)	($)
Imports				
Chromium in ores and concentrates				
United States	10 534	1 598 000	12 389	1 876 000
Finland	—	—	16 103	1 464 000
Philippines	21 641	1 810 000	8 167	1 433 000
Mozambique	—	—	4 047	435 000
Other countries[1]	7 689	2 113 000	520	224 000
Total	39 864	5 521 000	41 226	5 432 000
Ferrochromium				
United States	6 863	5 223 000	9 200	6 365 000
South Africa	10 066	6 158 000	9 740	5 493 000
Brazil	3 996	1 543 000	8 498	3 597 000
Other countries[2]	998	891 000	5 509	2 499 000
Total	21 923	13 815 000	32 947	17 954 000
Chromium sulphates, including basic				
United States	1 059	461 000	1 508	766 000
United Kingdom	267	107 000	289	144 000
Total	1 326	568 000	1 797	910 000
Chromium oxides and hydroxides				
United States	1 106	1 429 000	1 197	1 949 000
United Kingdom	76	95 000	120	211 000
West Germany	15	22 000	19	36 000
Other countries[3]	64	58 000	—	—
Total	1 261	1 604 000	1 336	2 196 000
Chrome dyestuffs				
Netherlands	2	9 000	24	80 000
United States	7	33 000	9	42 000
West Germany	6	47 000	8	36 000
Other countries[4]	7	39 000	14	48 000
Total	22	128 000	55	206 000

Source: Statistics Canada.
[1]Includes Netherlands, Portuguese Africa, South Africa, Turkey. [2]Includes Japan, Mozambique, Norway, Sweden, West Germany. [3]Includes Netherlands and Switzerland. [4]Includes France, Italy, Japan, Netherlands, Poland, Switzerland and United Kingdom.
pPreliminary; — Nil.

construction of new plants increased the Republic of South Africa's share of the world ferrochrome market to 23 per cent. Further expansion, to be completed by the end of 1978, is expected to increase its share to 50 per cent. Production capacity in 1977 was 400 000 tonnes a year and it will rise to some 600 000 tonnes by the end of 1978.

South African chromite shipments through Maputo suffered a slowdown when an accident closed the ore-loading wharf for about three months; however, exports were continued through use of the main cargo wharf. Currently, South Africa exports one million tonnes of ore through Maputo, while 360 000 tonnes are shipped through Durban S.A. Should Maputo be closed to South Africa for political reasons the ports of Durban and East London could handle all of the country's ore exports. Facilities for alloy and ore shipping at the new port of Richard's Bay, north of Durban, are still being planned, but they could be implemented by 1980-81, depending on the priority given them by the government-owned Railway Administration.

After a somewhat stormy history the controversial Byrd Amendment of 1972, under which the United States imported Rhodesian chromite in face of the 1966 United Nations sanctions against that country, was repealed on March 18, 1977. The Amendment narrowly survived a House of Representatives vote in September 1975, when African leaders in Rhodesia threatened a total cutoff of chromite supplies to the United States from any future African government in Rhodesia. Immediately following the repeal, a complex certification procedure, requiring all imported material containing more than 3 per cent chromium to carry a certificate indicating that the contained chromium was not of Rhodesian origin, was put in force. Initially there were some bottlenecks at points of entry, however shipments were flowing smoothly at year-end 1977.

Ferrochrome producers in the United States, alarmed by the increase of low-priced, high-carbon ferrochrome imports into the country, sought to have import tariff imposed. Following an investigation, the International Trade Commission in December 1977 recommended that an ad valorem tariff be applied on high-carbon ferrochrome imports; however the recommendation was rejected by President Carter on the grounds that such tariffs would:

- be inflationary, adding to consumer costs, especially in the stainless steel industry;
- possibly lead to retaliatory tariffs against the U.S.;
- undermine the United States international leadership to reduce trade barriers and only benefit the dominant firm in the industry, which is already in a strong competitive position.

United States ferrochrome imports increased by 75 per cent, from 97 347 tonnes in 1976 to 170 835 tonnes in 1977, with South Africa alone accounting for 96 502 tonnes of this increase, up 160 per cent from 37 540 tonnes in 1976.

The U.S.S.R. drastically reduced its shipments of chromite ore to all countries except the Comecon countries. It appears that the Soviet Union is experiencing a difficult transition from open-pit to underground mining techniques in the high-grade ore region of Kazakhistan. According to the current five-year plan, 1976-80, Soviet chromite production is to reach 23 million tonnes in the final year. Discussions on the construction of a ferrochromium plant continued during the year, with representatives of ferroalloy producers from Japan, Europe and the United States taking part. The U.S.S.R. would prefer to repay technical services in terms of product from the plant.

In Turkey there was a large stock of ore at ports and mine heads, as consumers balked at high prices; contract negotiations went slowly during the first half of the year.

Etibank Genel. Mudurluger has plans to construct a $50 million chrome and ferrochrome plant at Elazig in Turkey. The facility will produce 25 000 tonnes a year of chrome and 75 000 tonnes a year of ferrochrome. The Japanese company, Mitsubishi Metal Corporation, is to provide technical assistance.

In Brazil, Companhia de Mineracao Serra da Jacolsins began to ship chromite concentrates from its new mine and mill. Reserves are estimated at 4 million tonnes. The entire mine output will be shipped to Japan under the terms of the joint venture contract.

Elsewhere, Acoje Mining Co. Inc. of the Philippines is to increase chromite ore processing capacity from 800 to 1 200 tonnes a day. India will have additional charge chrome production with the construction of facilities at Byropore with an initial capacity of 6 000 tonnes a year, at an expected cost of $1.1 million. Three Japanese firms and the Indonesian government have signed a contract for chromite exploration in a 200-kilometre area in Indonesia. The Sudan government, with two Japanese firms, will develop chromite deposits in the Ingessena region of Sudan. After an initial feasibility study, a joint venture, consisting of the Sudan Government with a 51 per cent share and Japanese interests holding 49 per cent, will produce between 200 000 and 300 000 tonnes a year of ore by 1980.

Uses and technology

There are three commercial grades of chromite: metallurgical, refractory and chemical. Though interchangeable to a limited extent, each has a well-defined field of application.

Metallurgical-grade chromite is used primarily in the production of ferroalloys. Some is also used in the production of chromium metal. The principal ferroalloys produced are high-carbon (HC) ferrochromium, low-carbon (LC) ferrochromium and ferrochromium-silicon.

As a constituent of iron castings, steels and superalloys, chromium increases resistance to oxidation and corrosion and the ability to withstand stress at high temperatures. In addition, chromium helps to refine the grain structure in iron castings.

Table 2. Canada, chromium trade and consumption, 1960, 1965, 1970, 1975, 1976 and 1977

	Imports		Consumption[2]	
	Chromite[1]	Ferrochromium[2]	Chromite	Ferrochromium
	(tonnes)			
1960	53 545	4 183	49 288	8 008
1965	32 122	13 913	62 691	11 705
1970	27 619	20 814	56 212	28 356
1975	29 663	41 109	36 790	18 417
1976	39 864	21 923	30 783	32 177
1977[p]	41 226	32 947	30 299	. .

Source: Statistics Canada.
[1]Chromium content. [2]Gross weight.
[p]Preliminary; . . Not available.

The principal use of chromium ferroalloys is in the production of stainless and heat-resisting steels. Most applications of stainless and heat-resisting steels are in corrosive environments, e.g., petrochemical processing; high-temperature environments, e.g., turbines and furnace parts; and consumer goods areas, e.g., cutlery and decorative trim. Chromium is added to alloy and tool steels to increase their hardening ability and to improve some mechanical properties, such as yield strength. Superalloys containing chromium have a high degree of resistance to oxidation and corrosion at elevated temperatures and are used in jet engines, gas turbines and chemical processing. Chromium-containing castings are usually used for high-temperature applications.

The development of the argon-oxygen decarburization (AOD) step in the manufacture of stainless and heat-resisting steels has prompted major changes in chromium usage. The AOD process, which was developed by Union Carbide Corporation and Joslyn Stainless Steels Division of Joslyn Mfg. & Supply Co., is essentially a refining step after the charge has been melted down. Argon, an inert gas, is used along with oxygen so that carbon instead of chromium will be preferentially oxidized. Among other benefits, this serves to increase the recovery of chromium in the steels.

The ability to use charge chrome, which requires less energy to produce than the other chromium ferroalloys, and the reduction in the total amount of ferroalloys required, should lead to a quick adoption of technologies similar to the AOD step. The overall advantages obtained are lower cost of chromium additions, and in major stainless steel-producing countries where electricity is expensive or in short supply, some savings in energy consumption for the production of ferroalloys. Another process, similar to AOD refining, is the Creusot-Loire-Uddleholm (CLU) process which is being developed commercially by some European steelmakers.

In effect, this means that the growth rate of chromium usage will be less than that of stainless steel because of the more efficient use of chromium additions.

The refractory industry uses chromium in the form of chromite, principally in the manufacture of refractory bricks. Some chromite is employed for refractory purposes in mortars and in ramming, castable and gunning mixes, or directly for furnace repair.

Refractories composed of both chromite and magnesite are used principally in applications where basic slags and dust are encountered. The principal areas of use are in the ferrous and nonferrous metal industries. In the ferrous industry, chrome-magnesite brick is used in the basic open hearth and basic electric furnaces. The declining importance of the basic open hearth in steelmaking had led to a decline in the amount of chromite used as a refractory in the steel industry. The continuing decline in open-hearth production will be partially compensated for by the increase in electric furnace production; and a slower decline or, possibly, a stabilization, of chromite refractory consumption in the steel industry should result in the next few years. In the nonferrous industry, chrome-magnesite brick finds its principal use in converters. If oxygen-blowing in converters becomes economically feasible, the higher operating temperatures generated may necessitate a change to a higher-magnesite-content brick and thereby decrease chromite refractory usage.

The glass industry uses some chrome-magnesite brick in the reheating chambers of glass furnaces, and the kraft paper industry uses a dense chromite brick in recovery furnaces to resist chemical attack by spent liquors.

Chromite mortars and gunning mixes are used in the bonding and coating of basic bricks, or in areas where separation of various types of bricks by a chemically neutral substance is desirable. Castables and ramming mixes find their chief use in the open-hearth furnace.

Chromium chemicals have a wide variety of uses in a number of industries. Most chromium chemicals are derived from sodium dichromate, which is manufactured directly from chemical-grade chromite. The principal uses of chromium compounds are: in pigments, as mordants and dyes in the textile industry; as a tanning agent for all types of leathers; and in the chrome electroplating, anodizing and dipping of various products. Among other uses, chromium compounds are used as oxidants and catalysts in the manufacture of various products such as saccharin; in the bleaching and purification of oils, fats and chemicals; and as an agent to promote the water insolubility of various products such as glues, inks and gels.

Outlook

In the short run, the health of the chromium industry is dependent on the stainless steel industry and forecasts for significant increases in stainless steel production are not in the offing. However, in the long run, chromium is expected to have an average annual growth rate of 3.6 per cent through to the year 2000.

Perhaps the most significant change is the great increase in high-carbon ferrochromium production capacity in South Africa. South Africa already has the potential of supplying one-half of the world's ferrochrome demand; however, the political uncertainty affecting the country has made consumer countries wary of becoming too dependent. Some major consumers have already started to diversify their sources of supply.

Another uncertainty on the horizon is the technological advances being made in the development of techniques to utilize low-grade chromite deposits. Outokumpu Oyin of Finland is producing charge ferrochromium for its own use from low-grade deposits. Chromite is a strategic material in the production of specialty steels, and as such, consuming countries are looking for stable sources of supply.

Prices

Chrome prices published by "Metals Week"

	December 31, 1976		December 31, 1977
		($U.S.)	
Chrome ore, dry basis, fob cars Atlantic ports			
Transvaal 44% Cr_2O_3, no ratio (per long ton)	38.00-46.00		56.00-61.00
Turkish 48% Cr_2O_3, 3:1 ratio (per long ton)	132.00-142.00		132.00-142.00
Russian 54-56% Cr_2O_3, 4:1 ratio (per metric ton (tonne))	150.00		150.00
Chromium metal		($U.S.)	
Electrolytic 99.8% fob shipping point (per pound)	2.63		2.63-2.79
Ferrochrome, fob shipping point (per lb Cr content)		(¢ U.S.)	
High carbon 66-70% Cr, 5-6.5% C	47.0-61.0		41.00
Imported charge chrome	35.5-37.0		33.0-36.5
Low carbon 67-73% Cr, 0.025% C	90.00		80.00

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
32900-1	Chrome ore	free	free	free	free
34700-1	Chromium metal in lumps, powder, ingots, blocks or bars, and scrap alloy metal containing chromium for use in alloying purposes	free	free	free	free
37506-1	Ferrochrome	free	5%	5%	free
92821-1	Chromium oxides and hydroxides	free	15%	25%	free
	With the following exceptions: For use in the manufacture of artificial resins and plastics	free	free	25%	free
	For use in the manufacture of additives for heating, lubricating and fuel oils	free	5%	25%	free
92821-2	Chromium trioxide for use in the manufacture of galvanized and tin plated steel	free	free	25%	free
92838-8	Chromium potassium sulphate	free	free	10%	free
92838-9	Chromium sulphate, basic	free	free	10%	free

United States

Item No.		
601.15	Chrome ore	free
607.30	Ferrochromium, not containing over 3% by weight of carbon	4%
607.31	Ferrochromium, containing over 3% by weight of carbon, on chromium content	0.625¢ per lb
632.18	Chromium metal, unwrought (duty on waste and scrap suspended)	5%
632.84	Chromium alloys, unwrought	9%
420.98	Chromate and dichromate	0.87¢ per lb
473.10-20	Chrome colours	5%
531.21	Chrome refractories	12.5%

Sources: For Canada, the Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1978), TC Publication 843.

Clays and Clay Products

G.O. VAGT

Clays are natural, earthy, fine-grained minerals of secondary origin composed mainly of a group of hydrous aluminum silicates and may contain iron, alkalis and alkaline earths. The clay minerals, formed by the chemical weathering or alteration of aluminous minerals such as feldspar and mica, are generally classified into three major groups based on detailed chemistry and crystalline structure — the kaolinite group, the montmorillonite group and the illite group. Clay deposits suitable for the manufacture of ceramic products may include nonclay minerals such as quartz, calcite, dolomite, feldspar, gypsum, mica, iron-bearing minerals and organic matter. The nonclay minerals may, or may not be deleterious, depending upon individual amounts present and on the particular application for which the clay is intended.

The commercial value of clays, and of shales that are similar in composition to clays, depends mainly on their physical properties — plasticity, strength, shrinkage, vitrification range and refractoriness, fired colour, porosity and absorption — as well as on the proximity of any given deposit to growth centres in which clay products will be consumed.

Uses, type and location of Canadian deposits

Common clays and shale. Common clays and shales are the principle raw materials available from Canadian deposits for the manufacture of clay products. These materials are usually higher in alkalis, alkaline earth materials and iron-bearing minerals and much lower in alumina than the high-quality kaolins, fire clays, ball clays and stoneware clays. Common clays and shales are found in all parts of Canada, but deposits having excellent drying and firing properties are generally scarce and new deposits are continually being sought.

The clay minerals in common clays and shales are chiefly illitic or chloritic. Their fusion points are low, usually well below pyrometric cone equivalent (PCE) number 15 (PCE 15), which is defined by a temperature of approximately 1 430°C and is considered to be the lower limit of the softening point for fire clays. (The pyrometric cones are a convenient method of relating temperature and time by a single value.) The presence of iron usually results in a salmon or red fired colour.

Suitable common clays and shales are utilized in the manufacture of heavy clay products such as common brick, facing brick, structural tile, partition tile, conduit tile, quarry tile and drain tile. Some Canadian common clays are mixed with stoneware clay for the manufacture of facing brick, sewer pipe, flue lining and related products. The raw materials utilized in the heavy clay industry usually contain up to 35 per cent quartz. If the quartz, together with other nonplastic materials, exceeds this percentage, the plasticity of the clay is reduced and the quality of the ware is lowered. If calcite or dolomite is present in sufficient quantities, the clay will fire buff and the fire strength and density will be adversely affected.

Most of the surface deposits of common clays in Canada are the result of continental glaciation and subsequent stream transport. Such Pleistocene deposits are of interest to the ceramic industry and include stoneless marine and lake sediments, reworked glacial till, interglacial clays and floodplain clays. These deposits are characterized by low melting temperatures.

The common shales provide the best source of raw material for making brick. In particular, those found in Cambrian, Ordovician and Carboniferous rocks in eastern Canada, and Jurassic, Cretaceous and Tertiary rocks in western Canada, are utilized by the ceramic industry. In many instances these shales are more refractory than the Pleistocene clays. Several federal and provincial government reports are available describing the physical and chemical properties of ceramic raw materials that offer potential for the manufacture of numerous products.

China clay (kaolin). China clay is a high-quality white, or nearly white, clay formed from the decomposition of crystalline rocks such as granite. Alteration to form primary kaolins may result from hydrothermal or weathering processes or both. The natural decomposition process, known as kaolinization, results in a hydrated aluminum silicate ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$) with the approximate percentage composition as follows: 40 per cent Al_2O_3, 46 per cent SiO_2 and 14 per cent H_2O.

None of the crude kaolins known to exist in Canada have been developed, primarily because of beneficiation problems and the small size of some deposits. Most occurrences contain a high proportion of quartz particles of varied sizes; mica, feldspar, magnetite, pyrite and colloidal iron have been noted as well. In the

Table 1. Canada, production of clay and clay products from domestic sources, 1975-77

	1975	1976	1977p
		($000)	
Production from domestic sources, by provinces			
Newfoundland	457	569	575
Nova Scotia	3 155	3 900	4 575
New Brunswick	1 310	1 565	1 989
Quebec	16 468	14 317	17 333
Ontario	44 769	53 152	56 511
Manitoba	1 386	2 492	2 624
Saskatchewan	2 730	3 540	3 243
Alberta	8 530	10 774	10 330
British Columbia	7 172	7 238	6 970
Total Canada	85 977	97 547	104 150
	1975r	1976	1977
		($000)	
Production[1] from domestic sources, by products			
Clay, fire-clay and other clay	795	938	979
Brick-soft mud process	3 255	21 039	13 206
-stiff mud process	42 064	37 670	45 587
-dry press	9 195	4 320	7 874
-fancy and ornamental, sewer brick and paving brick	678	927	906
Structural hollow blocks	241	230	271
Drain tile	3 869	3 948	4 447
Sewer pipe	7 007	9 982	9 571
Flue linings	2 804	2 713	3 145
Pottery (glazed and unglazed) including earthenware, sanitaryware, stoneware, flowerpots, etc.)	3 478	4 216	4 364
Other products	6 944	5 267	7 020
Small establishments not reporting detail	5 647	6 297	6 780
Total	85 977	97 547	104 150

Source: Statistics Canada.
[1]Producers' shipments. Distribution for 1977 estimated by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
pPreliminary; rRevised.

crude material the percentage of kaolinite frequently is small, making removal of impurities from Canadian kaolins difficult.

China clay is used primarily as a filler and coater in the paper industry, a raw material in ceramic products and a filler in rubber and other products. The following properties are required in clays used by the paper industry: low-viscosity characteristics when in clay-water systems; intense whiteness; high coating retention; and freedom from abrasive grit. In the ceramic

Table 2. Canada, imports and exports of clay, clay products and refractories, 1976 and 1977

	1976		1977p	
	(tonnes)[1]	($000)	(tonnes)	($000)
Imports				
Clays				
Bentonite	274 095	5 288	357 995	7 873
Drilling mud	28 733	7 458	42 453	8 665
China clay, ground or unground	176 751	7 340	154 512	9 572
Fire clay, ground or unground	33 340	1 319	45 605	1 800
Clays, ground or unground	145 670r	4 303	135 055	5 474
Clays and earth, activated	92 496	4 920	120 132	5 750
Subtotal, clays	751 085	30 628	855 752	39 134
	(000 tonnes)		(000 tonnes)	
Clay products				
Brick-building, glazed	3 327	262	4 883	614
Brick-building, nes	704 501	4 687	45 976	4 743
Building blocks	. .	1 169	. .	1 387
Clay bricks, blocks and tiles, nes	. .	3 538	. .	3 226
Earthenware tile	(m^2)		(m^2)	
under 2½" x 2½"	1 661 522	5 447	1 520 416	6 327
over 2½" x 2½"	4 549 509	13 855	5 624 277	21 643
Subtotal, brick, blocks, tile	. .	28 958	. .	37 940
Tableware, ceramic	. .	53 533	. .	61 869
Porcelain, insulating, fitting	. .	9 335	. .	13 648
Pottery settings and firing supplies	. .	756	. .	749
Subtotal porcelain pottery	. .	63 624	. .	76 266
	(tonnes)	($000)	(tonnes)	($000)
Refractories				
Firebrick				
Alumina	28 934	8 580	48 116	12 603
Chrome	3 676	1 604	2 832	1 491
Magnesite	16 130	7 627	15 966	8 403
Silica	10 850	3 671	10 029	3 049
nes	129 953	22 792	165 693	24 125
Refractory cements and mortars	. .	6 322	. .	8 388
Acid-proof brick	. .	149	. .	268
Crude refractory material	7 327	712	9 707	1 003
Grog (refractory scrap)	15 618	967	15 533	1 756
Refractories, nes	. .	3 599	. .	5 345
Subtotal refractories	. .	56 023	. .	66 431
Total clay, clay products and Refractories	. .	179 233	. .	219 771

industry china clay is used as a refractory raw material. In prepared whiteware bodies such as wall tile, sanitaryware, dinnerware, pottery and electrical porcelain, quantities of nepheline syenite, silica, feldspar and talc are used as well.

Lower-quality kaolins in North America might be mined, and more expensive processing might be justified as higher-quality deposits become depleted. If this situation arises, the development of a few Canadian deposits could become more attractive, particularly if new processing techniques and equipment become available.

In southern Saskatchewan, deposits of sandy kaolin occur near Wood Mountain, Fir Mountain, Knollys, Flintoft and other localities. Despite considerable work, no satisfactory method of producing a good commercial kaolin from these deposits has been developed.

A deposit of refractory clay which is very plastic to very sandy, and is similar to a secondary china clay, occurs along the Fraser River near Prince George, British Columbia. This material has been investigated as a source of kaolin, as a fire clay and as a raw material for facing brick.

Various kaolinitic-rock deposits have been investigated in Manitoba. The reported deposits are principally in the northwest at Cross Lake and Pine River, on Deer Island (Punk Island) and Black Island in Lake Winnipeg, and at Arborg.

Table 2. (cont'd)

	1976		1977p	
	(tonnes)	($000)	(tonnes)	($000)
Imports (concl'd)				
By main countries				
United States	. .	94 654	. .	114 364
United Kingdom	. .	33 206	. .	38 889
Japan	. .	16 144	. .	19 731
Italy	. .	9 564	. .	14 817
West Germany	. .	8 881	. .	6 981
France	. .	1 818	. .	4 905
Spain	. .	2 089	. .	2 929
Greece	. .	2 464	. .	2 852
South Korea	. .	1 342	. .	2 043
Austria	. .	1 673	. .	1 666
Other countries	. .	7 398	. .	10 594
Total	. .	179 233	. .	219 771
Exports				
Clays, ground and unground	988	100	1 737	145
	(000 tonnes)		(000 tonnes)	
Clay products				
Building brick, clay	5 026	1 319	6 169	1 768
Clay bricks, blocks, tiles, nes	. .	301	. .	627
Subtotal, bricks, blocks, tiles	. .	1 620	. .	2 395
High-tension insulators and fittings	. .	2 845	. .	2 503
Tableware	. .	4 401	. .	4 958
Subtotal porcelain tableware	. .	7 246	. .	7 461
	(tonnes)		(tonnes)	
Refractories				
Firebrick and similar shapes	39 770	11 005	40 678	13 017
Crude refractory materials	820 645	1 840	747 950	1 187
Refractory nes	. .	2 968	. .	6 391
Subtotal refractories	. .	15 813	. .	20 595
Total clays, clay products and refractories	. .	24 779	. .	30 596

Table 2. (concl'd)

	1976		1977p	
	(tonnes)	($000)	(tonnes)	($000)
Exports (concl'd)				
By main countries				
United States	. .	16 875	. .	22 017
South Africa	. .	257	. .	1 178
Dominican Republic	. .	1 496	. .	986
Venezuela	. .	19	. .	698
New Zealand	. .	141	. .	417
United Kingdom	. .	376	. .	374
Lebanon	. .	35	. .	370
Australia	. .	507	. .	293
Iran	. .	353	. .	248
Trinidad-Tobago	. .	123	. .	234
Turkey	—	—	. .	233
Pakistan	. .	224	. .	233
Other countries	. .	4 373	. .	3 315
Total	. .	24 779	. .	30 596

Source: Statistics Canada.
[1]The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.
pPreliminary; rRevised; . . Not available; — Nil; nes Not elsewhere specified.

Several companies have shown considerable interest in Quebec's kaolin-bearing deposits although the deposits, in general, contain an excessive amount of quartz and iron minerals. Kaolin-bearing rock occurs at St-Rémi-d'Amherst, Papineau County; Brébeuf, Terrebonne County; Point Comfort, on Thirty-one Mile Lake, Gatineau County; and Chateau-Richer, Montmorency County.

Extensive deposits of kaolin-sand mixtures occur in northern Ontario along the Missinaibi and Mattagami rivers. Distance from markets and the difficult terrain and climate of the area have hindered development, although some encouraging results were obtained. The kaolin has good refractory characteristics and meets specifications for filler-grade material. Potential uses for the silica, which comprises 80 per cent of the deposit, include glass manufacture, abrasive flour and ceramic application.

Ball clay. Ball clays are a very fine grained, sedimentary kaolinitic type of clay with unfired colours ranging from white or various shades of grey depending on the amount of carbonaceous material present.

Ball clays obtained in Canada are mineralogically similar to high-grade, plastic fire clay. They are composed principally of fine-particle kaolinite, quartz, illite and mica with less alumina and more silica than kaolin. Ball clays are extremely refractory materials. In whitewares they impart a high green strength as well as plasticity to the bodies. Although white firing clays are most suitable, fired products, which are cream coloured, do not interfere with the quality of the whiteware products.

Ball clays are known to occur in the Whitemud Formation of southern Saskatchewan. Good-quality deposits are present at Willows, Readlyn, Big Muddy Valley, Blue Hills, Willow Bunch, Flintoft and in other areas. Clay from the Willows area has been used for many years in the potteries at Medicine Hat and Vancouver; however, the lack of proper quality control, the distance from large markets and lack of reserves have been the principal disadvantages affecting the widespread use of this material. Some ball clays from the Flintoft area are used for white-to-buff facing brick and for household pottery and crocks.

Fire clay. Fire clays contain high percentages of alumina and silica. They may be sedimentary or residual in origin, plastic or nonplastic and are composed mainly of kaolinite. The classification of fire clays may be related to the composition, physical characteristics, refractoriness, use or association with other minerals. Descriptive terminology includes plastic fire clay, nonplastic fire clay, high-alumina fire clay, or high-heat duty fire clay. Fire clays are plastic when pulverized and wetted, rigid when subsequently dried and of sufficient purity and refractoriness for use in commercial refractory products.

Canadian fire clays are used principally for the manufacture of medium- and high-duty firebrick and refractory specialties. High-duty refractories require raw materials having a PCE of about 31.5 to 32.5 (approximately 1 699 to 1 724°C). Intermediate-duty refractories require raw materials having a PCE of about 29 (approximately 1 659°C) or higher. Clays having a PCE of less than 29 but greater than 15 (approximately 1 430°C) may be suitable for low-duty refractories or ladle brick as well as for other clay products. Known Canadian fire clays are not sufficiently refractory for the manufacture of super-duty refractories without the addition of some very refractory material such as alumina.

Various grades of good-quality fire clay occur in the Whitemud Formation in southern Saskatchewan.

Good-quality fire clays occur on Sumas Mountain in British Columbia. Some fire clay from the Sumas deposit is exported to the United States, and a small quantity is used at plants in Vancouver.

Fire clay and kaolin occur in the James Bay watershed of northern Ontario along the Missinaibi, Abitibi, Moose and Mattagami rivers. Considerable exploration has been carried out in some parts of these areas in recent years.

At Shubenacadie, Nova Scotia, some seams of clay are sufficiently refractory for medium-duty refractories. Research has indicated that these deposits may be suitable for production of ladle brick. Clay from Musquodoboit, Nova Scotia has been used by a few foundries in the Atlantic provinces, and the properties and extent of this clay were investigated by the Nova Scotia Department of Mines.

Ontario and Quebec have no producing domestic sources of fire clay. These provinces import most of their requirements from the United States.

Stoneware clay. Stone clays are similar to low-grade plastic clays and are characterized by good plasticity, a vitrification range between PCE 4 and 10, a long firing range and a fired colour from buff to grey. They range from commercially inferior material through semi-refractory to firebrick clays. They should have low fire shrinkage, enough plasticity and toughness for shaping, no lime- or iron-bearing concretions and very little coarse sand.

Stoneware clays are used extensively in the manufacture of sewer pipe, flue liners, facing brick, pottery, stoneware crocks and jugs, and chemical stoneware.

The principal source of stoneware clay in Canada is the Whitemud Formation in southern Saskatchewan and southeastern Alberta. The Eastend area in Saskatchewan was formerly the source of much of the clay used at Medicine Hat. Stoneware clay pits are presently located in the Alberta Cypress Hills, southeast of Medicine Hat, and at Avonlea, Saskatchewan. Stoneware clays occur on Sumas Mountain, near Abbotsford, British Columbia. These clays are used in the manufacture of sewer pipe, flue lining, facing brick and tile.

In Nova Scotia, stoneware clays occur at Shubenacadie and Musquodoboit. The Shubenacadie clays are used principally for the manufacture of buff facing brick. Other similar deposits occur at Swan River, Manitoba, where some buff brick has been manufactured, Kergwenan, Manitoba and in British Columbia at Chimney Creek Bridge, Williams Lake, Quesnel and near the Alaska Highway at Coal River. Quebec and Ontario import stoneware clay from the United States for manufacture of facing brick and sewer pipe.

Table 3. Canada, shipments of clay products produced from imported clay[1], 1974-76

	1974		1975		1976^p	
	(000 m^2)	($000)	(000 m^2)	($000)	(000 m^2)	($000)
Electrical porcelains	. .	26 260	. .	28 138	. .	24 874
Glazed floor and wall tile	2 046	10 193	1 554	9 036	1 366	7 950
Sanitaryware	. .	37 208	. .	37 238[2]	. .	8 948[2]
Pottery, art and decorative ware	. .	2 629	—	—	—	—
Pottery, other	. .	169	—	—	. .	. .

Source: Statistics Canada.
[1]Does not include refractories. [2]Does not include same items as 1974.
^{p}Preliminary; . . Not applicable or not available; — Nil.

Table 4. Canada, shipments of refractories, 1974-76

	1974		1975		1976^p	
	(tonnes)	($000)	(tonnes)	($000)	(tonnes)	($000)
Firebrick and similar shapes	135 330	31 306	129 057	36 707	109 573	32 473
Cement, mortars, castables	95 885	19 713	122 886	28 277	. .	29 459

Source: Statistics Canada.
^{p}Preliminary; . . not available.

Table 5. Canada, clay and clay products, production and trade 1960, 1965, 1970, 1975, 1976 and 1977

Year	Production			Refractory Shipments[1]	Imports	Exports
	Domestic Clays	Imported Clays	Total			
	($ million)					
1960	38.2	21.5	59.7	18.6	46.7	5.3
1965	42.8	31.4	74.2	27.4	59.4	10.3
1970	51.8	33.6	85.4	42.3	81.2	15.6
1975	86.0	59.1	145.1	69.9	117.4ʳ	24.8ʳ
1976	97.5	59.0	156.5	66.2	179.2ʳ	24.8ʳ
1977ᵖ	104.2	. .	. .	. .	219.8	30.6

Source: Statistics Canada.
[1] Includes fire brick and similar shapes, refractory cements, mortars, castables, plastics, etc., plus all other products shipped.
ᵖPreliminary; ʳRevised; . . Not available.

Canadian industry and developments

The value of clays and clay products produced from domestic sources in 1977 was over $104 million, up from the 1976 figure of $97.6 million. Operators List 6, Ceramic Plants in Canada, (1975) published by the Department of Energy, Mines and Resources, indicates that there were 185 operating plants. Some plants manufacture more than one ceramic product or group of ceramic products. The distribution of production facilities in Canada is presented in Table 6. The quantity of clays imported in 1977, other than bentonite and drilling mud, which substantially increased, was essentially the same as in 1976.

The brick and tile manufacturing industry accounts for nearly 30 per cent of the ceramic plants in Canada. These plants manufacture clay products, which include common brick, facing brick, structural tile, quarry tile and drain tile, primarily from local common clays and shales.

Thunder Brick Company in Thunder Bay, Ontario, completed a new combination face brick and split tile plant in Thunder Bay, Ontario. The plant is the first in North America equipped for automatic production of extruded split tiles and has a design capacity of approximately 20 million a year.

Ceramco Canada Ltd. completed a ceramic tile plant at the Becancour Industrial Park at Trois-Rivières, Quebec. Some United States markets, as well as Canadian markets, are expected to be served.

In recent years, requirements for brick as a structural material in low- to medium-rise buildings have been emphasized. The use of an oversize "through the

Table 6. Distribution of production facilities for ceramic products in Canada, 1975

Ceramic Product	Number of Plants					
	Atlantic Provinces	Quebec	Ontario	Prairie Provinces	British Columbia	Total
Abrasives	—	5	10	—	—	15
Brick and tile	4	7	32	5	3	51
Clay sewer pipe	1	—	2	2	1	6
Glass	1	5	9	4	2	21
Porcelain and pottery	—	11	26	4	5	46
Porcelain enamel	2	4	20	1	—	26
Refractories	—	5	12	1	4	22
	8	28	111	17	15	187

Note: Some plants produce more than one group of products.
Source: Based on Operators List 6, Ceramic Plants in Canada (1975), Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
— Nil.

wall'' (TTW) brick, which provides wall thickness, now provides a significant market for brick manufacturers.

Six plants manufacture sewer pipe from domestic common clay, shale and fire clay. Of the porcelain and pottery producers, sanitaryware plants, electrical porcelain plants, wall tile plants, dinnerware plants and the art potteries are the principal consumers of ceramic-grade china clay and ball clays. These raw materials are imported mainly from the United States and Britain. Some of the art potteries and one of the dinnerware plants import unfinished ware and complete the manufacturing process by glazing or decorating.

Most of the refractory manufacturing plants utilize imported clay including ball clay, fire clay and kaolin, as the principal ingredients in many of their products.

Didier Refractories Corp. is completing its refractory products plant at Becancour, Quebec. This company is an affiliate of Didier-Werke A.G., a well established producer of refractories from Germany. High alumina brick, basic brick and a broad range of refractory specialties will be manufactured. The plant is designed to manufacture 40 000 to 50 000 tonnes* of refractories a year, primarily for Canadian and United States markets.

The nine abrasives plants utilized both domestic and imported raw materials. The distribution was approximately half and half, except for silicon carbide, which was supplied entirely from domestic sources, and petroleum coke, which was imported. Domestic and foreign sources of raw materials were used by Canadian glass plants. Those in Quebec and Ontario accounted for most of the imported silica sand used.

Porcelain enamel was produced and utilized at 26 plants.

World review

Mine production of clays in the United States increased to $U.S.56 million in 1977 from $U.S.53 million in 1976. Most of the increase was attributed to kaolin and common clay. Weak capital spending in the construction industry prevailed much of the year however a sharply rising trend resulted near year-end giving an overall record total.

The major uses for specific clays in the United States are as follows: *kaolin* — paper manufacture, refractories, rubber manufacture; *ball clay* — dinnerware, sanitaryware, floor and wall tile; *fire clay* — firebricks, foundry sand moulds; *bentonite* — iron ore pelletizing, foundry sand bonding, drilling mud; *fuller's earth* — absorbents and fillers, insecticide carriers; *common clay* — construction material.

Demand for clays in the United States is expected to increase at annual rates of between 2 and 5 per cent through 1985; however, continued growth of the energy intensive clay-based industries could be severely impeded by persistent energy problems and lowered construction rates. Environmental problems and the need for planned land utilization must also be considered in any projection of future developments in the clay industry.

Adequate reserves of high-quality clays of all types, together with possession of clay-processing technology, assure the United States a position as a major world supplier of clays. The United States is the world's leading producer of kaolin, accounting for 6.6 million tonnes in 1977. The United Kingdom is the second-largest producer and is the leading exporter of kaolin, mainly to Europe, United States and Japan. Other major producers are U.S.S.R., Brazil, France, Czechoslovakia, West Germany and Spain.

A new development in northern Brazil by National Bulk Carriers Inc. of New York is producing paper-coating-grade kaolin on a normal basis at Morro do Felipe in the territory of Amapa. Design capacity is approximately 200 000 tonnes a year of two paper-coating grades of kaolin. Brazil, after the United States and the United Kingdom, is now the world's third major producer of this type of clay. A second development to produce kaolin is being undertaken by a new company, Caulim do Para, under joint venture with J.M. Huber Corporation of the U.S. A plant, now under construction, will have a capacity of 280 000 tonnes a year, of which 200 000 tonnes will be coating grade and 80 000 tonnes will be filler grade. Products will be mainly exported to Japan and Europe.

In Western Australia, the Gabbin kaolin deposit continues to be under evaluation. Production of 250 000 tonnes a year of clay is foreseen.

The installation of magnetic separators continues at several kaolin processing plants in the United States. This technological development is a key element in

Table 7. Canada, consumption (available data) of china clay, by industries, 1975 and 1976

	1975	1976^{p}
	(tonnes)	
Paper and paper products	85 570	111 973^{e}
Ceramic products	13 498	7 267
Paint and varnish	4 294	4 580
Rubber and linoleum	3 470	3 431
Other products[1]	19 009	47 068
Total	125 841	174 319

Source: Statistics Canada. Industry allocation by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
[1]Includes adhesives, chemicals, foundry, glass fibre, wire and cable and miscellaneous products.
^{p}Preliminary; ^{e}Estimated.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

producing better-quality coating clays, reducing chemical reagent consumption and extending mineral reserves.

Outlook

New and repair building construction and engineering expenditures in Canada are projected to be greater than $37 billion in 1978, $2 billion more than in 1977.

Better fuel management is currently very essential and will be more critical in the future. Research continues into the use of oxygen-enriched air in industrial processes such as ceramic and glass manufacture as well as ferrous and nonferrous metal foundry operations.

In the United States, coal firing is becoming of more interest to some brick producers as a result of the severe gas shortage in 1976 and the projected high cost of this fuel. Refractory fibres are being increasingly used in the lining of kilns and furnaces. Also fuel efficiency has been improved with fibre linings over existing refractory brick linings.

The few known deposits of fire clays and ball clays in the developed areas of Canada are being utilized. Much assessment work has been done on deposits containing kaolin; but, because of small size, high cost of beneficiation, or remoteness from transportation or industry, none have been developed. Ontario and Quebec are particularly deficient in developed deposits of refractory- or kaolin-type clays.

Demand for high-grade, super-duty refractories continued to be high through 1977. Steel processes such as the basic oxygen furnace, pressure pouring and continuous casting, represent relatively new refractory requirements. New products and designs have also been dictated by changes in reducing atmospheres in the chemical and petrochemical industry, by increased demand for high-purity glass and by the need for more economical production of ceramics.

Clay and shale, like other low-cost construction materials, must be produced near the heavily populated areas where the markets are situated. This necessary feature of the industry will continue to produce increasingly complex problems related to rising land costs, land-use conflicts, environmental control requirements, and cost of land rehabilitation. The situation is particularly acute in southwestern Ontario where suitable reserves of brick-shales and other construction materials are being depleted with few prospects for the opening of new pits and quarries under present controls. Some end-use products such as brick and tile find competition from cement, glass, metals and plastic manufacturers; however, clays, being generally less expensive and very satisfactory for their intended uses, are usually able to hold their own, or to increase at the expense of the alternate materials, for many end-uses.

Bentonite and fuller's earth

Bentonite, a clay that consists primarily of montmorillonite, a hydrous aluminum silicate with weakly attached cations of sodium and calcium, is reviewed in a separate section of the *Canadian Minerals Yearbook, 1977.*

Fuller's earth is primarily a calcium montmorillonite clay characterized by natural bleaching and absorbent properties; it is similar to nonswelling bentonite. The terminology is confusing and bentonite and fuller's earth may not necessarily be separated in world trade and production statistics by country. Attapulgite, a magnesium-aluminum silicate, is a form of high-quality fuller's earth.

Prices

United States clay prices, according to "Chemical Marketing Reporter", December 26, 1977

	($ per short ton)
Ball clay	
Domestic, crushed, moisture-repellent, bulk car lots, fob Tennessee	8 — 11.25
Imported lump, bulk, fob Great Lakes ports	40.50
Imported, airfloated bags, car lots, Atlantic ports	70.00
China clay (kaolin)	
Water washed, fully calcined, bulk car lots, fob Georgia	145 — 182.50
Uncalcined, No. 1 coating, same basis	61.50
Dry-ground, airfloated soft, fob Georgia	20.00

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
		(%)	(%)	(%)	(%)
29500-1	Clays, including fire clay, pipe clay not further manufactured than ground	free	free	free	free

Tariffs (cont'd)
Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
		(%)	(%)	(%)	(%)
29525-1	China clay	free	free	25	free
28100-1	Firebrick containing not less than 90 per cent silica; magnesite firebrick or chrome firebrick; other firebrick valued at not less than $100 per 1 000 rectangular shaped, not to exceed 100 X 25 in.^{3} for use in kiln repair or other equipment of a manufacturing establishment	free	free	free	free
28105-1	Firebrick, nop, of a class or kind not made in Canada, for use in construction or repair of a furnace, kiln, etc.	free	free	15	free
28110-1	Firebrick, nop	5	10	22½	5
28200-1	Building brick and paving brick	10	10	22½	6½
28205-1	Manufactures of clay or cement, nop	12½	12½	22½	8
28210-1	Saggars, hillers, bats and plate setters, when used in the manufacture of ceramic products	free	free	free	free
28300-1	Drain tiles, not glazed	free	17½	20	free
28400-1	Drain pipes, sewer pipes and earthenware fillings therefor; chimney linings or vents, chimney tops and inverted blocks, glazed or unglazed, nop	15	20	35	13
28405-1	Earthenware tiles, for roofing purposes	free	32½	35	free
	General Agreement on Tariffs and Trade		17½		
28415-1	Earthenware tiles, nop	12½	20	35	12½
28500-1	Tiles or blocks of earthenware or of stone prepared for mosaic flooring	15	27½	30	13
	General Agreement on Tariffs and Trade		20		
28600-1	Earthenware and stoneware, viz., demijohns, churns and crocks, nop	20	30	35	13
	General Agreement on Tariffs and Trade		20		
28700-1	All tableware of china, porcelain, semiporcelain or white granite, excluding earthenware articles	free	15	35	free
28705-1	Articles of chinaware, for mounting by silverware manufacturers	12½	17½	22½	11½
28710-1	Undecorated tableware of china, porcelain, semiporcelain for use in the manufacture of decorated tableware	free	10	35	free
28800-1	Stoneware and Rockingham ware and earthenware, nop	17½	20	35	13
28805-1	Chemical stoneware	free	10	35	free
28810-1	Hand forms of porcelain for manufacture of rubber gloves	free	10	35	free
	General Agreement on Tariffs and Trade		free		

Tariffs (concl'd)

Canada

28900-1	Baths, bathtubs, basins, closets, closet seats and covers, closet tanks, lavatories, urinals, sinks and laundry tubs of earthenware, stone, or cement, clay or other material, nop	12½	15	35	12½

United States

		(¢ per long ton)
521.51	Fuller's earth, not beneficiated	25
521.41	China clay or kaolin	33
521.54	Fuller's earth, wholly or partly beneficiated	50
521.81	Other clays, not beneficiated	free
521.84	Other clays, wholly or partly beneficiated	50
521.61	Bentonite	40
521.71	Common blue clay and other ball clays not beneficiated	42
521.74	Common blue clay and other ball clays, wholly or partly beneficiated	85
521.87	Clays artificially activated with acid or other material	0.05¢ per lb. + 6% ad valorem

Sources: The Customs Tariff and Amendments, Department of National Revenue, Ottawa. Tariff Schedules of the United States, Annotated (1978) T.C. Publication, 843.
Nop: Not otherwise provided for.
Note: In addition to the above tariffs various duties are in existence on manufactured clay products, viz., brick pottery, artware, etc.

Coal and Coke

J.A. AYLSWORTH and H.J. WEYLAND

The year 1977 was one of growth for Canada's coal industry. The volume and value of production increased by significant amounts given the continuing stability of many coal markets. The Canadian industry held its own in world coking coal markets despite difficult contract negotiations, while growing demands in the domestic thermal sector provided the major impetus for increased production and consumption. Exploration activity continued to reflect a confidence in the future growth of Canada's coal industry. Mining and oil companies intensified exploration and other predevelopment activities in many areas of western Canada. Several thermal coal properties reached the application or development stage as Alberta, Saskatchewan, Ontario, New Brunswick and Nova Scotia planned for increased use of coal. Research and development work on a wide range of coal issues indicated the priority of government, industry and universities in relation to future use of coal. Work continued on a new west-to-east coal delivery system scheduled to initiate regular movements of western Canadian thermal coal to Ontario Hydro in 1978. Provincial and federal governments continued to work towards the development of coal policies. In 1977 British Columbia became the second province to release a coal policy, following Alberta which released its policy in 1976.

Canadian coal production was 28.7 million tonnes* in 1977, up 13 per cent from 25.5 million tonnes in 1976, while the value of production increased 11 per cent to $674 million from $608 million. The volume and value of sub-bituminous and lignite production increased in Alberta and Saskatchewan. Bituminous production was up in British Columbia and Nova Scotia but down in Alberta and New Brunswick. The overall volume of bituminous production increased 6 per cent in 1977 to 15.3 million tonnes, up from 14.4 million tonnes in 1976. Sub-bituminous coal production increased by 23 per cent to 7.9 million tonnes in 1977, while lignite production rose 17 per cent to 5.5 million tonnes.

The volume of exports increased by approximately 4 per cent in 1977 to 12.4 million tonnes, up from 11.9 million tonnes in 1976. This was achieved despite a 2 per cent decrease in the volume of shipments to Japan. Exports to European and Asian countries made up the difference, with Denmark, West Germany and Belgium the major importers in Europe, and South Korea the other major importer in Asia. Mexico and Brazil also imported Canadian coal in 1977. The 1977 Canadian imports, practically all from the United States, increased by 8 per cent reaching 15.8 million tonnes compared to 14.6 million tonnes a year earlier.

Canadian coal consumption reached 30.9 million tonnes in 1977, up 11 per cent from 27.8 million tonnes in 1976. Of this 30.9 million tonnes: 22.4 million were used to generate electricity, 6.7 million to produce coke and 1.8 million to general industry and commercial users.

Outlook

Coal production and consumption are forecast to increase in Canada in the 1980s. This bright future is based on growth prospects in traditional markets and the development of new markets. Domestic thermal markets will provide the major impetus for growth in the near term. Coking coal markets, which are export oriented, are forecast to grow at a slower pace than has been evident in the past decade.

Over the last three years, the growth in thermal coal consumption has been the major factor behind the increase in Canada's coal production. Domestic consumption has been growing by approximately 15 per cent annually since 1975. Forecasts based on utilities' projections suggest an annual domestic growth rate of approximately 10 per cent until 1980. This would result in a yearly consumption of approximately 30 million tonnes of coal by 1980. All areas of Canada are forecast to share in this increase, with the major growth in absolute terms occurring in western Canada. Alberta will have the largest growth in thermal coal consump-

* The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

tion, although Ontario, Saskatchewan, New Brunswick and Nova Scotia will also experience increases. British Columbia may also become a major consumer of thermal coal in the 1980s. In addition to domestic demand, Canada may export significant amounts of thermal coals in the next few years, probably to Asian and European markets.

In the long term, domestic coal resources could help reduce Canada's dependence on foreign oil supplies and declining conventional crude oil reserves. This vulnerability could be reduced by increased use of coal in both the conventional (thermal electric) and nonconventional (substitute synthetic fuels) sectors. It is predicted that by 1990 Canadian consumption in the latter sector could exceed 10 million tonnes and total coal consumption for thermal energy purposes could be in the range of 80 million tonnes a year. This would represent more than a two-fold increase over current

Table 1. Canada, coal production[1] by type and province, 1976 and 1977

	1976		1977	
	tonnes (000)	$ (000)	tonnes (000)	$ (000)
Bituminous:				
Nova Scotia	2 000	54 500	2 165	81 733
New Brunswick	297	6 300	277	6 168
Alberta	4 583	203 127	4 274	196 026
British Columbia	7 509	306 500	8 585	339 686
Total	14 389	570 427	15 301	623 613
Sub-bituminous:				
Alberta	6 409	25 000	7 902	29 962
Lignite:				
Saskatchewan	4 677	13 039	5 478	20 762
All types, Canada total	25 475	608 466	28 681	674 337

Sources: Statistics Canada and Department of Energy, Mines and Resources, Ottawa.
[1] Production represents clean coal output, plus raw coal sales from the mine where there is a preparation plant at the mine, plus raw coal shipments where there is no preparation plant at the mine.

Table 2. Canada, coal production, imports, exports and consumption, 1967-77

	Production	Imports[1]	Exports	Domestic Consumption
		(tonnes)		
1967	10 107 248	14 618 547	1 214 133	22 667 217
1968	9 969 059	15 464 547	1 312 707	24 782 275
1969	9 681 366	15 737 300	1 249 984	23 999 872
1970	15 063 044	17 112 932	3 983 967	26 773 320
1971	16 721 410	16 452 867	7 015 963	25 627 819
1972	18 787 175	17 476 814	7 723 229	25 757 783
1973	20 472 755	14 830 511	10 907 717	24 870 489
1974	21 269 588	12 381 118	10 774 106	24 844 710
1975	25 258 956	15 254 906	11 694 655	26 126 654
1976[r]	25 476 044	14 585 002	11 761 930	28 219 804
1977[p]	28 681 759	15 438 717	12 386 550	30 895 999

Sources: Statistics Canada and Department of Energy, Mines and Resources, Ottawa.
[1] Coal imports for consumption from the United States and United Kingdom.
[p] Preliminary; [r] Revised.

consumption rates (of 22 million tonnes) and would allow coal to meet an increased share of Canada's energy requirements.

The production of coking coals is closely tied to the international steel industry, particularly that of Japan. This dependence on Japan is forecast to change somewhat as other markets develop in Asia, Latin America, Europe, and to some extent in central Canada. Although the current slow down in the growth of world coal trade is forecast to continue into the early 1980s, production of coking coals in Canada will increase throughout the next decade. Exports of coking coals from Nova Scotia have concentrated on European and Latin American markets. Shipments to Canadian steel companies have demonstrated the marketability of eastern coals in central Canada. Western Canadian coal properties have also attracted interest and some investment from the Canadian steel industry. The development of the unit train — lake freighter delivery system for thermal coals from western Canada to central Ontario may encourage the development of coking coal movements to central Canada.

Provincial and national coal policies and related developments

In June of 1977, British Columbia became the second province to release a coal policy. The policy is embodied in 11 policy statements which were put forward "to clarify for the industry and the public the basis upon which current and future development of the coal resource (of British Columbia) will be undertaken". Key points of the policy include: (1) commitment to the development of coal resources in a manner consistent with overall provincial energy, economic, environmental, regional development and social objectives; (2) commitment to the concept of meeting provincial coal needs first, followed by requirements of other provinces and finally export demand; (3) commitment to the use of provincial expertise and resources in coal developments; (4) commitment to development of multi-resource communities rather than single-resource or company communities; (5) support and encouragement for research and development programs and manpower-planning activities; (6) commitment to the philosophy that the coal industry be taxed at a rate similar to that applied to other industries; (7) retention of the existing $1.48 a tonne royalty on coking coal; (8) commitment to the philosophy that coal sold outside the province must be marketed at competitive world prices; and (9) commitment to the support and encouragement of programs related to initiation of alternative end uses and further processing of coal in the province.

The extent and quality of coal available in British Columbia has led to the development of a coking coal industry oriented towards the Japanese steel industry demands. Future developments, as outlined in the coal policy statement, will depend on thermal coal markets and on industrial fuel requirements, as well as on coking coal exports to Japan and elsewhere. British Columbia is expected to continue its investigation of thermal coal issues in relation to development of a provincial energy policy.

While Saskatchewan did not release a coal policy in 1977, it did complete the final stage in a process that will result in a coal policy announcement in 1978. The process began in 1971 with a joint Federal - Provincial study and assessment of the quantity and quality of the coal resources of southern Saskatchewan. In 1973, a moratorium was placed on the disposition of additional Crown coal rights and 1977 saw the passing of the Coal Conservation Act. The final stage in the process, leading to the development of a provincial coal policy, occurred in early 1977 with the completion of a coal development study. This internal study reviewed five subject areas: the provincial coal resource base; mining, transportation and conversion technology; provincial energy security of supply; economic benefits related to coal mining; and the impact that coal developments may have on other provincial resources. The aim of the study was to assess the potential for development of the province's coal resources as an imput into a coal policy statement.

Nova Scotia acted on several fronts to reduce its dependence on expensive imported oil and increase its use of provincial coal resources. In 1977 the provincial government announced that it was investigating the possible conversion of some of its oil-fired power plants to coal and that exploration programs for open-pit coal mines near Stellarton would be speeded up.

On the federal scene, a draft preliminary statement of a national coal policy was an agenda item at the Energy Ministers' Conference held in December in Ottawa. Further work on the development of a national coal policy has centered on the development of working papers in broad strategy areas. Consultations with provinces, industry and others are underway.

During 1977, the Department of Energy, Mines and Resources released the first in a series of publications that will ultimately provide an estimate of coal reserves in terms of their cost and availability. The publication entitled *1976 Assessment of Canada's Coal Resources and Reserves*, provides an updated estimate of Canada's coal deposits. Canada's reserves, which are defined as those resources that have "been reasonably well delineated and can be produced with current technology and delivered at competitive market prices", are conservatively estimated at 650 million tonnes of coking coal and 4.7 billion tonnes of thermal coal. Coal resources of immediate interest south of the 60th parallel of latitude were estimated at 28.9 billion tonnes in the measured category, 13.3 billion tonnes in the indicated category and 164.7 billion tonnes in the inferred category.

Two major agreements were signed in 1977 that provided $17.5 million for studies and investigations of

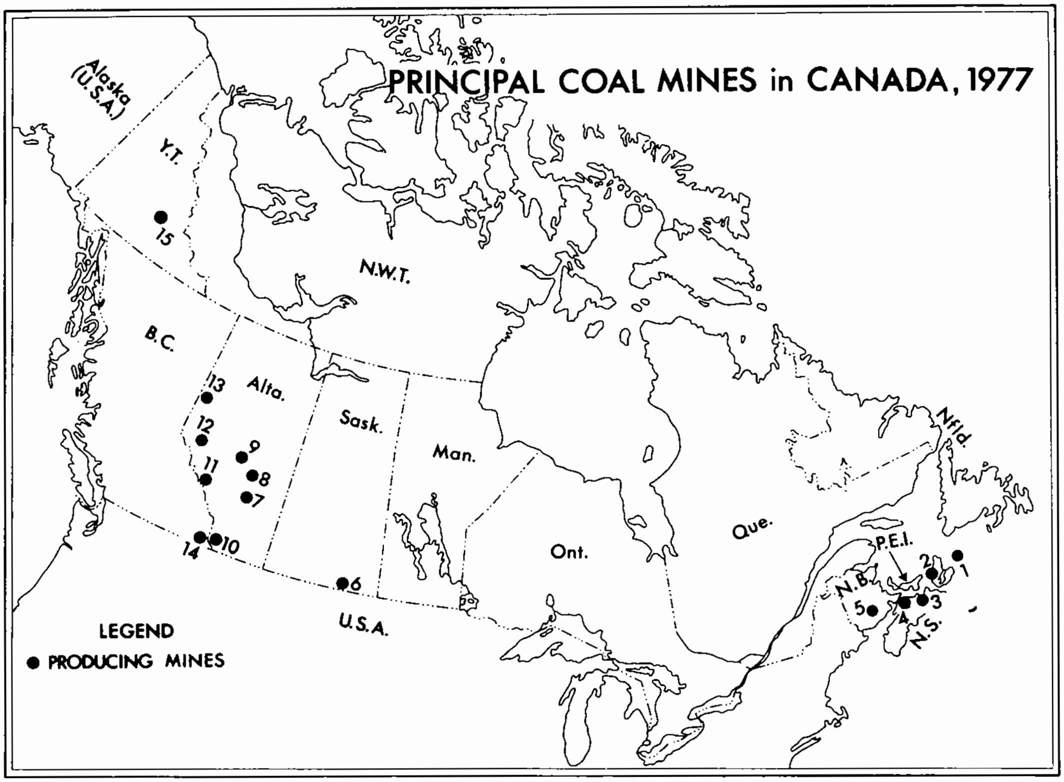


Table 3. Principal coal producers in 1977

Company and Mine Location	1977 Raw Coal Production[p]	Coal Rank	Chief Markets	Remarks
(numbers refer to the map above)	(000 tonnes)			
NOVA SCOTIA				
1. Cape Breton Development Corporation (DEVCO)				
Lingan Mine, Lingan	1 479	Hvb A	Power Generation	Underground
No. 26, Glace Bay Colliery	811	Hvb A	Metallurgical, Industrial, Domestic	Underground
Prince Mine, Point Aconi	205	Hvb A	Power Generation	Underground
Thomas Brogan Limited Florence	25		Power Generation Residential	Surface
2. Evans Coal Mines Limited St. Rose	32	Hvb B	Power Generation Residential	Underground

Table 3. (cont'd)

Company and Mine Location	1977 Raw Coal Production^p	Coal Rank	Chief Markets	Remarks
	(000 tonnes)			
NOVA SCOTIA (cont'd)				
3. Drummond Coal Company Limited Drummond Westville	14	Mvb & Hvb A	Power Generation	Underground
3. Thorburn Mining Limited Stellarton	44		Power Generation Residential	Underground
4. River Hebert Coal Company Limited	29	Hvb A	Power Generation	Underground
NEW BRUNSWICK				
5. N.B. Coal Limited Minto, Chipman areas	313	Hvb A	Power Generation Paper Mills	Surface, operates at six locations
SASKATCHEWAN				
6. Manitoba and Saskatchewan Coal Company (Limited) M&S Mine, Bienfait	555	Lig A	Power Generation Industrial	Surface
Boundary Dam Mine, Estevan	1 712	Lig A	Power Generation	Surface
6. Manalta Coal Ltd. Klimax Mine, Estevan	1 530	Lig A	Power Generation Industrial	Surface
6. Manalta Coal Ltd. Utility Mine, Estevan	1 385	Lig A	Power Generation	Surface
6. Saskatchewan Power Corp., Souris Valley Coal Mine, Estevan	296	Lig A	Power Generation	Surface, began production in Nov. 1976
ALBERTA				
Sub-bituminous Mines				
7. Century Coals Limited Atlas Mine, East Coulee	24	Sub B	Power Generation Residential	Underground
8. Manalta Coal Ltd. Roselyn Mine, Sheerness	422	Sub C	Power Generation	Surface
8. Manalta Coal Ltd. Vesta Mine, Halkirk	409	Sub C	Power Generation Domestic	Surface
8. Forestburg Collieries Limited Diplomat Mine, Forestburg	928	Sub C	Power Generation Domestic	Surface
9. Manalta Coal Ltd. Whitewood Mine, Wabamun	1 417	Sub A & B	Power Generation	Surface
Highvale Mine, Sundance	4 645	Sub C	Power Generation	Surface

Table 3. (concl'd)

Company and Mine Location	1977 Raw Coal Production[p]	Coal Rank	Chief Markets	Remarks
	(000 tonnes)			
ALBERTA (cont'd)				
Bituminous Mines				
10. Coleman Collieries Limited Vicary Creek, Coleman	170	Mvb	Japan for coke-making	Underground
Tent Mountain, Coleman	1 147	Mvb	Japan for coke-making	Surface
11. The Canmore Mines, Limited Canmore	122	An & Lvb	Japan for coke-making	Underground
12. Cardinal River Coals Ltd. Cardinal River Mine, Luscar	1 891	Mvb	Japan for coke-making	Surface
13. McIntyre Mines Limited Smoky River Mines, Grande Cache	1 760 1 387	Lvb	Japan for coke-making	Surface and Underground
BRITISH COLUMBIA				
14. Kaiser Resources Ltd. Michel Colliery, Natal	786	Lvb	Japan for coke-making	Underground (hydraulic mining, shortwall)
Harner Ridge Sparwood	5 988	Lvg	Japan for coke-making	Surface
14. Fording Coal Limited Fording Mine, Fording Valley	4 013	Lvb	Japan for coke-making	Surface
14. Byron Creek Collieries Limited, Corbin	366	Mvb	Ontario and Europe for steam generating	Surface
YUKON				
15. Cyprus Anvil Mining Corporation Carmacks Coal Mine, Carmacks	7	Hvb B	Anvil lead-zinc mine for heating and concentrate drying	Underground

Sources: Statistics Canada and Department of Energy, Mines and Resources, Ottawa.
An — Semi-anthracite; Lvb — Low volatile bituminous; Mvb — Medium volatile bituminous; Hvb — High volatile bituminous; Sub — Sub-bituminous; Lig — Lignite.
[p] Preliminary.

Table 4. Canada, coal production by rank, province and type of mining, 1977

	Production[1]	
	Underground	Surface
	(000 tonnes)	
Bituminous		
Nova Scotia	2 635	26
New Brunswick	—	313
Alberta	1 679	4 539
British Columbia	788	10 623
Sub-bituminous		
Alberta	29	7 872
Lignite		
Saskatchewan	—	5 479
Canada, 1977[p]	5 131	28 852
1976	4 654	25 935
Total, all mines		
1977[p]	33 983	
1976	30 589	

Sources: Statistics Canada and Department of Energy, Mines and Resources, Ottawa.
[1]Raw coal production only.
[p]Preliminary; — Nil.

coal resources in Canada. In May, the British Columbia and federal governments each agreed to contribute $5 million for feasibility studies of possible coal developments in British Columbia's Peace River coal field. This field is located northeast of Prince George and contains substantial deposits of good quality coking coals. The studies funded under this agreement were to review geological, mining, infrastructure, environmental, social and transportation issues related to the possible development of this coal in the 1980s. In addition to mine developments, production from this region would require major townsite, railroad and port infrastructure. The recent worldwide steel recession and the resulting surplus of coking coal has given both industry and government the opportunity to study all aspects on this development. A final decision with regard to rail, port and mine development must await firm contracts from overseas markets.

On Canada's east coast, Nova Scotia signed an agreement with the federal government for an offshore and onshore coal exploration program. The $7.5 million agreement, funded 80 per cent by the federal government and 20 per cent by Nova Scotia, allocated $6.5 million for offshore drilling to investigate the extent of coal in the Sydney Basin and $1 million for onshore drilling in Cumberland, Pictou, Inverness, Cape Breton, Richmond and Colchester countries. The program supports Nova Scotia's policy of developing its indigenous resources to replace expensive imported oil for electricity generation.

Production and mine development

British Columbia. Canada's most westerly province continued to lead all other provinces in production of coking coal in 1977. Raw coal production approached 11 million tonnes from three mines. Mapping, exploration and predevelopment work continued in several regions of the province, as potential producers prepared for the next expansion in coal demand expected to begin in the 1980s.

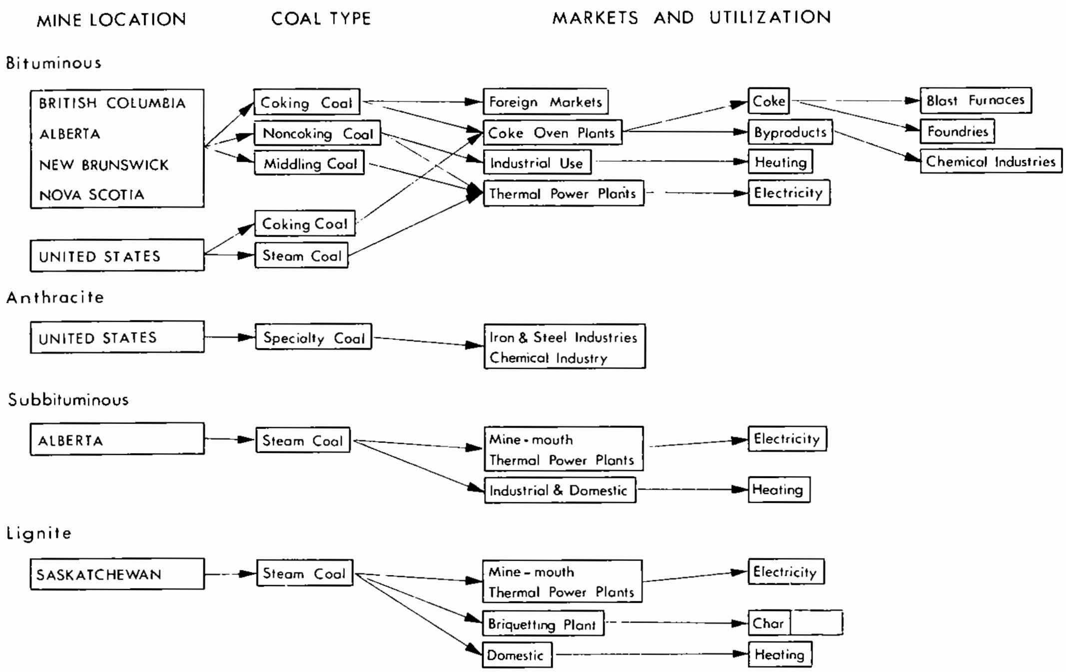
Kaiser Resources Ltd. remained British Columbia's largest producer with total raw coal output reaching 6.8 million tonnes, marginally down from its 1976 figure of 6.9 million tonnes. Output in 1977 from the Harmer Ridge surface mine approached 6.0 million tonnes, making it the largest single producing mine in Canada. The hydraulic Michel Colliery produced 0.8 million tonnes of raw coal. Hydraulic mining uses a high-pressure water jet to cut coal from the mine face and then hydraulically transports the coal to the surface by gravity or by mechanical pumps. Although this method is used only by Kaiser Resource Ltd. at the present, other potential applications are being investigated in western Canada.

Kaiser Resources Ltd. continued to market the majority of its coal to Pacific-rim countries in 1977. Clean coal shipments to Japan approached 4.3 million tonnes in 1977, with other markets receiving 0.7 million tonnes. This latter figure represented a 40 per cent increase over 1975 levels. Kaiser Resources concluded new long-term sales contracts for coking coals in 1977 with Pakistan and Brazilian customers and increased the volume of its South Korean contract. The eight-year contract with The Pohang Iron & Steel Company, Ltd. was expanded to 6.1 million tonnes from the 3.8 million tonnes contracted under the previous agreement. The new contract is to run from 1977 to 1985. In addition to the above markets, sales were made to Mexico, Argentina and Denmark.

During the year a feasibility study of the proposed 2 million-tonne-a-year Hosmer Wheeler underground mine was completed. This project involved Kaiser Resources Ltd., Mitsubishi Corporation, Mitsui Mining Co. Ltd. (Tokyo) and Companhia Vale do Rio Doce (Brazil). Weak steel markets and the resulting soft demand for coking coal was the main reason behind the decision not to develop the mine at this time.

Fording Coal Limited produced 4.0 million tonnes of raw coal in 1977 and 2.8 million tonnes of saleable clean coal. As in former years, Fording marketed the majority of its coal to Japan. In 1977, 2.3 million tonnes of clean coal were shipped to Japanese customers and 23 000 tonnes marketed to Argentina. Although increased production is dependent on developments in metallurgical and thermal coal markets, Fording un-

COAL'S ROUTE TO CONSUMPTION



dertook exploration and other work in 1977 related to possible expansions of production capacity for the 1980s.

Byron Creek Collieries Limited is the other major-producing mine in British Columbia. Raw coal production reached 366 000 tonnes in 1977, up slightly from 1976. Ontario Hydro received 186 000 tonnes, while other markets included smelters in British Columbia and Manitoba and the Japanese steel industry. During 1977 Byron Creek worked on infrastructure and mine-related facilities that will eventually allow production to reach the million tonne a year level. Facilities under construction included 20 kilometers (km) of rail line, 12 km of powerline and a new coal-cleaning plant. These additions are to be completed by 1978 when major movements of coal will begin through the new terminal at Thunder Bay for transshipment down the Great Lakes to Ontario Hydro generating stations on Lake Erie. Byron Creek is under contract to supply nearly 700 000 tonnes a year to Ontario Hydro.

While there were no other major producers in British Columbia in 1977, exploration, leasing, feasibility studies and preproduction work were underway in several areas of the province on coal properties that may come into production in the next few years. In northeastern British Columbia several companies were involved in work on coal properties and leases in the Peace River coalfield.

Some of the companies involved in work during 1977 in this area included: Brameda Resources Limited, which had interests in the Bullmoose, Burnt River and Mount Spieker coal properties; Brascan Resources Limited (Sukunka); The British Petroleum Company Limited (Bullmoose, Chamberlain and Sukunka); Cinnabar Peak Mines Ltd. (Cinnabar Peak); Denison Mines Limited (Belcourt, Quintette and Saxon); Imperial Oil Limited (Quintette); Norco Resources Ltd. (Bowron River); Pan Ocean Oil Ltd. (Pine Pass); and Utah Mines Ltd. (Carbon Creek).

Decisions with regard to production in northeastern British Columbia depend on firm contracts with coking coal customers and on provision of the necessary townsite, transportation and port infrastructure. Studies on the infrastructure required for such a major development began in 1977 under a joint federal-provincial program and will continue in 1978. Major movements of coal from this area are unlikely to begin before the early 1980s.

In the south-central part of the province, two potential mining properties received attention in 1977. British Columbia Hydro and Power Authority's Hat Creek minesite was the centre of considerable drilling and trenching work, with further work planned for 1978. To the southeast, Cyprus Anvil Mining Corporation undertook exploration work at its Tulameen property. Further west on Vancouver Island, Weldwood of Canada Ltd. carried out work on its Quinsam property near Campbell River.

British Columbia's other major area of exploration and development is the southeastern corner of the province. In addition to those properties now in production, several new leases are under active investigation. Companies involved in this work include: Elco Mining Limited, The Steel Company of Canada, Limited, Home Oil Company Limited and Scurry-Rainbow Oil Limited, on the Elk River coal property; Rio Algom Limited and Pan Ocean Oil Ltd., on the Sage Creek property; and as of February 1978, Shell Canada Resources Limited, on the Line Creek property. These projects, as with all western Canadian coking coal projects, are currently constrained by lack of demand and long-term contracts.

Yukon and Northwest Territories. Although lacking the infrastructure and market opportunities available south of the 60th parallel of latitude, the coal resources in Canada's northern jurisdictions are beginning to receive more attention. Cyprus Anvil Mining Corporation's Tantalus Bulte Mine at Carmacks, Yukon Territory is Canada's northernmost coal mine. Production in 1977 was 7 732 tonnes, down from 27 000 tonnes in 1976, as the company ran down its stockpile and deferred production from its surface operations. Exploration work was underway or under consideration by several companies, including Pan Ocean Oil Ltd. and Phoenix Canada Oil Company Limited.

Alberta. In terms of total production, Alberta is Canada's leading coal-producing province. Output in 1977 was 12.2 million tonnes composed of 7.9 million tonnes sub-bituminous and 4.3 million tonnes bituminous coal. Most of Alberta's sub-bituminous coal is used to generate electricity in thermal power stations, while the majority of the bituminous coal is exported to Japanese steel industry producers.

McIntyre Mines Limited was Alberta's largest coking coal producer in 1977, with raw coal output reaching 3.1 million tonnes, just down from the 1976 output of 3.2 million tonnes. Raw coal production from surface operations was 1.7 million tonnes and output from underground operations was approximately 1.4 million tonnes.

During 1977, No. 2-4 and 2A-4 Mines were depleted and closed. Expansion and depillaring operations in the No. 2R-4 Mine (Reiff Terrace) and development

Table 5. Producers' disposition of Canadian coal[1], 1977

	Originating Province					
Destination	Nova Scotia	New Brunswick	Saskatchewan	Alberta	British Columbia and Yukon	Canada
			(000 tonnes)			
Railways in Canada	—	—	55	—	—	55
Newfoundland	2	—	—	—	—	2
Prince Edward Island	13	—	—	—	—	13
Nova Scotia	945	3	—	—	—	948
New Brunswick	45	173	—	—	—	218
Quebec	58	102	—	—	—	160
Ontario	458	—	53	75	186	772
Manitoba	—	—	1 358	12	62	1 432
Saskatchewan	—	—	4 008	424	—	4 432
Alberta	—	—	—	7 443	—	7 443
British Columbia	—	—	—	8	220	228
Total Canada	1 521	278	5 474	7 962	468	15 703
United States	—	—	2	—	—	2
Japan	—	—	—	3 940	6 711	10 651
Other	630	—	—	44	1 059	1 733
Total shipments	2 151	278	5 476	11 946	8 238	28 089

Sources: Statistics Canada and Department of Energy, Mines and Resources, Ottawa.
[1]Saleable coal (includes clean coal which has been through a preparation plant, raw coal which has not been through a preparation plant and middlings coal).
— Nil.

Table 6. Canada, exports and imports of coal, 1976 and 1977

	1976r		1977p	
	(000 tonnes)	($ 000)	(000 tonnes)	($ 000)
Exports				
Japan	10 813	580 893	10 651	607 479
South Korea	297	16 035	357	20 586
West Germany	287	6 550	315	9 096
Denmark	227	5 854	382	12 509
France	82	1 759	26	721
Sweden	54	1 156	54	2 397
Mexico	51	2 704	178	9 433
United States	2	30	4	34
United Kingdom	20	526	—	—
Romania	—	—	52	2 748
Belgium	—	—	81	4 608
Brazil	—	—	197	10 264
Argentina	—	—	25	1 336
Italy	—	—	65	2 925
Others	24	600	—	—
Total	11 857	616 107[1]	12 387	684 361[1]
Imports				
Anthracite and Bituminous	14 622	636 473	15 439	772 000

Source: Department of Energy, Mines and Resources, Ottawa.
[1] Value at port of export.
p Preliminary; r Revised; — Nil.

of new blocks in the Smoky River and Sheep Creek drainage areas replaced production from the two closed mines. In the latter part of the year the Alberta Energy Resources Conservation Board approved a long-range mining and reclamation plan that covered approximately 65 million tonnes of recoverable coal.

While the Japanese steel industry continued to take the majority of McIntyre's production, several other customers and the H.R. Milner Generating Plant at Grande Cache also received McIntyre coal. Domestic consummers included Dominion Foundries and Steel, Limited, The Steel Company of Canada, Limited and the Sydney Steel Corporation. These consumers received 48 000, 36 000 and 26 000 tonnes respectively; the Brazilian Steel Company, Usiminas, received over 21 000 tonnes. Sales to Japan were 1.4 million tonnes and 205 000 tonnes were sold to the local Alberta Power Limited generating station.

The Luscar Ltd., Cardinal River Mine No. 1768 was the second-largest coking coal producer in Alberta in 1977. Raw coal output reached 1.9 million tonnes, down from 2.3 million tonnes in 1976. While almost all of the current production is marketed to Japan, new markets were developed during 1977. The Pohang Iron and Steel Company of Seoul will take an initial 100 000 tonnes in 1978. This will increase to 200 000 tonnes annually and continue until 1985.

Coleman Collieries Limited produced approximately 1.3 million tonnes of raw coal in 1977, down marginally from 1.4 million tonnes in 1976. All of Coleman's production is marketed to Japanese steel mills. During 1977 a new three-point agreement was signed providing for price escalation and volume commitments for 1977 through 1980. Volume under the new agreement will be approximately 800 000 tonnes in 1977-78 and 1 000 000 tonnes in both 1978-79 and 1979-80.

The Canmore Mines, Limited is Alberta's smallest coking coal mine and in 1977 produced 114 000 tonnes of raw and 90 000 tonnes of clean semi-anthracite coal. Virtually all of this was marketed to Japan. During 1977 some exploration and development work was underway in the Wind Valley area and at the Riverside Mine.

The majority of the sub-bituminous coal produced from the Plains Region of Alberta is consumed at mine-mouth thermal power stations. Other thermal coal is exported to Saskatchewan and Ontario. Most of

Table 7. Canada, supply and demand of coal, 1966 and 1976

	1966	1976
	(000 tonnes)	
Supply		
Production	10 334	25 476
Landed imports	14 815	14 603
Total inventory change	+900	+620
Total supply	24 249	39 459
Demand		
Domestic sales		
Electric utilities	7 148	19 045
Mining and manufacturing	6 944	901
Coke-making	5 327	7 389
Subtotal	19 419	27 335

	1966	1976
	(000 tonnes)	
Demand		
Residential	1 594	–
Railways	192	59
Ships bunkers	372	29
Government and institutional	153	–
Subtotal	2 311	88
Coal mine and local use	605	175
Unaccounted for coal	800	622
Total domestic demand	23 135	28 220
Exports	1 115	11 857
Total demand	24 250	40 077

Sources: Statistics Canada and Department of Energy, Mines and Resources, Ottawa.
– Nil.

Alberta's thermal quality coal is consumed by Calgary Power Ltd. and Alberta Power Limited at five generating stations.

The Highvale Mine produced 4.6 million tonnes of raw coal for the Sundance power generating station in 1977, up from 2.6 million tonnes in 1976. Output from this strip-mining operation should increase substantially when the fifth and sixth units at the Sundance generating station come on stream by 1980. The Highvale Mine is Alberta's largest mine and could be the largest in Canada when output approaches 8.0 million tonnes in the next few years. Production at the nearby Whitewood mine declined to 1.2 million tonnes in 1977, down from 2.1 million tonnes in 1976. During 1977 work began on the erection of a new 45-cubic metre (m^3) dragline to replace existing equipment. The new dragline will be in operation in 1979.

In the Forestburg-Halkirk region, the Manalta Coal Ltd. (Vesta Mine) and Forestburg Collieries Limited (Diplomat Mine) produced coal for thermal power station use and other markets. Production at the Vesta Mine was 409 000 tonnes in 1977, down from 533 000 tonnes in 1976. Production capacity will be increased at this mine by the replacement of the current 11-m^3 dragline with a new 45-m^3 dragline. Output at the Diplomat Mine increased by 27 per cent in 1977 to 928 000 tonnes, reflecting increased consumption of coal for electricity generation.

Output at Manalta's Roselyn Mine near Sheerness increased by 16 per cent to 422 000 tonnes in 1977, with all but 7 000 tonnes marketed to the Saskatchewan Power Corporation's Queen Elizabeth generating station in Saskatoon.

Exploration and preliminary development work continued in Alberta, although no new mines came on stream in 1977. Work continued at the Luscar Sterco Ltd. Coal Valley project west of Edmonton. This mine about 65 km southwest of Edson will begin to market coal in 1978, with production of 2.0 million plus tonnes scheduled for the 1980s. The Coal Valley operation has a 15-year contract with Ontario Hydro.

Throughout much of 1977, discussions were underway between Gregg River Resources Ltd., owned by Manalta Coal Ltd., and Japanese steelmakers over a proposed new mine south of Hinton. Further development of this property must await improved world steel markets. Other potential coal mines receiving attention in Alberta included the Judy Creek project of Imperial Oil Limited, which is considering the use of coal in the upgrading of its Cold Lake heavy oils project; the newly proposed Forestburg Collieries; the Hudbay Coal Company's Fall Creek property and others.

Saskatchewan. The major coal deposits of Saskatchewan are concentrated in the Southern region of the province, although deposits also occur in central Saskatchewan. Current production originates from five mines in the Estevan-Bienfait region. Production of clean or saleable coal was 5.5 million tonnes in 1977, up 17 per cent from 1976. Approximately 20 per cent of the provincial output was marketed outside the province, primarily to Manitoba for the generation of electricity. Nearly 1 million tonnes of lignite coal were used by The Manitoba Hydro Electric Board (Manitoba Hydro) to compensate for a second year of reduced electricity output from hydro sources. Over 4 million tonnes of lignite were delivered to power stations within Saskatchewan for electricity generation.

Production from the Boundary Dam Mine and the Utility Mine, both near Estevan, increased by approximately 12 per cent to 1.7 and 1.4 million tonnes respectively. The nearby Souris Valley Mines, owned by the Saskatchewan Power Corporation, produced approximately 296 000 tonnes of coal in its first full year of operation. Output from the Klimax Mine, to the north of Bienfait, rose to 1.5 million tonnes, up 34 per cent from 1976, while production at the M&S Mine, south of Bienfait, fell 27 per cent to 555 000 tonnes.

Output of coal will increase in Saskatchewan in the next few years when a new mine and thermal power facility become operational and as deliveries begin to the expanded Ontario Hydro station at Thunder Bay. The new mine, near Coronach, will supply the Poplar River power project with 2 million tonnes of coal annually. Production of coal for the Thunder Bay station will be approximately 1 million tonnes a year and will come from the Bienfait Mine.

New Brunswick. All of the coal produced in New Brunswick in 1977 came from the Grand Lake coal basin the Minto-Chipman area of eastern New Brunswick, where high-volatile bituminous coal is produced by a provincial Crown corporation, N.B. Coal Limited. Total raw coal production in 1977 was 313 000 tonnes, down from 430 000 tonnes in 1976. The 1977 production was sold to the New Brunswick Electric Power Commission, which received 168 000 tonnes; to industrial markets in Quebec, which received 102 000 tonnes; and to industrial-commercial markets in New Brunswick, which received the remaining 43 000 tonnes.

Work on the new coal mine near Salmon Harbour continued, with start up scheduled for mid-1979. Work on erection of the new 50-m^3 dragline was about half complete. Production from this mine will eventually be consumed at both the Grand Lake and the soon to be completed Dalhousie power plants.

Table 8. Provincial coal royalties in Canada

Province	Effective Date	Terms
Nova Scotia	1975	$0.28 a tonne
New Brunswick	1968	$0.15 a tonne
Saskatchewan	1957	$0.06 a tonne
Alberta	July 1/76	Royalty is determined by a formula based on annual costs of production, annual gross revenue, and allowed cumulative investment, including working capital
British Columbia	1975	$1.48 tonne, metallurgical grade $0.74 tonne, thermal grade
Yukon and Northwest Territories	1965	lease: $0.11 tonne permit: $0.28 tonne

Source: Energy Policy Sector; Department of Energy, Mines and Resources, Ottawa.

Nova Scotia. Nova Scotia's medium and high-volatile bituminous coal is found in, and off, Cape Breton Island and in the northern part of the mainland. Much of the coal contained in the productive Sydney coalfield is located offshore. Coalfields on the west coast of Cape Breton Island also lie both onshore and offshore. The mainland coalfields of Pictou, Springhill and Joggins have been mined extensively in the past but still contain mineable reserves.

Production in Nova Scotia reached 2.7 million tonnes of raw coal in 1977, up 15 per cent from 1976. Approximately 93 per cent (2.5 million tonnes) of this was produced by the three mines of the Cape Breton Development Corporation (Devco). Output increased at the Lingan Mine, No. 26 Colliery and the Prince Mines, with production reaching 1 479 000; 811 000 and 205 000 tonnes respectively. During 1977 output in the 4-East longwall operation at Lingan produced a record of nearly 6 000 tonnes of clean coal in one three-shift period. Production at the Prince Mine, which began operation in 1976, increased by approximately 25 per cent in 1977 to 205 000 tonnes, while output from No. 26 Colliery at Glace Bay remained virtually unchanged from 1976 levels.

Approximately 1.3 million tonnes of saleable clean coal were produced from the 1.6 million tonnes of raw coal processed during the first full year of operation at the Victoria Junction Preparation Plant. Of this 1.3 million tonnes, 1.1 million tonnes represented coking coal and 0.2 million tonnes thermal coal.

Devco looked within and beyond Nova Scotia's borders for both thermal and coking coal markets in 1977. Coking coal was sold to two steel companies in central Canada, to the Sydney Steel Corporation and to steel companies in Europe and Latin America. Thermal coal went to the Nova Scotia Power Corporation and countries in Europe. This trend to market diversification will continue.

Five other small mines produced another 144 000 tonnes of coal in 1977, the majority of which was marketed for power generation and residential use. During 1977 the Nova Scotia government acquired some near-surface coal deposits in Cape Breton and began, in conjunction with the Federal Government, a drilling program to proveup further thermal coal reserves in line with an announced program to use domestically-produced coal rather than imported oil for power generation.

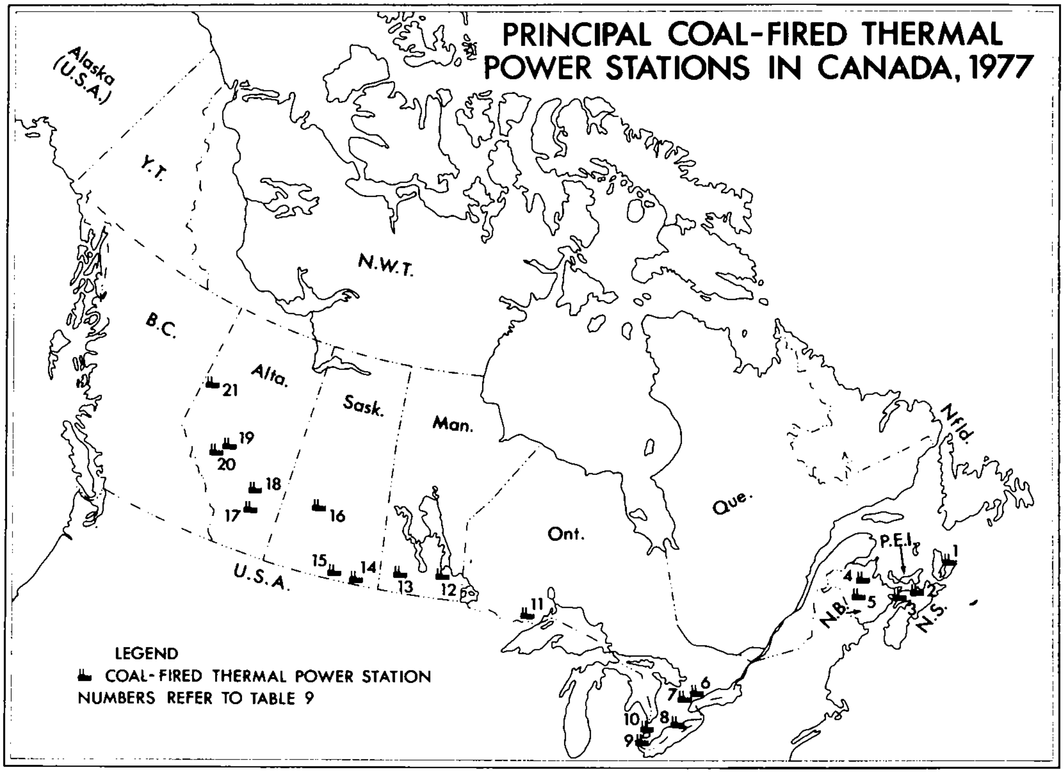


Table 9. Principal coal-fired thermal power stations in Canada, 1977

Utilities	Station	Total Station Capacity	Remarks
(numbers refer to map above)		(kilowatts)	
Nova Scotia			
1. Nova Scotia Power Corporation	Glace Bay	111 000	
2. Nova Scotia Power Corporation	Trenton	210 000	
3. Nova Scotia Power Corporation	Harrison Lake	25 000	
New Brunswick			
4. New Brunswick Electric Power Commission	Chatham	32 500	
5. New Brunswick Electric Power Commission	Grand Lake No. 1	13 750	
New Brunswick Electric Power Commission	Grand Lake No. 2.	85 000	
Ontario			
6. Ontario Hydro	Richard L. Hearn	1 222 500	
7. Ontario Hydro	Lakeview	2 422 500	
8. Ontario Hydro	Nanticoke	3 022 500	Two 500 MW units to be added by 1978.

Table 9. (concl'd)

Utilities	Station	Total Station Capacity	Remarks
(numbers refer to map above)		(kilowatts)	
Ontario (cont'd)			
9. Ontario Hydro	J. Clark Keith	271 500	Station was closed down in early 1976 for modification and renovation; on stream in 1980.
10. Ontario Hydro	Lambton	2 022 500	
11. Ontario Hydro	Thunder Bay	128 300	Two 150 MW lignite-fired units to be added by 1980.
Manitoba			
12. Manitoba Hydro	Selkirk	155 800	
13. Manitoba Hydro	Brandon	237 000	
Saskatchewan			
14. Saskatchewan Power Corporation	Estevan	70 000	New 300 MW Poplar River Power station to come on stream 1980.
15. Saskatchewan Power Corporation	Boundary Dam	875 000	
16 Saskatchewan Power Corporation	Queen Elizabeth	232 000	
Alberta			
17. Alberta Power Limited	Drumheller	15 000	
18. Alberta Power Limited	Battle River	362 000	One 375 MW-addition scheduled for 1979.
19. Calgary Power Ltd.	Wabamun	582 000	
20. Calgary Power Ltd.	Sundance	1 350 000	Two 375-MW units to be added by 1981.
21. Alberta Power Limited	H.R. Milner	150 000	Burns coal preparation plant byproducts.

Source: Statistics Canada.

Table 10. Coal used by thermal power stations in Canada by province, 1962-77

	Nova Scotia	New Brunswick	Ontario	Manitoba	Saskatchewan	Alberta	Total Canada
			(000 tonnes)				
1962	467	110	1 354	101	1 024	323	3 379
1963	484	97	2 547	60	956	528	4 672
1964	530	222	2 795	132	1 006	999	5 684
1965	633	334	3 567	175	1 085	1 211	7 005
1966	799	294	3 500	79	1 116	1 360	7 148
1967	758	275	4 435	38	1 334	1 427	8 267
1968	646	240	5 523	179	1 354	2 128	10 070
1969	676	150	6 424	51	1 123	2 378	10 802
1970	548	113	7 696	503	1 969	2 951	13 780
1971	689	271	8 560	446	1 996	3 653	15 615
1972	663	281	7 599	410	2 145	4 113	15 211
1973	585	193	6 615	386	2 806	4 474	15 059
1974	606	292	6 721	132	2 902	4 771	15 424
1975	571	248	6 834	323	3 251	5 345	16 572
1976	730	207	7 612	979	3 521	5 996	19 045
1977[p]	572	198	8 795	1 113	4 304	7 461	22 443

[p]Sources: Statistics Canada and Department of Energy, Mines and Resources, Ottawa.

Trade and exports

Exports. Like many other coal-exporting countries Canada continued to feel the effects of the global steel recession and a reduced demand for coking coals. Exports reached 12.4 million tonnes, up 4 per cent over 1976 shipments of 11.9 million tonnes. Coking coals continued to make up over 90 per cent of all coal exports, with Japan receiving over 90 per cent of the coking coal exported. Thermal coal exports approached the million tonne level with the majority sold to European customers.

The total value of exports reached $684 million, up 11 per cent from $616 million in 1976. The average value per tonne of coal exported in 1977 was $55.25, up from $51.97 the year before. British Columbia and Alberta were the leading provinces in terms of volume and value of exports, although exports were also a significant part of Nova Scotia's coal industry.

Japan remained the major consumer of Canadian exports taking 10.6 million tonnes of coal in 1977, down from 10.8 million tonnes in 1976. Exports of coking coal to Japan are expected to remain depressed until the recovery of the Japanese steel industry, now predicted for the early 1980s. The development of contracts between Canadian coal producers and South Korean and Brazilian steel companies reflected the growth in steel production capacity among developing countries. Canadian coal producers will be looking to these, as well as the Japanese and European steel markets, to provide the impetus for increased coking coal production in the 1980s.

Coking coals are expected to continue to be the main element in Canada's export trade, but thermal coal exports are predicted to become more prominent over the next decade. Markets in Asia and Europe are developing, and forecasts suggest that Canadian coals could be competitive in these markets.

In 1977 Canada exported approximately 900 000 tonnes of thermal coal, representing 7 per cent of total coal exports. All of this coal was marketed in Europe, primarily in Germany, Denmark and France. These exports originated in both western and eastern Canada, and although Nova Scotia will continue to market some thermal coal in Europe, the majority of future thermal coal exports will originate in western Canada.

Imports. Imports of coal totalled 15.8 million tonnes in 1977, up 8 per cent from 14.6 million tonnes in 1976. Over 99 per cent of imports came from the United States, with the remainder coming from Poland. Approximately 15.4 million tonnes of bituminous coal were imported in addition to 356 000 tonnes of anthracite.

Ontario Hydro imported 8.8 million tonnes of coal in 1977, up from 6.9 million tonnes in 1976, and Canadian steel companies imported 6.0 million tonnes, down from 6.7 million tonnes in 1976. Imports for general industry and other uses in 1977 decreased to 1 million tonnes from 1.4 million tonnes in 1976.

Imports from the United States are expected to grow slowly over the next few years. Ontario Hydro estimates that it could be consuming between 13 and 14 million tonnes of coal in the 1980s. Beginning in 1978, Ontario Hydro will receive western Canadian coal shipments, which by the mid-1980s will total nearly 4 million tonnes. Steel companies and other industrial users in central Canada are likely to continue to rely on coal imported from the U.S. for the majority of their coal requirements. Nevertheless, such consumers will continue to evaluate western Canadian coal in relation to United States imports and other sources when looking for additional supplies.

Thermal power industry

Consumption of coal for the generation of electricity increased to 22.4 million tonnes in 1977, up 18 per cent from 19.0 million tonnes in 1976. Approximately 40 per cent of the coal used to generate electricity came from the United States, the remaining 60 per cent was produced in Canada. Ontario, Manitoba, Saskatchewan and Alberta recorded increased thermal coal consumption in 1977, while Nova Scotia and New Brunswick consumed less.

Ontario Hydro is constructing one, and considering another, thermal generating station that will burn western Canadian coal. The former, the new 300 megawatt extension of the existing Thunder Bay station, will be in service by 1981. The second station, in northwestern Ontario at Atikokan, is tentatively scheduled to come on stream in the mid-1980s. To facilitate delivery of western Canadian coal to these stations and to supply coal to new units at Nanticoke, Ontario Hydro recently became involved in the development and upgrading of a coal delivery system to eastern Canada. The system involves new and expanded mines in western Canada; an upgraded rail route; a new $60 million coal bulk terminal at Thunder Bay; development of a lake vessel system to move the coal through the Great Lakes; and new blending facilities at the Nanticoke station on Lake Erie. The complete system will cost over $400 million and will facilitate delivery of at least 4 million tonnes of coal to existing and new thermal-powered generating stations in Ontario by the early 1980s.

The consumption of coal for the generation of electricity also continued to grow in Alberta during 1977, reaching 7.5 million tonnes, up 24 per cent over the 1976 level of 6.0 million tonnes. The consumption of coal will continue to grow as expansions to existing facilities are completed and when new stations come on stream in the 1980s.

Work was underway on the expansion of two coal-fired facilities in Alberta in 1977. Two new 375-megawatt units will be commissioned by Calgary Power Ltd. at its Sundance power plant west of Edmonton in 1978 and 1980. To the south and east, a fifth 375-megawatt unit is scheduled to begin service in 1981 at the Battle River Power station of Alberta Power Limited.

Table 11. Coke oven and other carbonization plants in Canada

Company	Operating Batteries and No. of Ovens	Oven Type	Year Built	1977 Coal Feed	1977 Coke Production	Byproducts
				(000 tonnes/year)		
The Algoma Steel Corporation Limited, Sault Ste Marie, Ontario	No. 5 — 86	Koppers-Becker Underjet	1943	1 800	1 294	Tars, light oil, gas
	No. 6 — 57	Koppers-Becker Underjet	1953			
	No. 7 — 57	Wilputte Underjet	1958			
	No. 8 — 60	Wilputte Underjet	1967			
The Steel Company of Canada Limited, Hamilton, Ontario	No. 3 — 61	Wilputte Underjet	1947	2 817	1 750	Tars, gas, light oil, anhydrous ammonia
	No. 4 — 83	Wilputte Underjet	1952			
	No. 5 — 47	Wilputte Underjet	1953			
	No. 6 — 73	Otto Underjet	1967			
	No. 7 — 83	Otto Underjet	1972			
Dominion Foundries and Steel Limited, Hamilton, Ontario	No. 1 — 25	Koppers-Becker Gun Type Comb	1951	1 535	1 235	Tars, light oil, gas, sulphur, ammonium sulphate
	No. 2 — 35	Koppers-Becker Gun Type Comb	1956			
	No. 3 — 45	Koppers-Becker Gun Type Comb	1958			
	No. 4 — 53	Koppers-Becker Gun Type Comb	1967			
	No. 5 — 53	Koppers-Becker Gun Type Comb	1971			
Sydney Steel Corporation, Sydney, Nova Scotia	No. 5 — 53	Koppers-Becker Underjet	1949	333	217	Tars, light oil, gas
Kaiser Resources Ltd. Natal, British Columbia	10 units	Curran-Knowles	1943	151	96	Crude tar, gas, coke breeze
	16 units	Curran-Knowles	1949			
	16 units	Curran-Knowles	1952			
Manitoba and Saskatchewan Coal Company (Ltd.) Char Briquetting Div. Bienfait, Saskatchewan	2 units	Lurgi carbonizing retort	1925	97	55 (chart)	Tar
	1 unit	Salem Rotary Hearth Calciner				
Gaz Metropolitain, inc. Ville la Salle, Quebec	No. 1 — 59	Koppers-Becker	1928	95	71	Tars, light oil, gas
	No. 2 — 15	Koppers-Becker	1947			

Source: Department of Energy, Mines and Resources, Ottawa.

Table 12. Canada, coke production and trade, 1976 and 1977

	1976		1977^p	
	(tonnes)	($)	(tonnes)	($)
Production				
Ontario	4 751	*	4 445	*
Other provinces	538	*	400	*
Total	5 289	*	4 845	*
Imports				
United States	272	25 665	343	40 687
West Germany	10	1 136	33	2 761
France	5	506	7	945
United Kingdom	—	—	—	—
Total	287	27 307	383	44 393
Exports				
United States	78	4 452	155	10 305
West Germany	27	928	27	1 284
Netherlands	65	2 344	17	598
Total	170	7 724	199	12 187

Sources: Statistics Canada and Department of Energy, Mines and Resources, Ottawa.
*Practically all coke production is used by producers in the iron and steel industry and is not given a value.
^{p}Preliminary; — Nil; . . . Insignificant.

Several major new thermal-powered generating stations are under consideration in Alberta for the 1980s. Late in the year, the Calgary Power Ltd.'s 750 megawatt Keephills generating station and related coal mine development received approval from the Alberta Energy Resources Conservation Board. This new station will be located just south of the existing Sundance station and will consume in excess of 3 million tonnes of coal annually when fully operational. Two other new thermal-coal generating facilities are under consideration for the late 1980s. The Alberta Power Limited's 750-megawatt facility at Sheerness in southern Alberta could come on stream in the mid 1980s. A third 750-megawatt station has been proposed by Edmonton Power, at Genesee southwest of Edmonton, for the late 1980s.

In 1977, a sixth coal-fired unit was installed at the Saskatchewan Power Corporation's Boundary Dam Station. The addition of this 300-megawatt unit brings total station capacity to 875 megawatts. To the west, work continued on a 300-megawatt unit at the new Poplar River power station. The new coal mine and power station are scheduled to be in operation in 1979, with a second 300-megawatt unit under consideration for 1982.

Manitoba consumed a record 1.1 million tonnes of coal in 1977, up from the 979 000 tonnes in 1976. This unusually large consumption of coal, for a second year, again reflected low water conditions and reduced hydroelectric generation within the province. It is expected that 1978 consumption of coal will return to the more normal level of approximately 300 000 tonnes.

Consumption of coal declined by 5 per cent in New Brunswick in 1977 because of better-than-average water flows and increased generation of electricity from hydro sources. Total coal consumption was 198 000 tonnes, down from 207 000 tonnes in 1976. Consumption will more than double when the new 200-megawatt, coal- and oil-fired, generating station comes on stream at Dalhousie in 1979.

Above normal precipitation and high water flow, in addition to the availability of low cost energy through interprovincial connections, contributed to the reduced consumption of coal in Nova Scotia in 1977. The Nova Scotia Power Corporation consumed 572 000 tonnes of coal in 1977, down 22 per cent from 730 000 tonnes the year before. However, coal consumption will increase by significant amounts when the new Lingan coal-fired generating station becomes operational. The first 150-megawatt unit will be completed in 1979, with the second 150-megawatt unit scheduled for completion in 1981. Each unit will consume approximately 350 000 tonnes of coal. A decision to build two additional 150-megawatt units in the 1980s would increase provincial thermal coal requirements to approximately 2 million tonnes a year.

Coke industry

In 1977, 5.8 million tonnes of bituminous coking coal were carbonized to produce 4.8 million tonnes of coke, a decline from the 1976 figures of 6.6 and 5.3 million tonnes respectively. The majority of the coking coal imported into Canada was used by the three Ontario iron and steel companies and the Sydney Steel Corporation in Nova Scotia.

Canada imported about 4.9 million tonnes, or 85 per cent of the bituminous coal used to produce coke in 1977. The remainder came from Nova Scotia and western Canadian coal mines. Long-term contracts, blending practices, equity holding in United States coal mines, and geographical separation of producing and consuming areas have, in the past, restricted the use of western and eastern Canadian bituminous coals in Ontario. However concern over long-term-pricing trends; development of a coal transfer facility at Thunder Bay; and a desire to diversify supply sources have helped to make both eastern and western Canadian coking coals more attractive in recent years. Thus, while the United States will remain the major source of coking coal in the future, Canada's coal reserves will assume increasing importance.

The Algoma Steel Corporation, Limited (Algoma) of Sault Ste Marie produced 1.29 million tonnes of coke from 1.8 million tonnes of dry coking coal in 1977. All of Algoma's coking coal originated in the United States in 1977. The No. 9 coke oven battery, which was shut down in 1976 because of technical problems, did not operate during 1977.

The Steel Company of Canada, Limited (Stelco), at Hamilton, produced 1.75 million tonnes of coke from 2.8 million tonnes of coking coal. Stelco imported 90 per cent of its coking coal requirements from the U.S.; the remaining 10 per cent was obtained from eastern Canada. Construction of Stelco's new Nanticoke iron and steel facility continued throughout 1977, with initial production scheduled for 1980.

Dominion Foundries and Steel, Limited (Dofasco) of Hamilton produced 1.24 million tonnes of coke from 1.54 million tonnes of coking coal. Dofasco purchased 91 per cent of its coking coal from the U.S., 6 per cent from western Canada and 3 per cent from eastern Canada. Construction of Dofasco's No. 6 coking battery continued during 1977. Start up in 1978 should increase Dofasco's coke production by 400 000 tonnes.

Sydney Steel Corporation (Sysco) of Sydney, Nova Scotia produced a total of 217 000 tonnes of coke from 333 000 tonnes of coking coal, down 13 per cent from the 1976 output of 251 000 tonnes. The coke was produced from blending coking coal as follows: 77 per cent high-volatile eastern Canadian coal; 19 per cent low-volatile western Canadian coal; and 4 per cent high-volatile U.S. coal. Sysco's No. 6 coke oven battery was taken out of production, but kept on stand-by throughout 1977.

Coke output at Kaiser Resources Ltd.'s Natal, British Columbia plant was 96 000 tonnes, all of which was marketed in western Canada. The Manitoba and Saskatchewan Coal Company (Limited) Char and Briquetting Division in Bienfait, Saskatchewan produced 55 000 tonnes of char. This output was exported to the United States.

Research and development

Recent energy forecasts and projections have highlighted the need for increased coal research and devel-

Table 13. Canada, coke production and trade, 1967-77

	Production		Imports		Exports	
	Coal Coke	Petroleum Coke	Coal Coke	Petroleum Coke	Coal Coke	Petroleum Coke
			(tonnes)			
1967	4 019 100	206 735	351 125	513 318	59 232	16 911
1968	4 817 842	216 455	231 700	509 300	130 427	5 207
1969	4 537 988	210 176	254 833	638 279	247 659	2 364
1970	5 142 122	188 376	358 295	706 769	248 469	48 313
1971	4 631 897	187 278	586 430	665 774	288 272	11 171
1972	4 675 866	242 370	481 816	555 710	238 478	881
1973	5 369 861	286 530	357 815	637 664	367 916	1 960
1974	5 443 427	274 412	509 058	746 033	260 892	24 940
1975	5 277 837	270 685	546 456	572 557	96 081	161 576
1976	5 289 185	678 432	287 249	591 859	169 895	136 970
1977[p]	4 845 066	921 363	382 827	986 678	198 727	157 191

Sources: Statistics Canada and Department of Energy, Mines and Resources, Ottawa.
[p] Preliminary.

Table 14. World coal production

	1972	1973	1974	1975r	1976p
			(000 tonnes)		
North America	562 182	561 552	571 486	641 291	664 638
South America	7 789	7 074	8 159	8 896	8 598
Europe	1 625 037	1 646 090	1 651 315	1 056 211	1 080 683
Africa	61 748	66 043	69 550	78 507	74 241
Asia	511 762	538 667	567 489	728 473	628 449
Oceania	85 567	87 797	92 986	76 390	69 633
World					
Lignite (estimate)	804 525r	819 437r	834 152r	727 725	709 874
Bituminous and anthracite (by subtraction)	2 049 560	2 087 786	2 126 833	1 862 043	1 816 368
Total, all types	2 854 085r	2 907 223r	2 960 985r	2 589 768	2 526 242

Source: United States Bureau of Mines.
pPreliminary; rRevised.

opment. In the area of coal conversion, funding commenced early in 1977 for a joint research and development program involving the federal government, provincial governments, public utilities and private industry in projects concerned with coal substitution for oil, more efficient and environmentally acceptable routes to produce electricity from coal, coal gasification, coal liquefaction, and coal utilization as chemical feedstock. Under the coal conversion program, 17 projects had been approved to receive 50 per cent federal funding support. In addition, 100 per cent federal funding for some coal conversion studies will be provided to small organizations and universities that do not have independent research funds.

Because of the increased cost of fuel oil, the eastern Canadian provinces, especially New Brunswick and Nova Scotia, are looking for means to replace, at least partially, coal for oil in existing oil-fired utility boilers. It appears that firing of a 50 per cent coal and 50 per cent oil slurry could meet these objectives. Such a process was recently demonstrated successfully by the New Brunswick Electric Power Commission in its Chatham plant. It is estimated that this partial substitution of coal for oil could save Canada approximately 640 000 m^3 (4 million barrels) of oil or about $60 million a year for imported oil.

New thermal-electric coal-fired generating plants in Canada will probably be based on advanced technology, such as fluid bed combustion or gasification followed by combined cycle generation, which provides not only higher thermal efficiencies, but also less expensive and better environmental control of the sulphur associated with coal. The new fluid bed technology will be demonstrated through a new 18 000 kg (40,000 pound) per hour boiler installation at the Armed Forces Base at Summerside, Prince Edward Island. Such technology will permit the development of coalfields (such as the B.C. Hat Creek coal deposit) which might not otherwise be developed under the restrictions of existing technology.

The production of low and medium heat value industrial fuel gas (carbon monoxide and hydrogen) by mine-mouth coal gasification plants is likely as soon as this gas is able to complete economically with natural gas. The production of substitute natural gas or high-heat value gas (SNG) from coal does not appear to be likely on a cost competitive level with natural gas in the foreseeable future in Canada.

Because of the anticipated domestic and world shortage of crude oil, much interest has developed in coal liquefaction. In the Canadian context, "coal liquefication" could be interpreted to imply the following processes: direct coal liquefaction; production of hydrogen from coal for the upgrading of hydrogen-poor heavy oils; the thermal use of coal for increased extraction of heavy oils and tar sands; and the use of coal-derived carbon dioxide to enhance tertiary recovery from conventional oil fields. In addition, the co-use of coal and methane as a methanol feedstock may significantly reduce the capital requirements and thus make methanol a viable fuel or fuel intermediate. Methanol can be used as a utility fuel, transportation fuel extender, an intermediate to produce high-octane motor gasoline via the Mobile "M" process, and as feedstock for the chemical industry.

Cobalt

W.E. KOEPKE

In 1977 Canadian production of cobalt was 1 508 tonnes*, up slightly from the previous year. The value of production, at $18 million was up sharply from the previous year's $13.2 million, a reflection of continued strong demand and rising prices during 1977. World cobalt prices had been weak throughout the 1960s and then began to rise markedly from the $2.00 to $3.00 a pound range in 1970-73 to about $5.00 by the end of 1976. By December 1977, the North American price had risen to $U.S. 6.00 a pound, and further increases were posted during the early months of 1978.

The tight supply situation and rising prices are attributed to several factors: supply disruptions from Zaire, which had been the source of 60 per cent of the world's cobalt output, beginning in early 1976; a reversal in United States government stockpiling policy; a coproduct relationship with copper and nickel that does not enable producers to readily respond to increasing cobalt prices; and a rise in prices in response to currency fluctuations. There are several dimensions to the Zairean supply problem. Cobalt is produced in association with copper, demand for which has been sluggish in recent years with production off. Further, there have been transportation bottlenecks in moving the products through Angola to tidewater, and more recently there have been rebel attacks in the copper-cobalt mining areas of Shaba province that damaged mining installations. News reports state that the supply problems have been rectified, but production data have yet to substantiate such predictions.

In the United States, cobalt has been stockpiled under the Strategic and Critical Materials Stock Piling Act of 1946. In 1973 the stockpile objective was lowered from 38.2 million pounds to 12 million pounds, the decision resulting in sales that in 1974 accounted for 40 per cent of the U.S. market. General Services Administration (GSA) stockpiles had been far in excess of the official objective. On October 1, 1976 the Federal Preparedness Agency of GSA raised the objective sharply to 85.4 million pounds; at that time the stockpile stood at 41.7 million pounds of cobalt, which represents nearly three times the U.S.A.'s annual consumption of about 18 million pounds. While the stockpile falls well short of the official objective, no purchases have been reported.

Most cobalt is produced in conjunction with copper and nickel mining. Because of this coproduct or byproduct relationship, production cannot be readily accelerated at will, other than through increases in recovery rates. The extraction of cobalt from some ores and concentrates is difficult and expensive. Recovery rates apparently range from 20 to 95 per cent of the contained cobalt in ores mined; hopefully the increase in prices will prompt greater attention to recovery rates.

Canada

Cobalt is produced in Canada as a byproduct of nickel-copper mining in the Sudbury area of Ontario and the Thompson area of Manitoba by two companies, Inco Limited and Falconbridge Nickel Mines Limited. The largest producer, Inco, recovers cobalt oxide at its three nickel refining operations: Copper Cliff and Port Colborne in Ontario, and Thompson, Manitoba. Until recently, Inco had been producing some electrolytic cobalt at Port Colborne. Falconbridge produces a cobalt bearing nickel-copper matte at its Sudbury area smelter that is then shipped to its refinery complex in Norway where electrolytic cobalt is recovered. Canadian production data as shown in Table 1 represents the cobalt content of materials shipped from the smelters and refineries of these two companies.

Canada's third nickel producer, Sherritt Gordon Mines Limited, recovers cobalt metal powder at its Fort Saskatchewan refinery, using imported nickel concentrates. Prior to 1977, some of its cobalt came from domestic ores as well. The cobalt powder is recovered from nickel-end solutions derived from hydrometallurgical processing.

A fourth company, Agnico-Eagle Mines Limited, produces cobalt-bearing silver concentrates in the Cobalt area of Ontario. In 1977, Agnico-Eagle reported

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Canada, cobalt production, trade and consumption, 1976 and 1977

	1976		1977p	
	(kilograms)	($)	(kilograms)	($)
Production[1] (all forms)				
Ontario	1 148 948	10 942 034	1 270 000	14 856 000
Manitoba	207 389	2 297 447	238 000	3 111 000
Total	1 356 337	13 239 481	1 508 000	17 967 000
Exports				
Cobalt metal				
United States	508 045	4 644 000	618 875	8 401 000
South Africa	7 545	118 000	25 726	396 000
West Germany	3 035	33 000	10 507	132 000
France	—	—	8 064	114 000
United Kingdom	—	—	17 421	111 000
South Korea	832	18 000	2 729	74 000
Sweden	2 233	35 000	—	—
Other countries	1 807	31 000	845	13 000
Total	523 497	4 879 000	684 167	9 241 000
Cobalt oxides and hydroxides[2]				
United Kingdom	461 167	3 048 000	600 000	4 891 000
Japan	10 161	78 000	5 000	44 000
Total	471 328	3 126 000	605 000	4 935 000
Consumption[3]				
Cobalt contained in:				
Cobalt metal	123 836	. .	110 804	. .
Cobalt oxide	28 527	. .	27 951	. .
Cobalt salts	8 129	. .	8 008	. .
Total	160 492	. .	146 763	. .

Source: Statistics Canada.
[1]Production (cobalt content) from domestic ores [2]Gross weight. [3] Available data reported by consumers.
pPreliminary; — Nil; . . Not available.

that its concentrates contained 3 474 kilograms (kg) of cobalt. The concentrates are shipped to the nearby silver refinery of Canadian Smelting & Refining (1974) Limited, where cobalt residues ranging from 2 to 7.5 per cent cobalt are recovered and stockpiled pending future extraction or sale; at year-end the stockpile was about 2 000 tonnes of residue.

World review

World cobalt output in 1977 was an estimated 21.4 thousand tonnes, up slightly from the previous year but well down from the peak level in 1974-75. Cobalt production data is sometimes misleading, inasmuch as some countries and/or companies report "mine production" whereas others report "recoverable cobalt" and still others report "refined" output. In commercial practice, recovery rates range from about 20 to 95 per cent; hence, statistical variances can be quite severe. Statistical data can be further complicated by the fact that the final extraction is seldom in the country of origin (see Tables 4 and 5).

About 60 per cent of the world's output is mined in association with copper in Zaire and Zambia. Given this coproduct relationship and the fact that world copper markets have been depressed in recent years, cobalt output has also been sluggish. The troubled political situation and transportation bottlenecks in south-central Africa have further aggravated cobalt supply from those two countries. Some coproduct cobalt is also mined in neighbouring Botswana.

In most other countries — Canada, Australia, Finland, New Caledonia, Philippines, Cuba and the U.S.S.R. — cobalt is mined in association with nickel. World nickel markets have also been depressed in recent years, and there have been some production

Table 2. Canada, cobalt production, trade[1] and consumption, 1960, 1965, 1970, 1975-77

		Exports		
	Production[2]	Cobalt metal	Cobalt oxides and hydroxides	Consumption[3]
	(tonnes)			
1960	1 619	383	533	114
1965	1 655	133	641	166
1970	2 069	381	837	148
1975	1 354	431	561	123
1976	1 356	523	471	160
1977[p]	1 508	684	605	147

Source: Statistics Canada.
[1]Imports not available. [2]Production from domestic ores, cobalt content. From 1967, production includes cobalt content of Inco and of Falconbridge Nickel Mines Limited shipments to overseas refineries, but prior years exclude Inco shipments to United Kingdom. [3]Consumption of cobalt in metal, oxides and salts.
[p]Preliminary.

Table 3. Sales of cobalt by major Canadian producers, 1975-77

	1975	1976	1977
	(tonnes)		
Inco	472	1 102	753
Falconbridge	619	943	678
Sherritt Gordon	148	285	316
Total	1 239	2 330	1 747

Sources: Company annual reports.

cutbacks; but these cutbacks have not severely affected coproduct cobalt output levels. In fact, cobalt output from nickel-producing operations has been on the rise. Part of the increase is attributed to the bringing on stream from 1974 to 1977 of new smelters and refineries with cobalt recovery units.

In Morocco, deposits grading as high as 1.2 per cent cobalt are mined in the Bou Azzer area of eastern Atlas Mountains. The concentrate is shipped to France for refining. Moroccan output declined sharply in 1976; and, while output in 1977 remained unchanged, there have been rumours that the mine could close.

Zaire certainly dominates world cobalt supplies. The copper-cobalt ore is mined by the state-owned Gecamines. Some sulphide concentrates are processed at the Kolwezie electrolytic refinery to produce cobalt metal, and the oxide concentrates are sintered and smelted to a cobalt slag for retreatment. Some of the smelted cobalt is exported as a white alloy matte and shipped to Belgium for refining. Société Zairoise de Commercialization (Sozacom) is the official marketing agency for Zairian cobalt. African Metals Corp. of New York is the exclusive dealer for Zairian and Belgian cobalt in the United States; African Metals markets about 70 per cent of the cobalt used in the U.S.A. and is usually regarded as the price leader, although Sozacom reportedly sets world prices.

Table 4. World production of recoverable cobalt, 1975-77

	1975	1976	1977[p]
	(tonnes)		
Zaire	13 633	10 686	10 686
Zambia	1 860	2 175	2 000
Canada	1 356	1 329	1 508
Finland	821	900	985
Morocco	1 961	862	850[e]
Australia[e]	400	700	1 000
Other western countries[e]	600	800	1 000
Subtotal	20 631	17 634	18 029
U.S.S.R.[e]	1 770	1 770	1 770
Cuba[e]	1 630	1 630	1 630
Grand total	24 031	21 034	21 429

Sources: Various.
[e]Estimate; [p]Preliminary.

Minerals and occurrences

Cobalt minerals are distributed widely throughout the world, invariably associated with other metallic minerals, such as nickel and copper. The minerals of cobalt can be classified into three broad groups; arsenides, sulphides and oxidized cobalt minerals. Although there are over 70 known or suspected minerals of cobalt, only a few are of economic importance. The most important economic minerals of cobalt are:

skutterdite } smaltite }	$CoAs_3$
cobaltite	$CoAsS$
linneaite	Co_3S_4
carrollite	$CuCo_2S_4$
heterogenite	$CoO{\cdot}OH$

There is a distinct relationship between cobalt minerals and the other metallic minerals with which they occur. The principal sources of cobalt are the copper deposits of Zaire and Zambia. In Zaire the cobalt occurs as both sulphides and oxidized minerals in the copper deposits, which are also both sulphides and oxides. In Zambia the cobalt appears primarily as a sulphide. As a constituent of the nickel ores of Canada,

Table 5. Principal world cobalt producers

Country	Company
North America	
Canada	Inco Limited Falconbridge Nickel Mines, Limited Sherritt Gordon Mines, Limited
United States	AMAX Nickel, Inc.
Europe	
Belgium	Metallurgie Hoboken-Overpelt, S.A.
Finland	Outokumpu Oy:n (government-owned)
France	Pechiney Ugine Kuhlmann Development
Germany, West	Duisburger Kupferhuette Gesellschaft fuer Electrometallurgie, GmbH, Herman C. Starck
Norway	Falconbridge Nikkelverk A/S
United Kingdom (Wales)	International Nickel Ltd.
U.S.S.R.	State plants located in Balkhash, Touva (Khozu-aksy), Norilsk, and Verkni-Oufalei
Africa	
Botswana	Botswana RST, Ltd.
Morocco	Société Minière du Bou Azzer et du Graara
Zaire	La Générale des Carrières et des Mine du Zaire (Gecamines)
Zambia	Roan Consolidated Mines Ltd. Nchanga Consolidated Copper Mines Ltd.
Oceania	
Australia	Freeport Queensland Nickel Inc. Metals Exploration Queensland Pty. Ltd. Western Mining Corporation Ltd. Great Boulder Mines Ltd.
Indonesia	P.T. Pacific Nikkel Indonesia
New Caledonia	Société Le Nickel (SLN)
Philippines	Marinduque Mining and Industrial Corp.

Source: U.S. Bureau of Mines.

Finland and Australia, the cobalt is primarily in the form of arsenides. Similarly, in the Cobalt area of Ontario cobalt occurs primarily as an arsenide or sulpharsenide.

The cobalt content of these ores is generally low. The deposits in Zambia and Zaire can grade as high as 3 or 4 per cent cobalt but more frequently below 0.5 per cent. In the Sudbury area of Canada, the ores can grade as high as 0.35 per cent but more commonly are less than 0.1 per cent cobalt.

One potential source of cobalt is the so-called manganese-nickel nodules on the ocean floor. Apparently these nodules typically contain 0.2 per cent cobalt.

Consumption and uses

Cobalt was first used over 2 000 years ago as a colouring agent for glass. The use of cobalt for this purpose in glass and ceramics dominated cobalt usage up to the early 20th century. At that time, research into the properties of metals similar to cobalt was stimulated by technological demands, and the use of cobalt in alloys rapidly replaced colouring agents as the most important consumer of cobalt. Cobalt's use in alloys stems principally from three properties; its relatively high melting point, its corrosion resistance and its ferromagnetism.

Cobalt usage is divided approximately as shown in the following listing:

Use	Percentage of Consumption[e]
High temperatures uses	20
Magnetic uses	25
Wear and abrasion-resistant uses	20
Pigments, colouring agents	20
Chemical uses	10
Other	5

[e] Estimated.

Cobalt-base, high temperature alloys or superalloys find their principal application in parts for jet engines. Cobalt-base superalloys contain from 20 to 65 per cent cobalt and can withstand temperatures up to about 900°C under conditions of low stress. Smaller amounts of cobalt are also contained in nickel- and iron-base superalloys. A growing area of use for cobalt-base superalloys is in parts for gas turbines.

Cobalt is one of very few materials that exhibit magnetic properties at room temperatures, the other major metals being iron and nickel. Cobalt is a component of almost all permanent magnet materials, materials that retain magnetic properties once the original magnetizing fields is removed. There are a wide range of permanent magnet materials, varying from iron-cobalt alloys to the Alnicos (aluminum-nickel-cobalt alloys) to cobalt-rare earth alloys. Nearly all of these magnetic alloys are used in electrical or electronic applications such as compact circuits, electrical motors, loudspeakers and telephones.

In the production of cemented carbide cutting tools, cobalt is used as a binder or metal matrix. Because of the extremely high melting points of the commonly used carbides, such as tungsten carbide, the cutting tools are made by heating a briquetted mixture of the carbide and cobalt. The cobalt melts and binds the hard carbides, providing the matrix that will give the toughness and shock resistance needed in their varying applications, such as drill bits, dies and lathe tools. Cobalt content can vary from 3 to 35 per cent in some dies.

Cobalt-base alloys are also used for cutting purposes. The most important group of cobalt-base alloys are the stellite group, containing cobalt, tungsten and chromium as their principal constituents. Stellites are suitable for a variety of uses. For example, their hardness and strength are mainly exploited for cutting tools and hard-wearing parts of machinery, such as in agricultural implements and excavating equipment. Their properties of corrosion resistance and ability to take a high polish are exploited by chemical plants dealing with acids and for exhaust valves in motors. These cobalt-base nonferrous alloys can also be used as hardfacing materials. Coating of a part with a particular cobalt alloy can provide greater resistance to abrasion, heat, impact and corrosion. Hardfacing alloys are not widely employed in the manufacture and repair of parts subject to abrasive conditions, such as ball mill liners, parts of crushing equipment and the teeth of power shovels.

Cobalt is used in high-speed tool steels to increase the red hardness of the steel or its ability to be used at higher rates of speed and for deeper cuts than would be the case if cobalt was not present. The cobalt content can range from 2 to 12 per cent. Cobalt is also used in some abrasion-resistant die steels. Generally, cobalt additions are more costly than other additions, and this has been an important factor in minimizing the usage of cobalt-containing steel.

In its metallic form, cobalt is also used in glass to metal seals, dental and surgical alloys, and in springs. Its isotope, cobalt 60, is used in place of X-rays or radium as an inexpensive source of gamma rays for the inspection of internal structures and for the treatment of cancer.

The most important nonmetallic form of cobalt is cobalt oxide. Cobalt oxide additions of from 150 to 4 500 grams a tonne of glass will impart a blue colour. Smaller additions, up to 45 grams a tonne, are made to neutralize the yellow tint of iron in plate and window glass. Similarly, cobalt is used in ceramics to neutralize the iron colour in pottery tile and sanitary ware. Larger additions are used to impart a blue or violet colour to the ceramics. Cobalt oxide is also used to eliminate the iron colour in white porcelain and in quantities of 0.2 to 2 per cent to promote the adherence of the enamel to steel.

Cobalt chemicals are used as dryers and pigments in paints and in the synthesis of liquid hydrocarbons. Since cobalt is a constituent of vitamin B_{12}, cobalt is also added to soil or herbage to maintain the health of cattle and sheep in some areas of the world where the cobalt content of the vegetation is too low.

Outlook

The outlook for cobalt is for continued short supply and buoyant, even volatile, prices through perhaps as far as 1980. Official prices were boosted to $U.S. 8.50 a pound in May 1978, and there have been reports of free market prices as high as $U.S. 24.00 a pound. When fighting broke out in Zaire in May 1978, a number of U.S. and European companies, as well as the U.S.S.R., made fairly heavy purchases thereby taking up readily available supplies. While most of the cobalt flow from Zaire has been reportedly sustained, the unsettled political and economic situations in south-central Africa have left many cobalt consumers in a quandary. A new cobalt refinery in Zaire with a 4 000-tonne-a-year capacity had been scheduled to come on stream in 1979, but the status of this project remains unclear.

Undoubtedly high cobalt prices will prompt producers in other parts of the world to search for new deposits, to strive for improved recovery rates at existing operations and to look towards scrap utilization. One company in the United States, GTE Sylvania, has already announced plans to begin recovering cobalt metal powders from scrap in 1978.

Despite efforts for better cobalt recovery at domestic operations, Canadian cobalt output is expected to decrease in 1978 due to official cutbacks in nickel production and possible labour disputes at the nickel producing operations. Some interest has focused on the old Cobalt camp, which for many years had produced considerable quantities of cobalt in association with silver, but investors would likely have to be assured of strong prices over a long term before embarking on new ventures.

Prices

	Dec. 1976	Dec. 1977
	($U.S.)	($U.S.)
Cobalt metal, per lb., fob New York, Shot, 99.5%		
less than 50 kg	5.05	6.15
50-kg drums	4.96	6.06
250-kg	4.90	6.00
Powder, 99%+		
300 and 400 mesh, 50-kg drums	8.36	9.96
extra fine, 125-kg drums	8.29	9.89
S grade, 10-ton lots	5.25	6.40

Source: *Engineering Mining Journal,* December 1976 and 1977.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
			(%)		
33200-1	Cobalt ore	free	free	free	free
35103-1	Cobalt metal, excluding alloys, in lumps, powders, ingots or blocks	free	free	25	free
35110-1	Cobalt metal, in bars	free	10	25	free
92824-2	Cobalt oxides	free	10	20	free
92824-1	Cobalt hydroxides	10	15	25	10

United States

Item No.		Most Favoured Nation
601.18	Cobalt ore	free
632.20	Cobalt metal, unwrought, waste and scrap	free
632.84	Cobalt metal alloys, unwrought	9% ad val.
633.00	Cobalt metal, wrought	9% ad val.
	Cobalt compounds:	
418.60	Oxide	1.2¢ per lb.
418.62	Sulfate	1.2¢ per lb.
418.68	Other	6% ad val.
426.24, 426.26	Cobalt salts	6% ad val.

Sources: For Canada, The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa; for United States, Tariff Schedules of the United States Annotated (1978), TC Publication 843.

Columbium (Niobium) and Tantalum

ALBERT BOUCHARD

Demand for columbium (Cb) in the steel sector remained strong in 1977, with this sector accounting for about 85 per cent of total world consumption. Columbium, which is produced for consumption in the form of ferrocolumbium or columbium pentoxide, is used in the manufacture of specialty steels, superalloys, columbium metal, columbium-based alloys and columbium carbides. Demand has been especially strong for columbium-bearing high strength low alloy (HSLA) steels for use in energy and energy-related applications such as pipeline steel and automobiles. Requirements in these sectors are expected to remain high.

Canadian production and developments

In 1977 Niobec Inc. operated at full capacity, shipping 2 516 931 kilograms (kg) of columbium pentoxide (Cb_2O_5) in concentrates. All of this production was exported to consumers in Luxembourg (53 per cent), the United States (23 per cent) and Japan (24 per cent). Niobec Inc., in which the Quebec Mining Exploration Company (SOQUEM) and Teck Corporation Limited each have a 50 per cent interest, works a pyrochlore deposit using the open stope method. This method consists basically of boring stopes or galleries around the deposit and blasting by sections, as is done in open-pit mining. This technique makes it possible to extract large quantities of ore with less equipment than is required in conventional underground mining.

The pyrochlore flotation process used by Niobec Inc. is unique and is protected by Canadian, American and British patents. The process is based on the use of oxalic acid as the pyrochlore flotation reagent rather than hydrofluoric acid, which has been commonly used. It consists of floating most of the gangue, in this case carbonates, before floatation of the pyrochlore. This new process produces high-quality concentrate and a good recovery. The concentrator has an annual production capacity of 4 173 000 kg of concentrate with a 60 per cent Cb_2O_5 content. The company's proved reserves are approximately 8.5 million tonnes with a 0.72 per cent Cb_2O_5 content; estimated reserves are approximately 30.0 million tonnes, with a 0.70 per cent Cb_2O_5 content.

During 1977 St. Lawrence Columbium and Metals Corporation (SLC) of Oka, Quebec made several efforts to find new financing for its operations, but before an agreement could be worked out the installations and equipment at the Oka mine were put up for sale by the company's creditors.

Minerals and Canadian occurrences

In nature, tantalum and columbium are almost invariably found together because of their chemical similarity, their nearly identical atomic radii and the similarity in their atomic structures and valences.

The principal source of columbium and tantalum is the columbite-tantalite series, which is an isomorphous series of iron, manganese, and columbium and tantalum oxides. The general formula for the series is $(Fe,Mn)(Cb,Ta_2O_6)$. The mineral is called tantalite if the tantalum pentoxide (Ta_2O_5) content exceeds the columbium pentoxide (Cb_2O_5) content, and columbite if the reverse is true. The only other commercial source of columbium and tantalum is the microlite-pyrochlore series which has the general formula $Ca_2(Cb,Ta)_2O_6(OH,F)$. Here again the mineral is called microlite if the tantalum pentoxide (Ta_2O_5) content exceeds the columbium pentoxide (Cb_2O_5) content, and pyrochlore if the reverse is true.

These minerals are found in granitic pegmatites and carbonatite — alkalic or alkalic igneous rock complexes. There are two basic mine sources of columbium and tantalum: deposits in which the tantalite-columbite series or the microlite-pyrochlore series are the principal minerals of interest, and deposits in which tantalite-columbite is recovered as a byproduct of tin-mining operations.

Following production of a tantalum-columbium concentrate, the next major processing step is separation of the tantalum and columbium. This is usually accomplished by dissolving the concentrate in hydrofluoric acid, followed by leaching with water and hydrochloric acid to remove impurities. Anhydrous hydrogen fluoride and potassium hydroxide are then added, and the solution is heated. This creates potassium-tantalum fluoride (K_2TaF_7) and potassium-columbium fluoride (K_2CbF_7). These two fluorides are then separated by solvent extraction.

There are more than 30 known carbonatite deposits in Ontario as well as several in Quebec, Labrador, British Columbia and the Northwest Territories. The main columbium mineral deposits in carbonatite complexes are:

- in Quebec: the St. Lawrence Columbium and Metals Corporation property; the holdings of Columbium Mining Products Ltd; the holdings of Main Oka Mining Corporation and Columbium Limited — all are located in the Oka Region; and the Niobec Inc. operations at St-Honoré near Chicoutimi.
- in Ontario: the deposits at James Bay; the Manitou Island deposits, near North Bay; and the deposits at Lackner Lake and Nemegosenda Lake, near Chapleau.

World production

Nearly 95 per cent of the world's columbium production is obtained from pyrochlore concentrate, the Cb_2O_5 content of which varies from 51 to 60 per cent. These concentrates are produced primarily in Brazil and Canada, with the rest coming from various countries, including Nigeria, Zaire, Mozambique, Australia and Thailand, in the form of tantalite-columbite concentrates.

The world's largest producer of columbium pentoxide and ferrocolumbium is Companhia Brasileira de Metalurgia e Mineracao (CBMM) of Araxa, Brasil, which is owned by the Brazilian group Moreira Salles (51 per cent), the American Molycorp Inc. (33 per cent) and the Canadian company, Pato Consolidated Gold Dredging Limited (16 per cent). During 1977, as a result of the continuing recession in the world steel industry and the entry of new producers into the market, CBMM operated substantially below full capacity, maintaining a monthly production rate of some 816 500 kg of Cb_2O_5. The company's potential capacity is approximately 1 134 000 kg a month. CBMM represents approximately 70 per cent of the total world production capacity for columbium ore concentrate. The remaining 30 per cent is largely accounted for by two new companies, which began producing concentrates late in 1976. These companies are Niobec Inc. of St-Honoré, Quebec and Mineracao Catalao de Goias, which operates near Catalao, Brazil.

Table 1. Production, trade and consumption of columbium (niobium) and tantalum in Canada, 1968-77

	Production[1]		Imports[2] from the United States					
	Cb_2O_5 content	Ta_2O_5 content	Columbium, metal and alloys, wrought	Tantalum, metal and alloys, wrought	Tantalum, metal and alloys unwrought, rejects and scrap	Tantalum, metal and alloys, powder	Exports[3] to U.S., columbium ore and concentrate	Consumption, ferrocolumbium and ferrotantalum-columbium, Cb and Cb-Ta content
	(kilograms kg)							
1968	989 423	—	170	894	1 557	830	133 961	130 635
1969	1 548 789	59 102	534	849	1 998	3 396	417 113	110 677
1970	2 129 271	143 800	—	387	848	1 125	576 227	132 449
1971	1 058 078	203 940	2 296	674	6 458	1 406	154 782	176 901
1972	1 757 120	18 652	741	526	1 440	656	29 535	263 084
1973	1 441 015	77 375	1 196	2 466	—	7 497	303	205 024
1974	1 920 081	198 874	1 992	2 330	—	5 662	3 933	231 332
1975	1 661 567	. .	—	—	—	—	9 682	215 910
1976	1 656 000	. .	—	—	—	—	478 368	126 098
1977^p	2 516 931	. .	—	2 921	—	1 290	757 090	. .

Source: Statistics Canada.
[1]Producers' shipments of columbium and tantalum ore and concentrate; Cb_2O_5 and Ta_2O_5 content. [2]From *Exports of Domestic and Foreign Merchandise*, report FT 410 of the U.S. Department of Commerce. Quantities in gross weight of material. [3]From *Imports of Merchandise for Consumption*, report FT 135 of the U.S. Department of Commerce. Quantities in gross weight of material.
^{p}Preliminary; . . Not available; — Nil.

Uses

The steel industry is the largest consumer of columbium in the form of ferroalloys. Ferrocolumbium is used as an additive element in four major classes of steel: HSLA steels, stainless steels, low alloy steels and superalloys. Among these various types of steel, HSLA steels consume the greatest quantity of ferrocolumbium. The addition of columbium to steel acts to control grain size and to improve its mechanical properties and strength-to-weight ratio. Between 0.35 and 1.0 kg of columbium is added to each tonne of HSLA steel. These steels are used in a wide variety of fields including ship building, industrial and pipeline construction, bridge building, the manufacture of large storage tanks, the automobile industry and other such applications.

Columbium metal, columbium-based alloys, superalloys and stainless steels are used in a wide variety of machinery and equipment that requires good corrosion resistance and a high strength-to-weight ratio at high temperatures. Columbium carbide, one of the hardest substances known, is used in machines designed for cutting, in drill bits and shovel teeth and in other digging equipment. There are numerous other sectors, such as the aerospace, nuclear and electronics industries, that are steadily increasing their consumption of columbium in the form of columbium metal and columbium-based alloys. Very low temperature applications constitute another promising source of demand.

Prices

In 1977 the price of Brazilian pyrochlore fob* shipping point increased from $U.S. 2.25 a pound of Cb_2O_5 content on January 1, 1977 to $U.S. 2.55 on May 13, and remained at this level the rest of the year. The price of Canadian pyrochlore fluctuated during the year, but always remained fairly close to the Brazilian price. Columbite concentrates cif** United States ports, priced at $U.S. 3.00 to $U.S. 3.50 a pound of pentoxide content ($Cb_2O_5 + Ta_2O_5$) between January 1 and March 1, were priced at $U.S. 2.85 to $U.S. 3.50 during the rest of the year.

Outlook

Columbium consumption should continue to grow in the future, particularly in the oil, gas and transportation industries. According to the United States Bureau of Mines, the annual growth rate in consumption to the

* fob free on board;
** cost insured freight.

Table 2. Production of columbium (Cb) and tantalum (Ta) concentrate, 1974-76[1,2]

	1974			1975			1976^p		
	Cb	Ta	Cb-Ta	Cb	Ta	Cb-Ta	Cb	Ta	Cb-Ta
	(000 kg gross)								
Brazil									
Pyrochlore	17 878	—	—	9 737	—	—	17 987^e	—	—
Columbite-tantalite	—	—	92	—	—	100	—	—	125
Canada									
Pyrochlore	1 920	—	—	1 662	—	—	1 656	—	—
Tantalite	—	371^e	—	—	334^e	—	—	350^e	—
Nigeria	1 193	1	—	990	1	—	650	1^e	—
Zaire	—	—	64	—	—	80	—	—	79
Mozambique									
Columbite-tantalite	—	46	—	—	46	—	—	46^e	—
Microlite	—	62	—	—	44	—	—	44^e	—
Malaysia	—	—	93	—	—	50	—	—	46
Thailand	10	82	—	7	103	—	7^e	100^e	—
Portugal	—	9	—	—	11	—	—	5	—
Rwanda	—	—	75	—	—	47	—	—	45
Australia	—	—	108	—	—	132	—	—	126^e
Other countries[3]	1	1	45	1	1	43	1	1	43
Total	21 002	572	477	12 397	540	452	20 301	547	464

Source: U.S. Bureau of Mines, *Minerals Yearbook 1976 Preprint*.
[1]Excludes tin slag containing columbium-tantalum. [2]Concentrates containing large amounts of both elements are shown under Cb-Ta when composition data is insufficient. [3]Other countries producing columbium and/or tantalum are Argentina, Rhodesia and Uganda.
^{p}Preliminary; ^{e}Estimated; — Nil.

year 2000 should be 5.6 per cent for the United States and 4.6 per cent for the rest of the world. In Canada, the annual production growth rate in the long term should be very close to the American government's estimated figure for world consumption. Canadian consumption should increase rapidly over the next five years due to Canadian production of pipe for several large pipeline projects.

TANTALUM

Close to two-thirds of the world's tantalum is produced as a byproduct of tin mining. It has physical and chemical properties that make it highly useful in various fields. Historically, the electronics industry has been the largest consumer of tantalum for the manufacture of capacitors. In 1977, however, the cemented carbide industry, which manufactures cutting tools, mining equipment and wear-resistant parts, assumed the leading position, accounting for approximately 45 per cent of world consumption in the form of tantalum pentoxide, tantalum carbide and recycled scrap. Although the capacitor market is growing steadily, it has lost its place as the largest consumer of tantalum. This is due primarily to the increasing efficiency of metal powders, the rapidly rising cost of the raw material, and the general trend toward miniaturization in the electronic industry, which means a reduction in the size of electronic components and hence in the quantity of tantalum consumed. Even so, the electronics industry accounted for nearly 40 per cent of world tantalum consumption in 1977.

Canada

There are several known tantalum deposits in Canada. The largest of these is the zoned pegmatites near Bernic Lake, Manitoba. Most of the tantalum in this deposit occurs as stanniferous tantalite in small disseminated grains ranging in size from 10 microns to 3 millimetres (mm). The chemical composition of this tantalite is 70 per cent tantalum pentoxide (Ta_2O_5), 1.3 per cent columbium pentoxide (Cb_2O_5) and 13 per cent tin oxide. This deposit is the world's largest exclusively tantalum-producing operation. The other known deposits in Canada are either too small or of too low a grade to be considered economic at the present time. During the 1950s, some tantalum was mined in the Northwest Territories, but the operation was deemed uneconomic and production ceased after only two years.

Table 3. Production of tantalite by the Tantalum Mining Corporation of Canada Limited, 1970-77

Year	Production
	(kg Ta_2O_5 content)
1970	192 367
1971	161 496
1972	147 911
1973	24 954
1974	121 777
1975	181 009
1976	127 813
1977[p]	146 056

Source: Department of Energy, Mines and Resources, Ottawa.
[p] Preliminary.

Table 4. Estimated world production of tantalum, 1975-77

	1975	1976	1977
	(000 kg Ta_2O_5 content)		
Concentrate			
Australia	38.6	45.4	54.4
Brazil	88.5	86.2	54.4
Canada	181.4	117.9	147.4
Malaysia and Thailand	86.2	86.2	56.7
Mozambique	18.1	22.7	45.4
Spain and Portugal	13.6	13.6	27.2
Zaire	45.4	45.4	45.4
Other African countries	13.6	27.2	40.8
Other countries	31.8	81.6	81.6
Subtotal	517.2	526.2	553.3
Tin slag			
Thailand	190.5	217.7	204.1
Other countries	315.2	408.2	453.6
Subtotal	505.7	625.9	657.7
Total, all sources	1022.9	1152.1	1211.0

Source: Department of Energy, Mines and Resources, Ottawa.

There is only one producer of tantalum in Canada, the Tantalum Mining Corporation of Canada Limited (Tanco) at Bernic Lake. Tanco is owned by the International Chemalloy Corporation (50.1 per cent), the Manitoba Development Corporation (25 per cent) and Kawecki Berylco Industries, Inc. (24.9 per cent). The Tanco concentrator can process 635 tonnes of ore daily containing about 635 kg of Ta_2O_5. Tanco's production for 1977 is estimated at 146 056 kg. The company's exploration program, which was instituted in 1976, was continued in 1977 at a cost of $200 000, but no major deposits were discovered. There has been no change in the company's minable reserves, which are estimated at 1.17 million tonnes with an average of 0.179 per cent Ta_2O_5 content. At the current rate of production, existing reserves are sufficient to last six to seven years. Canada's entire tantalum concentrate production is exported, mainly to the United States.

Tantalum in 1977

In 1977 the non-communist countries produced approximately 1.22 million kg of Ta_2O_5, very close to the 1976 production level. Less than half of the total production is obtained from concentrates, the remainder from tin slags. Although two thirds of all tantalum is produced as a byproduct or coproduct of tin, the record prices for tin coupled with those for tantalum itself, did not give rise to the discovery of any new sources of supply during this year. The growing gap between tantalum supply and demand has been narrowed considerably by the recovery of tantalum from low-grade slags, which have accumulated over the years at tin concentrating operations. The recovery of tantalum from these slag piles has become economic owing to the recent increase in the price of the metal. Not long ago, it was deemed uneconomic to recover tantalum contained in tin slags where the Ta_2O_5 content was less than 9 or 10 per cent, but in 1977 a West German company reportedly processed tin slag containing no more than 2 to 5 per cent Ta_2O_5. These additional sources should slow the rate at which the price has been increasing. Currently, the price of tantalum is rising dangerously close to the point at which manufacturers may begin to replace tantalum capacitors with aluminum ones.

Products and uses

The uses of tantalum stem from its physical and chemical properties:

1. its ability to form an oxide film which has excellent dielectric properties;
2. its resistance to chemical attack at moderate temperatures;
3. its high-melting point;
4. its strength and ductility; and
5. its ability to form stable carbides.

Its principal uses are in electronics, in the manufacture of chemical processing equipment and in cutting tools and dies. One of the most extensive uses of tantalum is in electronic components, principally capacitors. Tantalum has enjoyed a rapid growth in this field, because it has the highest dielectric constant of any known metal oxide and the ability to transmit alternating current in only one direction. Tantalum capacitors have become the standard for reliability among electronic capacitors. In addition to their high reliability they have a much longer service life, and because of tantalum's high dielectric constant, they are smaller for an equivalent capacitance than capacitors made of other materials. Until recently, tantalum capacitors were relatively expensive; but the metal's reliability gained markets in industrial and military applications where reliability is of great importance, and in some cases essential. Recently, tantalum capacitors have made inroads into consumer goods; but this area is much more competitive, as requirements for reliability and performance are less stringent than those of industrial and military products. The use of tantalum capacitors in military and industrial products would seem to be price-inelastic, while their use in consumer goods will depend primarily on price-competitiveness with other types such as aluminum capacitors. The trend toward miniaturization of electronic circuits will reduce the size, and consequently the weight, of the tantalum capacitors required. This factor will, however, be more than offset by a wider use of tantalum capacitors. Indeed, recent research has revealed that the dielectric properties of tantalum can be further improved by reducing the metal's grain size, which should make it an even more attractive material.

In addition to its use in capacitors, small amounts of tantalum are used in rectifiers, alarm and signal systems, and in electronic and vacuum tubes. Tantalum also finds a use in corrosion-resistant applications because of its relative chemical inertness. The oxide film that forms on the surface of tantalum metal is very stable, and not only does it appear to retard further oxidation of the metal, but it is also insoluble to most corrosive media. Because the film remains relatively thin, it does not impede heat transfer. These properties, in addition to the ability to maintain strength and corrosion resistance at moderate temperatures, leads to many uses in corrosion-resistant applications. Tantalum acts as a lining for vessels used in the production of hydrochloric acid, hydrogen peroxide, bromine and several high-purity chemicals, and in the recovery of sulphuric acid. Its ability to transmit heat is utilized in heat exchangers, condensers, coils and other such parts. In addition, these same properties account for its use in surgical implants, nuclear reactors and laboratory equipment. Columbium may be substituted for tantalum; however, tantalum usually has a much longer service life, and consequently a wide price differential would be necessary to make a such substitution economically attractive.

Tantalum carbide, when mixed with other metallic carbides, usually imparts greater shock resistance, greater resistance to cratering and to edge wear, and greater strength to the mixture. The tantalum carbide content can vary between 1 and 15 per cent in these mixtures but usually averages around 5 per cent. In addition to cutting tools used in the steel industry, tantalum carbides are used in dies and some parts of metal-working machinery, where it increases resistance to cratering. Tantalum carbide is the most expensive of the commonly used metallic carbides and this has undoubtedly limited its usage.

Tantalum is also used in some superalloys that are employed in aerospace structures, jet engines and gas turbines, where strength at high temperatures and corrosion resistance are required. Historically, one of the important uses of tantalum has been in the steel industry, where ferrotantalum and ferrocolumbium-tantalum were formerly used as grain refiners in carbon steels and as carbide formers in alloy steels. This usage has gradually disappeared, since ferrocolumbium can serve the same purposes at a much lower cost. Tantalum is not widely used in chemicals because of its inertness.

Outlook

With no new source of supply in sight, annual Ta_2O_5 production from concentrates and from tin slags is likely to change only slightly before 1980. Assuming that there is no production stoppage, enough tantalum should be obtained from secondary materials and from low-grade tin slags to offset the anticipated shortfall in supplies from primary sources. Known tantalum reserves are very small, and it is quite likely that a new shortage will occur in the mid to late 1980s if new mines do not enter production within the next five or six years.

Prices

Tantalum concentrate prices rose sharply during 1977. The cash price for tantalum ore went from between $17.25 and $18.00 a pound of Ta_2O_5 content on January 1 to between $19.00 and $20.00 in March, and to between $22.75 and $25.75 in August, making an increase of 30 per cent for the year. On September 29, Tanco announced a 35 per cent price increase effective December 19. Tanco's price for tantalite rose from $17.75 a pound of Ta_2O_5 content to $24.00. The price of tantalum metal has not yet reflected this increase in the cost of the raw material. Tantalum powder was priced between $40.00 and $58.25 a pound on May 1, as compared with $40.00 to $53.00 a pound at the beginning of the year. The price of tantalum bars and sheets did not change during the year, remaining between $52.00 and $80.00 and between $72.00 and $82.00 a pound respectively. In 1977 tantalum prices again indicated that raw materials are much more sensitive to economic changes than are manufactured or finished products. Because of their excess production capacity, manufacturers of tantalum capacitors were unable to pass along part of their increased costs to their customers, in spite of the fact that tantalum represents close to 50 per cent of the actual production cost.

The prices below are in United States currency and are taken from *Metals Week* of December 30, 1977.

	1976	1977
	($)	
Columbium ore		
columbite, per pound of pentoxide cif U.S. ports	3.00 – 3.50	2.85 – 3.50
Brazilian pyrochlore, per pound Cb_2O_5, fob shipping point, contact only	2.25	2.55
Ferrocolumbium, per pound Cb, fob shipping point		
low alloy	4.73	5.12
high-purity alloy	11.80 – 14.30	13.45
Columbium metal, per pound, 99.5 to 99.8% depending on size of order		
reactor		
powder roundel	30.00 – 45.00	29.00 – 37.00
ingot	18.00 – 25.00	26.00 – 33.00
Tantalum ore		
tantalite, per pound of pentoxide, Tanco price	16.00	24.00
Tantalum metal, per pound, fob shipping point depending on size of lot		
powder	35.40 – 48.00	40.00 – 58.25
bars	48.00 – 118.00	52.00 – 80.00
sheet	52.00 – 80.00	72.00 – 82.00

Tariffs

Canada

No.		British preferential tariff	Most favoured nation tariff	General tariff
		(%)	(%)	(%)
32900-1	Columbium and tantalum ore and concentrate	free	free	free
35120-1	Columbium and tantalum metals and alloys in powder, pellets, scrap, ingots, sheet, plate, strip bars, rods and wire for use in Canadian manufacturing (expires June 30, 1979)	free	free	25
37506-1	ferrocolumbium, ferrotantalum and ferrotantalum-columbium	free	5	5

Tariffs (concl'd)

United States

No.		
601.21	Columbium ore	free
601.42	Tantalum ore	free
628.15	Columbium metal, unwrought, and scrap and waste (duty on scrap and waste suspended to June 30, 1978)	5 ad valorem
628.17	Columbium alloys, unwrought	7.5 ad valorem
628.20	Columbium metal, wrought	9 ad valorem
629.05	Tantalum metal, unwrought, scrap and waste (duty on scrap and waste suspended to June 30, 1978)	5 ad valorem
629.07	Tantalum alloys, unwrought	7.5 ad valorem
629.10	Tantalum metal, wrought	9 ad valorem

Sources: Canadian Customs Tariffs and Amendments, Department of National Revenue, Customs, and Excise, Ottawa. Tariff Schedules of the United States Annotated (1978) TC Publication 843.

Copper

G.E. WOOD

Canadian mines

Production of primary copper in Canada in 1977 was 780 633 tonnes compared with 730 930 tonnes* in 1976. Primary production is defined as "blister copper plus recoverable copper in concentrates, matte, etc. exported." At least part of the increase in 1977 was due to a reduction of concentrate inventories held by producers and reflects a generally tight world supply position for copper concentrates. A number of mines continued to operate below normal rates, and further mine closures and production cutbacks appear likely in 1978.

Production costs at Canadian mines continued to rise in 1977 and for many producers total costs again exceeded the average realized copper price for the year, which remained at very depressed levels.

Some metals coproduced with copper also experienced weak prices and oversupply, particularly zinc and nickel. Market conditions for lead and molybdenum, other coproducts of copper, were more buoyant.

Newfoundland. Modifications to the concentrator circuit at Consolidated Rambler Mines Limited were undertaken in 1977 and were successful in reducing the level of troublesome impurities in the copper concentrate. As a result, the threat of mine closure was averted and full production was maintained throughout most of the year.

Ore reserves at the Buchans mine of ASARCO Incorporated had fallen to 430 000 tonnes by the end of 1977, and it was expected that the mine will be closed in 1979. Recovery of barite from the old mill tailings areas has been considered as a possible future activity at the property.

New Brunswick. Brunswick Mining and Smelting Corporation Limited announced plans in 1977 to reduce both capital and operating expenditures. The No. 3 shaft will now be completed at the 1 127-metre level and the expansion program to increase the No. 12 mine production to 10 000 tonnes a day will continue at a reduced rate.

Heath Steele Mines Limited completed the step-up of the operating rate at its mine and concentrator to 3 600 tonnes a day from 2 700 tonnes a day. Additional flotation capacity and process control equipment were installed at the concentrator. Ore reserves at the end of 1977 were reported to be 30.9 million tonnes with an average grade of 1.5 per cent lead, 4.3 per cent zinc, and 1.2 per cent copper.

Quebec. In Quebec the closure of the Cupra, D'Estrie and Clinton mines of Sullivan Mining Group Ltd. took place as expected early in 1977. The Madeleine mine of Madeleine Mines Ltd. also closed early in the year. New mines have not been developed in Quebec in recent years at a fast enough pace to maintain the rate of copper production at levels reached in the early 1970s.

The Quebec government responded to the situation by proposing, in April 1977, a five-year exploration project for the Abitibi region of Northwestern Quebec, at a cost of $60 to $80 million.

The program would involve the government-owned Quebec Mining Exploration Company (SOQUEM) and a number of other Canadian mining companies. It was hoped that exploration expenditures for fiscal 1977-78 would amount to $8 million in northwestern Quebec.

During December, Quebec signed an agreement with France for a joint exploration program in the same area of Quebec. Quebec and France will each provide $5 million for exploration, primarily for copper and other nonferrous metals, over a five-year period.

Quebec also held exploratory talks with Quebec-based mining companies and with the French government and French consumers late in the year aimed at creating a price stabilization scheme for Quebec copper, possibly tied to long-term sales contracts. No concrete plan had emerged by year-end.

Campbell Chibougamau Mines Ltd. was one of the companies which held discussions with the Quebec

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

government, with a view to maintaining the future viability of the mine in spite of present market conditions for copper. These discussions were continuing at year-end. Both the Henderson and Cedar Bay mines operated on a one-shift basis in 1977 and the Merrill pit was also in operation on that basis during the year. Capital and development expenditures were held to a bare minimum and were offset by the sale of surplus equipment.

Falconbridge Copper Limited completed diamond drilling at the Corbet mine. Ore reserves were stated to be 2 266 000 tonnes with an average grade of 3.47 per cent copper, 2.26 per cent zinc, 21.15 grams (gm) per tonne silver and 1.03 gm per tonne gold. Shaft sinking was continued towards a design depth of 1 216 metres. In July, stope production commenced at the Cooke mine.

Orchan Mines Limited suspended operations at the

Table 1. Canada, copper production, trade and consumption 1976-77

	1976		1977p	
	(tonnes)	($)	(tonnes)	($)
Production[1]				
British Columbia	265 105	399 703 394	291 757	446 840 000
Ontario	260 198	391 377 336	279 567	428 170 000
Quebec	112 733	169 969 219	107 686	164 927 000
Manitoba	54 602	82 325 028	60 443	92 572 000
New Brunswick	10 271	15 485 371	13 227	20 257 000
Yukon	10 642	16 045 963	11 793	18 062 000
Newfoundland	7 427	11 197 883	8 343	12 778 000
Saskatchewan	9 528	14 365 270	7 484	11 463 000
Northwest Territories	424	639 980	333	510 000
Total	730 930	1 101 109 444	780 633	1 195 579 000
Refined	510 469	. .	508 767	. .
Exports				
Copper in ores, concentrates and matte				
Japan	210 221	217 059 000	206 859	205 788 000
United States	53 477	51 993 000	20 594	19 243 000
West Germany	3 861	3 345 000	14 833	15 702 000
Norway	16 637	13 718 000	19 211	15 198 000
Spain	—	—	6 478	6 192 000
U.S.S.R.	12 411	16 369 000	5 871	5 230 000
South Korea	—	—	3 068	3 433 000
United Kingdom	1 271	1 724 000	1 569	2 084 000
Belgium and Luxembourg	1 127	612 000	936	809 000
Sweden	2 678	2 170 000	—	—
Other countries	1 372	1 338 000	90	13 000
Total	303 055	308 328 000	279 509	273 692 000
Copper in slag, skimmings and sludge				
United States	260	114 000	203	37 000
West Germany	3 600	794 000	—	—
Belgium-Luxembourg	2 899	639 000	—	—
Other countries	73	23 000	40	13 000
Total	6 832	1 570 000	243	50 000
Copper scrap (gross weight)				
United States	9 710	10 703 000	10 277	11 446 000
South Korea	1 909	2 187 000	1 997	2 253 000
Belgium and Luxembourg	1 877	2 066 000	912	977 000
Hong Kong	42	47 000	696	816 000
West Germany	215	215 000	577	741 000

Table 1. (cont'd)

	1976		1977[p]	
	(tonnes)	($)	(tonnes)	($)
Exports (cont'd)				
Taiwan	219	95 000	584	685 000
Japan	325	317 000	252	274 000
Netherlands	144	169 000	237	269 000
India	192	222 000	187	251 000
United Kingdom	821	402 000	653	245 000
Norway	54	68 000	126	140 000
Spain	520	551 000	137	82 000
Thailand	10	29 000	59	69 000
Other countries	–	–	70	76 000
Total	16 038	17 071 000	16 764	18 324 000
Brass and bronze scrap (gross weight)				
United States	9 847	9 991 000	11 454	11 432 000
Japan	1 101	959 000	1 814	1 589 000
India	313	283 000	858	765 000
Belgium and Luxembourg	655	606 000	604	532 000
South Korea	231	212 000	513	485 000
Italy	874	779 000	427	384 000
Taiwan	74	71 000	218	197 000
Hong Kong	35	32 000	75	84 000
United Kingdom	239	181 000	138	69 000
France	359	297 000	18	18 000
West Germany	309	300 000	18	9 000
Other countries	416	348 000	419	216 000
Total	14 453	14 059 000	16 556	15 780 000
Copper alloy scrap, nes (gross weight)				
United States	1 590	1 144 000	2 302	1 942 000
Japan	383	298 000	574	502 000
South Korea	37	31 000	778	249 000
United Kingdom	36	30 000	66	39 000
Other countries	219	173 000	57	40 000
Total	2 265	1 676 000	3 777	2 772 000
Copper refinery shapes				
United States	86 373	126 597 000	87 179	136 906 000
United Kingdom	92 852	131 007 000	82 773	117 444 000
West Germany	36 499	50 245 000	36 370	50 740 000
France	23 744	32 725 000	17 045	24 213 000
Belgium and Luxembourg	13 264	18 534 000	16 918	23 738 000
Italy	14 950	20 253 000	12 965	18 666 000
Sweden	12 838	17 455 000	11 665	16 266 000
Japan	12 443	19 300 000	4 638	7 396 000
People's Repub. of China	–	–	4 500	6 059 000
Portugal	5 056	7 098 000	4 170	6 038 000
Venezuela	1 759	2 234 000	2 926	4 560 000
Switzerland	5 040	6 920 000	3 141	4 252 000
Netherlands	4 299	6 292 000	2 270	3 192 000
Brazil	3 129	4 269 000	1 814	2 502 000
Other countries	4 875	7 055 000	5 870	8 562 000
Total	317 121	449 984 000	294 244	430 534 000

Table 1. (cont'd)

	1976		1977[p]	
	(tonnes)	($)	(tonnes)	($)
Exports (cont'd)				
Copper bars, rods and shapes, nes				
United States	2 551	5 201 000	2 031	4 527 000
Venezuela	3 052	4 681 000	2 489	3 671 000
Iran	3 606	6 440 000	2 140	3 654 000
Pakistan	1 248	1 881 000	2 468	3 558 000
Bangladesh	–	–	1 204	1 826 000
Switzerland	1 242	1 537 000	990	1 370 000
Dominican Republic	769	1 155 000	638	911 000
Israel	774	1 094 000	426	616 000
Nigeria	544	886 000	252	463 000
Thailand	230	358 000	140	227 000
Other countries	1 378	2 382 000	44	128 000
Total	15 394	25 615 000	12 822	20 951 000
Copper plates, sheet, strip and flat products				
United States	4 830	10 574 000	5 750	13 533 000
Venezuela	150	368 000	169	413 000
Thailand	60	90 000	198	316 000
New Zealand	3	6 000	8	21 000
Puerto Rico	3	6 000	1	4 000
Colombia	20	44 000	–	–
Total	5 066	11 088 000	6 126	14 287 000
Copper pipe and tubing				
United States	3 754	7 357 000	4 215	9 448 000
West Germany	790	1 333 000	1 294	2 476 000
Israel	426	847 000	620	1 362 000
Spain	227	465 000	515	1 185 000
Venezuela	108	328 000	204	552 000
Lebanon	33	122 000	78	297 000
United Kingdom	70	144 000	105	249 000
Algeria	553	1 071 000	96	197 000
Emirates, U.A.	–	–	40	158 000
Saudi Arabia	20	54 000	61	132 000
Other countries	489	1 052 000	286	706 000
Total	6 470	12 773 000	7 514	16 762 000
Copper wire and cable (not insulated)				
United States	195	279 000	237	383 000
Nigeria	–	–	38	88 000
Thailand	230	366 000	59	83 000
Saudi Arabia	8	16 000	24	45 000
Pakistan	230	401 000	4	9 000
Other countries	12	24 000	56	98 000
Total	675	1 086 000	418	706 000

Table 1. (cont'd)

	1976		1977^p	
	(tonnes)	($)	(tonnes)	($)
Exports (cont'd)				
Copper alloy refinery shapes				
United States	7 305	14 114 000	10 917	22 322 000
Venezuela	99	230 000	136	294 000
Ecuador	1	6 000	26	65 000
Japan	51	63 000	51	64 000
Belgium-Luxembourg	34	82 000	23	58 000
Guatemala	3	7 000	11	30 000
New Zealand	22	54 000	3	8 000
Barbados	21	73 000	—	—
Other countries	3	8 000	2	10 000
Total	7 539	14 637 000	11 169	22 851 000
Copper alloy pipe and tubing				
United States	2 109	4 374 000	2 783	6 733 000
Emirates, U.A.	—	—	1 006	4 095 000
Venezuela	—	—	33	96 000
New Zealand	14	45 000	22	61 000
Australia	13	52 000	21	41 000
Panama	—	—	10	21 000
Israel	43	103 000	7	18 000
Pakistan	14	38 000	. .	1 000
United Kingdom	16	46 000	—	—
Other countries	12	31 000	—	—
Total	2 221	4 689 000	3 882	11 066 000
Copper alloy wire and cable, not insulated				
United States	224	373 000	304	476 000
New Zealand	16	49 000	13	50 000
Venezuela	—	—	4	20 000
Philippines	—	—	4	19 000
Australia	16	56 000	3	13 000
Other countries	11	34 000	. .	4 000
Total	267	512 000	328	582 000
Copper alloy fabricated materials, nes				
United States	552	1 531 000	840	2 422 000
India	—	—	204	818 000
Portugal	—	—	173	583 000
United Kingdom	227	449 000	158	330 000
Thailand	—	—	21	33 000
Japan	105	125 000	—	—
Other countries	32	93 000	35	109 000
Total	916	2 198 000	1 431	4 295 000

Table 1. (cont'd)

	1976		1977p	
	(tonnes)	($)	(tonnes)	($)
Exports (cont'd)				
Wire and cable insulated[2]				
United States	3 612	8 242 000	4 379	12 043 000
Iran	642	1 754 000	2 367	6 674 000
Pakistan	249	581 000	2 352	4 969 000
Saudi Arabia	171	333 000	1 491	3 056 000
Dominican Rep.	548	1 472 000	574	1 617 000
Libya	–	–	638	1 310 000
Indonesia	658	1 214 000	609	1 173 000
Trinidad-Tobago	132	293 000	314	803 000
Singapore	63	124 000	370	737 000
Malaysia	1	2 000	159	532 000
Brazil	6	20 000	210	435 000
Leew-Wind Is.	–	–	115	357 000
Panama	272	516 000	129	312 000
South Africa	67	325 000	56	262 000
Ecuador	70	376 000	95	260 000
Bermuda	151	394 000	103	254 000
Philippines	748	1 746 000	101	246 000
Emirates, U.A.	120	154 000	180	246 000
Chile	2	8 000	60	245 000
Guatemala	374	797 000	71	184 000
Malta	182	463 000	–	–
Turkey	379	871 000	–	–
Other countries	1 211	3 152 000	662	2 175 000
Total	9 658	22 837 000	15 035	37 890 000
Total exports of copper and products		888 123 000		870 542 000
Imports				
Copper in ores, concentrates and scrap	13 930	14 849 000	4 605	3 152 000
Copper refinery shapes	9 122	12 998 000	18 819	28 560 000
Copper bars, rods and shapes, nes	4 083	6 464 000	2 397	4 052 000
Copper plates, sheet strip and flat products	533	1 223 000	913	2 146 000
Copper pipe and tubing	4 127	8 918 000	2 187	5 366 000
Copper wire and cable, except insulated	973	2 818 000	1 313	3 848 000
Copper alloy scrap (gross weight)	4 743	4 809 000	3 765	3 147 000
Copper powder	351	767 000	604	1 321 000
Copper alloy refinery shapes, rods and sections	6 663	11 025 000	8 089	14 413 000
Brass plates, sheet and flat products	3 867	7 133 000	3 815	7 431 000
Copper alloy plates, sheet, strip and flat products	927	3 017 000	1 432	4 497 000
Copper alloy pipe and tubing	2 794	6 890 000	2 477	6 704 000
Copper alloy wire and cable, except insulated	483	1 669 000	592	1 880 000
Copper and alloy fabricated material, nes	1 760	5 348 000	2 532	7 230 000
Insulated wire and cable	. .	27 082 000	. .	40 450 000
Copper oxides and hydroxides	240	612 000	258	508 000
Copper sulphate	1 406	681 000	2 411	1 315 000
Copper alloy castings	298	954 000	345	1 182 000
Total imports of copper and products	. .	117 257 000	. .	137 202 000

Table 1. (concl'd)

	1976		1977p	
	(tonnes)	($)	(tonnes)	($)
Consumption[3]				
Refined	206 205	. .	200 372	. .

Source: Statistics Canada.
[1]Blister copper plus recoverable copper in matte and concentrate exported. [2]Includes also small quantities of non-copper wire and cable, insulated. [3]Producers' domestic shipments, refined copper.
— Nil; pPreliminary; . . Not available; nes Not elsewhere specified.

Norita and main Orchan properties from December 2, 1977 until after year-end, in the face of deteriorating prices for zinc metal and a world oversupply situation.

Ontario. Union Minière Explorations and Mining Corporation Limited (Umex) reduced production at its Thierry mine to 1 800 tonnes a day from 3 600 tonnes a day in 1977. Production from the open pits ended in July and August, and underground production began in October, supplemented by ore from a surface stockpile.

As a result of the accumulation of excessive nickel inventories Falconbridge Nickel Mines Limited reduced production and employment in 1977. Sudbury operations were shut down from September 11 to October 9, over the Remembrance Day weekend, and between Christmas and New Year. A further employment reduction of 750 jobs was announced for 1978. In spite of weak metal markets and reduced cash flow from operations, Falconbridge continued with its smelter modernization program at Sudbury. The Hardy Pit and Longvack South mine were closed due to ore reserve exhaustion. The Lockerby mine began production in March 1977.

Inco Limited was forced by the same factors to announce in July reductions in employment and production. In October, Inco decided to make further cuts and announced a substantial decrease in nickel production for 1978, and employment reductions of 3 450. Because copper is coproduced with nickel at the Sudbury area mines of both Falconbridge and Inco, these nickel production cuts in 1977 and 1978 will also substantially reduce copper production.

The Lyon Lake mine of Mattagami Lake Mines Limited is scheduled to begin production in the second quarter of 1978. Mine development continued throughout 1977. More accurate definition of reserves in the known orebodies was undertaken in 1977 and indications were found of additional ore at lower levels of the mine.

Texasgulf Inc. announced a 40 per cent reduction in exploration spending for 1978, deferred completion of the new Timmins copper smelter and refinery, and of the No. 2 underground mine. In addition, Texasgulf published plans to close its Timmins operations for the entire month of July 1978. These measures were taken in response to poor metal market conditions, reduced cash flow, and high metal inventories. Initially promising results were obtained from exploration drilling adjacent to the Kidd Creek mine but a follow-up drilling program gave disappointing results.

Selco Mining Corporation Limited decided to undertake a program of deep exploration at the South

Table 2. Canada, copper production, trade and consumption, 1960, 1965, 1970 and 1975-77

	Production		Exports			Imports	Consumption[2]
	All forms[1]	Refined	Ore and matte	Refined	Total	Refined	Refined
	(tonnes)						
1960	398 492	378 322	43 212	252 257	295 469	23	106 718
1965	460 738	393 839	78 925	181 283	260 208	5 214	203 830
1970	610 279	493 261	161 377	265 264	426 641	13 192	215 834
1975	733 826	529 197	314 518	319 814	634 332	10 908	185 198
1976	730 930	510 469	303 055	317 121	620 176	9 122	206 205
1977p	780 633	508 767	279 509	294 244	573 753	18 819	200 372

Source: Statistics Canada.
[1]Blister copper, plus recoverable copper in matte and concentrate exported. [2]Producers' domestic shipments, refined copper.
pPreliminary.

Bay mine. The shaft will be deepened to 640 metres from 540 metres to provide access. A new all-weather road was completed into the Detour mine property. Two separate underground exploration programs were begun in the "B" and "A-1" ore zones, in addition to further exploration drilling from the surface. The underground programs are scheduled for completion by the end of 1978.

Manitoba. The Manibridge mine of Falconbridge Nickel Mines Limited was closed in April due to ore reserve exhaustion after producing 46 000 tonnes of ore in the first four months of the year.

Sherritt Gordon Mines Limited decided in 1977 to proceed with the development of the Ruttan underground mine. By year-end, development was under way and major equipment purchases had begun. Very encouraging results were obtained from a deep drilling program at the Ruttan. Additional tonnages of substantially higher grade ore than was mined from the open pit have been indicated. Operations at the open pit, due to end in 1982, improved substantially during 1977.

Hudson Bay Mining and Smelting Co., Limited opened a new mine, the Centennial mine, on June 30. The Centennial mine is located 25 kilometres (km) southeast of Flin Flon, and is expected to produce 620 tonnes a day of zinc-copper ore. The Westarm mine, another new zinc-copper mine, was scheduled to begin commercial production early in 1978. Construction began on a new concentrator at the Stall Lake Mine, six km from the town of Snow Lake. The new mill, which is expected to be in operation early in 1979, will treat 3 400 tonnes of ore a day from the nearby Stall Lake, Anderson Lake, Osborne Lake, Chisel Lake, Ghost Lake and Snow Lake mines.

British Columbia. Afton Mines Ltd. made steady progress throughout 1977 in the development of its mine-mill-smelter complex near Kamloops, B.C. Mine operations began in May 1977. A 10-year sales agreement was signed with two United Kingdom companies in August for the sale of 27 200 tonnes of blister copper a year. The concentrator started up late in October and the smelter was scheduled to begin operation in March 1978.

Another major development on the British Columbia mining scene in 1977 was the change in ownership of Bethlehem Copper Corporation. Bethlehem has a direct interest in the Valley Copper Mines Limited, a Cominco Ltd. subsidiary. In April it was learned that Cominco, which has a controlling interest in Valley Copper, had acquired a 12 per cent equity interest in Bethlehem. By the end of July Cominco had increased this to over 38 per cent, but failed to acquire the 26 per cent interest in Bethlehem held by Granges Essem A/B of Sweden, which was sold instead to Gulf Resources & Chemical Corporation. The Valley Copper orebody, located in the Highland Valley between the mines of Bethlehem and Lornex Mining Corporation Ltd. could well be the next major copper deposit to be developed in B.C.

Brenda Mines Ltd. reported further improvements in concentrator performance in 1977 as a result of refining and extending the degree of computer control to include grinding operations and part of the flotation operations. The copper content of ores mined in 1979 and 1980 are expected to fall below the ore reserves average grade, but are expected to recover in subsequent years. The truck fleet was expanded to 15 from 12 in preparation for higher stripping requirements in future years. Ore reserves at December 31, 1977 were 99 000 000 tonnes grading 0.165 per cent copper and 0.040 per cent molybdenum.

Wesfrob Mines Limited shut down milling operations for the last two months of 1977 due to reduced shipments and large inventories of iron concentrates. Copper production was reduced to 1 230 tonnes, from 2 330 tonnes in 1976.

Gibraltar Mines Ltd. mined a lower average grade of ore during 1977 than in 1976. Average copper grade mined was 0.38 per cent in 1977 compared with 0.45 per cent in 1976. Waste removal per tonne of ore increased to 1.35 tonnes compared with 0.85 tonnes in 1976. Total ore reserves remaining at the end of 1977 were 259 million tonnes with an average grade of 0.37 per cent copper and 0.016 per cent molybdenum. The anticipated waste/ore ratio over the long term is 2.35/1. The Pollyanna Stage I pit replaced the Granite Lake Stage I pit as the main ore source in August 1977. Mining of the Pollyanna pit will continue until the third quarter of 1979 when mining will be resumed in the Gibraltar East pit. Gibraltar warned shareholders and employees in 1977 that, should poor market conditions for copper continue through 1978, the mine could cease operating in 1980.

Lornex Mining Corporation Ltd. recorded a decline in copper production to 64 000 tonnes in 1977 compared with 66 000 tonnes in 1976 as a result of a slightly lower average mill head grade of ore. There was also an increase in the ratio of waste handled to ore mined by about 32 per cent.

Craigmont Mines Limited raised its ore cut-off grade from 0.7 per cent to 1.0 per cent copper due to the low level of copper prices. Geological ore reserves remaining at the end of October, 1977 were 1 852 000 tonnes with an average grade of 2.53 per cent copper. Production is expected to end in 1979 when the presently known ore reserves are exhausted.

Improved ore grades and a 15 per cent increase in the tonnage of ore milled resulted in a 23 per cent increase in copper production at the Granisle mine of Granby Mining Corporation. Equipment purchases were made to facilitate increased waste removal at Granisle.

The Granduc mine at Stewart, British Columbia will be closed at the end of June, 1978. Newmont Mining Corporation and ASARCO Incorporated, both of which have interests in the operation, wrote off their investments in 1977. Mine development was discontinued in 1977.

Smelters and refineries

Copper anode production from the Gaspé smelter of Noranda Mines Limited increased for the fourth successive year in 1977. Vat leaching of oxide ore to produce cement copper started on a production scale in May but was suspended in November, pending the development of a practical procedure for lowering the iron content of the plant effluent.

At the Horne Smelter of Noranda Mines Limited concentrate supplies again fell short of plant capacity in 1977. The No. 2 reverberatory furnace was converted to a wet-charge operation and recommenced operations in September. The Noranda Continuous Reactor operations improved steadily, as did overall smelter metallurgical performance.

Falconbridge Nickel Mines Limited continued construction during the year on its smelter modernization program at Falconbridge, Ontario. Expenditures up to the end of 1977 amounted to $66 million and construction was 90 per cent complete. One furnace was scheduled for start-up in April, 1978.

Sherritt Gordon Mines Limited and Cominco Ltd. jointly developed the S-C process for production of nonferrous metals from concentrates by hydrometallurgical methods. Technical and financial details of the process were published in 1977, based upon a successful one-year pilot plant test in 1976 on copper sulphide concentrates. The process, partly funded by a federal government Program for Advancement of Industrial Technology (PAIT) grant, is available for licencing from the developers by other metal producers. In the S-C process, concentrate feed is pelletized, roasted and acid-leached with sulphuric acid. The sequence of metals removal by leaching is: iron, zinc, copper, leaving a precious-metals concentrate. Copper is recovered by electrowinning and sulphur is produced in elemental form. The S-C process is expected to have lower capital costs than flash smelting and to have competitive operating costs. It is seen as especially attractive for the treatment of low-grade copper concentrates containing zinc.

Work on the mine-smelter complex of Afton Mines Ltd. proceeded during 1977 and start-up of the top blown rotary converter unit was expected to take place early in 1978. The official opening of the complex was scheduled for April, 1978.

Production of anode copper at the Flin Flon, Manitoba smelter of Hudson Bay Mining and Smelting Co., Limited increased to 62 843 tonnes in 1977 from 55 588 tonnes in 1976. The improved performance was the result of uninterrupted furnace operation and increased daily throughout. The furnace rebricking cycle has been extended to 18 months from the previous 12-month cycle.

World supply and demand

World mine production of copper grew from 7 900 300 tonnes in 1976 to 8 110 500 tonnes in 1977, an increase of 3 per cent. In the non-communist countries, the largest increases occurred in Chile and Canada.

World production of refined copper also increased in 1977, but by a greater amount, from a total of 8 849 000 tonnes in 1976, to 9 127 000 tonnes in 1977, an increase of 3.1 per cent. Substantial individual increases were recorded by Belgium, South Africa, Japan and Peru.

In the United States, 1977 was a year for copper industry labour contract renewals. The three-year contracts between most U.S. producers and the unions expired on June 30. Three major producers; Kennecott Copper Corporation, Newmont Mining Corporation and Magma Copper Company, agreed to new contract terms in July. Other producers followed, and by the end of August only ASARCO Incorporated was still on strike. Total production lost as a result of the contract renewals was of the order of 110 000 tonnes. The aftermath was a period of very depressed demand and prices as consumers reduced inventories built up as a hedge against a lengthy strike. There was also a considerable psychological let-down as it had been anticipated that a long strike would have had a very beneficial effect on world copper stocks and prices.

In Peru, the rapid expansion of the country's copper-producing capacity continued in 1977. Cerro Verde was due to begin production during 1977 with a capacity of 33 000 tonnes of copper a year. A further major mine modernization and expansion program was started during the year at Cobriza. By 1980, capacity at Cobriza is scheduled to quadruple to 56 000 tonnes a year.

(text continued on page 163)

Table 3. Principal copper mines in Canada, 1977 and (1976)

Company and Location	Mill or mine Capacity	Grade of Ore Milled: Copper	Zinc	Lead	Nickel	Silver	Gold	Ore Milled	Copper Concentrates Produced	Grade of Copper in Concentrates	Contained Copper Produced[1]	Destination of Copper Concentrates[2]
	(tonnes ore/day)	(%)	(%)	(%)	(%)	(gms/tonne)	(gms/tonne)	(tonnes)	(tonnes)	(%)	(tonnes)	
Newfoundland												
ASARCO Incorporated, Buchans	1 100	0.99	10.76	6.12	–	106.95	0.75	174 180	3 670	26.60	1 558	11
	(1 100)	(0.96)	(10.69)	(6.03)	(–)	(105.59)	(0.71)	(188 694)	(3 752)	(26.44)	(1 627)	(9)
Consolidated Rambler Mines Limited, Ming mine, Baie Verte	1 100	4.25	–	–	–	23.07	2.44	197 949	31 347	24.0	8 293	2,12
	(1 100)	(3.68)	(–)	(–)	(–)	(21.73)	(2.61)	(187 284)	(28 264)	(23.0)	(6 512)	(2,6,12)
New Brunswick												
Brunswick Mining and Smelting Corporation Limited, No. 6 and No. 12 mines Bathurst	9 100	0.37	7.82	3.11	–	84.75	–	3 134 419	17 872	21.9	6 728	1
	(9 100)	(0.38)	(7.18)	(2.87)	(–)	(68.3)	(–)	(2 247 234)	(6 728)	(20.86)	(3 233)	(1)
Heath Steele Mines Limited, Newcastle	3 650	1.22	3.90	1.53	–	68.2	0.69	1 150 338	34 544	22.56	9 215	1
	(3 600)	(0.99)	(4.53)	(1.85)	(–)	(77.82)	(0.61)	(1 052 568)	(26 027)	(22.13)	(7 036)	(1,2)
Nigadoo River Mines Limited, Robertville	1 000	0.15	2.54	2.39	–	85.7	–	179 458	..	..	..	..
	(1 000)	(0.16)	(2.63)	(2.43)	(–)	(93.94)	(–)	(198 698)	(398)	(20.24)	(166)	(9)
Quebec												
Campbell Chibougamau Mines Ltd., Cedar Bay, Henderson mines, Merrill pit, Chibougamau	4 000	1.43	–	–	–	7.5	1.94	264 309	15 235	23.32	3 553	2
	(3 600)	(1.62)	(–)	(–)	(–)	(8.6)	(2.42)	(132 996)	(8 297)	(24.20)	(2 008)	(2)

Falconbridge Copper Limited, Lake Dufault Division, Norbec and Millenbach mines, Noranda	1 400 (1 400)	3.27 (3.09)	3.74 (3.44)	— (—)	— (—)	38.7 (41.5)	0.78 (0.82)	389 967 (458 447)	46 070 (50 224)	26.22 (26.56)	12 053 (13 339)	2,12 (2)
Opemiska Division, Perry, Cooke, Springer mines, Chapais	2 700 (2 700)	2.04 (2.01)	— (—)	— (—)	— (—)	13.7 (12.5)	1.06 (0.60)	926 918 (947 054)	75 598 (75 394)	.. (..)	18 164 (18 166)	2 (2)
Gaspé Copper Mines, Limited, Needle Mountain and Copper Mountain mines, Murdochville	30 600 (30 600)	0.53 (0.53)	— (—)	— (—)	— (—)	.. (..)	.. (..)	11 051 410 (11 139 325)	207 444 (213 720)	24.1 (23.75)	50 013 (45 493)	1 (1)
Lemoine Mines Limited Lemoine Mine Chibougamau	350 (350)	4.67 (4.35)	10.64 (10.03)	— (—)	— (—)	107.0 (102.6)	5.64 (5.49)	110 677 (88 237)	19 120 (16 248)	25.32 (24.57)	4 840 3 746	2,11 (2,11)
Madeleine Mines Ltd., St. Anne des Monts	— (2 300)	— (1.07)	— (—)	— (—)	— (—)	— (..)	— (—)	— (738 398)	— (..)	— (33.20)	— (7 391)	— (1)
Mattagami Lake Mines Limited, Matagami	3 500 (3 500)	0.52 (0.55)	6.64 (73.3)	— (0.10)	— (—)	30.9 (31.9)	0.48 (0.48)	946 343 (1 112 156)	15 399 (18 633)	24.4 (24.2)	4 182 (5 175)	2 (2)
Noranda Mines Limited, Horne Division, Noranda	— (1 900)	— (1.40)	— (—)	— (—)	— (—)	— (14.1)	— (4.35)	— (123 746)	— (23 292)	— (6.98)	— (1 626)	— (2)
Orchan Mines Limited, Orchan and Garon Lake mines, Matagami	1 900 (1 700)	0.54 (0.78)	6.35 (6.74)	— (—)	— (—)	29.06 (31.9)	0.38 (0.51)	508 273 (424 260)	7 901 (9 933)	24.30 (25.04)	1 920 (2 487)	2 (2)
Patino Mines (Québec) Limited, Copper Rand, Copper Cliff and Portage mines, Chibougamau	2 500 (2 500)	1.74 (1.72)	— (—)	— (—)	— (—)	10.63 (10.3)	3.65 (3.08)	605 102 (516 356)	44 122 (34 508)	22.83 (24.03)	10 071 (8 293)	2 (2)

Table 3. (cont'd)

Company and Location	Mill or mine Capacity	Grade of Ore Milled: Copper	Zinc	Lead	Nickel	Silver	Gold	Ore Milled	Copper Concentrates Produced	Grade of Copper in Concentrates	Contained Copper Produced[1]	Destination of Copper Concentrates[2]
	(tonnes ore/day)	(%)	(%)	(%)	(%)	(gms/ tonne)	(gms/ tonne)	(tonnes)	(tonnes)	(%)	(tonnes)	
Ontario												
Union Minière Explorations and Mining Corp. Limited (UMEX) Thierry mine, Pickle Lake	3 600 (3 600)	1.26 (1.14)	— (—)	— (—)	0.13 (0.10)	8.2 (7.5)	.. (..)	875 810 (230 608)	36 564 (9 541)	27.40 (24.80)	10 019 (2 366)	2 (2)
Falconbridge Nickel Mines Limited, Lockerby, Falconbridge, Hardy Open pit, Longvac South, North and Strathcona mines, Sudbury	11 200 (12 700)	0.74 (..)	— (—)	— (—)	1.45 (1.34)	.. (..)	.. (..)	2 599 318 (2 920 555)	.. (..)	.. (..)	18 057 (15 457)[3]	4 (4)
Falconbridge Copper Limited, Sturgeon Lake Joint Venture, Sturgeon Lake	1 100 (1 100)	3.46 (2.15)	10.44 (9.57)	1.26 (1.23)	— (—)	206.4 (183.8)	0.89 (0.55)	383 883 (377 257)	55 249 (28 499)	22.18 (22.42)	12 408 (6 390)	2 (2)
Inco Limited, Clarabelle, Coleman, Copper Cliff North, Copper Cliff South, Frood, Stobie, Garson, Kirkwood, Levack, Little Stobie, MacLennan and Crean Hill mines Sudbury, and includes Shebandowan mine, Shebandowan	61 200 (61 200)	1.15 (1.13)	— (—)	— (—)	1.31 (1.33)	.. (..)	.. (..)	14 628 668 (14 949 699)	.. (..)	.. (..)	154 766[3] (161 474)[3]	3 (3)

Kanichee Mining Incorporated, Temagami	— (500)	— (..)	— (—)	— (—)	— (..)	— (—)	— (—)	— (5 213)	— (..)	— (6 96)	— (31)	— (4)
Mattabi Mines Limited, Sturgeon Lake	2 700 (2 700)	1.01 (1.23)	8.40 (8.13)	0.84 (0.76)	— (—)	121.7 (121.0)	— (..)	938 427 (966 798)	31 109 (37 738)	26.35 (26.20)	8 739 (9 963)	2 (2)
Noranda Mines Limited, Geco Division, Manitouwadge	4 500 (4 500)	1.94 (1.69)	2.62 (2.55)	0.11 (0.12)	— (—)	41.8 (44.2)	0.17 (0.17)	1 591 675 (1 529 781)	104 752 (88 875)	27.57 (27.01)	29 497 (24 530)	2 (2)
Pamour Porcupine Mines, Limited; Schumacher Division, Schumacher	2 700 (2 700)	0.36 (..)	— (—)	— (—)	— (—)	2.65 (..)	2.57 (..)	909 938 (846 504)	12 115 (11 274)	.. (25.43)	2 805 (2 867)	2 (2)
Selco Mining Corporation Limited, South Bay Mine, Uchi Lake	500 (500)	1.68 (1.73)	9.87 (10.38)	— (—)	— (—)	76.8 (79.9)	— (—)	164 792 (163 482)	9 464 (9 387)	26.30 (26.28)	2 591 (2 504)	2 (2)
Teck Corporation Limited, Silverfields Mining Division, Cobalt District	250 (200)	0.6 (0.5)	— (—)	— (—)	0.25 (0.2)	356.5 (246.8)	— (—)	84 468 (69 989)	19 (18)	.. (..)	.. (..)	.. (..)
Texasgulf Inc. Kidd Creek Mine Timmins	8 165 (9 100)	1.84 (1.74)	72.6 (8.05)	0.22 (0.30)	— (—)	104 (119.7)	— (—)	3 299 033 (3 242 279)	220 892 (206 657)	24.75 (23.95)	58 593 (51 921)	2 (2)
Willroy Mines Limited Manitouwadge Division Manitouwadge	.. (1 500)	.. (0.56)	.. (3.67)	.. (0.17)	.. (—)	.. (54.5)	— (—)	.. (311 431)	.. (6 422)	.. (26.20)	.. (1 614)	.. (2)

Manitoba

Dumbarton Mines Limited, Maskwa East and West Extensions, Bird River	— (—)	— (0.29)	— (—)	— (—)	— (1.04)	— (—)	— (—)	— (128 111)	— (—)	— (—)	— (338)	— (4)

Table 3. (cont'd)

Company and Location	Mill or mine Capacity	Grade of Ore Milled: Copper	Zinc	Lead	Nickel	Silver	Gold	Ore Milled	Copper Concentrates Produced	Grade of Copper in Concentrates	Contained Copper Produced[1]	Destination of Copper Concentrates[2]
	(tonnes ore/day)	(%)	(%)	(%)	(%)	(gms/ tonne)	(gms/ tonne)	(tonnes)	(tonnes)	(%)	(tonnes)	
Manitoba (cont'd)												
Falconbridge Nickel	900	..	—	—	..	..	—	46 266	..[4]	..	..	4
Mines Limited,	(900)	(..)	(—)	(—)	(..)	(..)	(—)	(188 994)	(..)[4]	(..)	(..)	(3,4)
Manibridge mine,												
Wabowden												
Hudson Bay Mining	7 700	2.2	2.8	0.2		20.6	1.37	1 652 526	183 945	18.13	33 845	6
and Smelting Co.,	(7 700)	(2.3)	(2.7)	(0.2)	(—)	(20.6)	(1.37)	(1 417 617)	(174 670)	(17.02)	(30 173)	(6)
Limited,												
Anderson, Chisel Lake, Flin Flon, Ghost, Osborne, Stall Lake, White Lake, Centennial and Westarm mines,												
Flin Flon and Snow Lake												
Inco Limited,												
Birch, Pipe and	..	..	..	..	..	..	..	..	..	..	..	..
Thompson mines,	(16 700)	(..)	(—)	(—)	(..)	(—)	(—)	(2 751 947)	(..)[5]	(..)	(..)	(3)
Thompson												
Sherritt Gordon Mines	—	—	—	—	—	—	—	—	—	—	—	—
Limited,	(3 600)	(0.42)	(—)	(—)	(0.97)	(—)	(—)	(178 979)	(1 440)	(28.88)	(698)	(6)
Farley mine,	2 700	1.46	1.93	—	—	..	..	807 688	43 428	25.11	11 121	6
Lynn Lake	(2 700)	(1.56)	(1.68)	(—)	(—)	(—)	(—)	(755 123)	(43 412)	(25.32)	(11 121)	(6)
Fox mine,	9 100	1.13	1.95	—	—	..	..	2 261 227	92 313	24.79	23 741	2,6
Lynn Lake	(9 100)	(1.08)	(2.14)	(—)	(—)	(..)	(..)	(2 413 870)	(92 218)	(24.63)	(23 729)	(2,6,7)
Ruttan mine,												
Ruttan Lake												
British Columbia												
Afton Mines Ltd.,	6 350	..	—	—	—	..	..	122 340	1 071	57.65	618	—
Dominion pit,	(—)	(—)	(—)	(—)	(—)	(—)	(—)	(—)	(—)	(—)	(—)	(—)
Kamloops District												

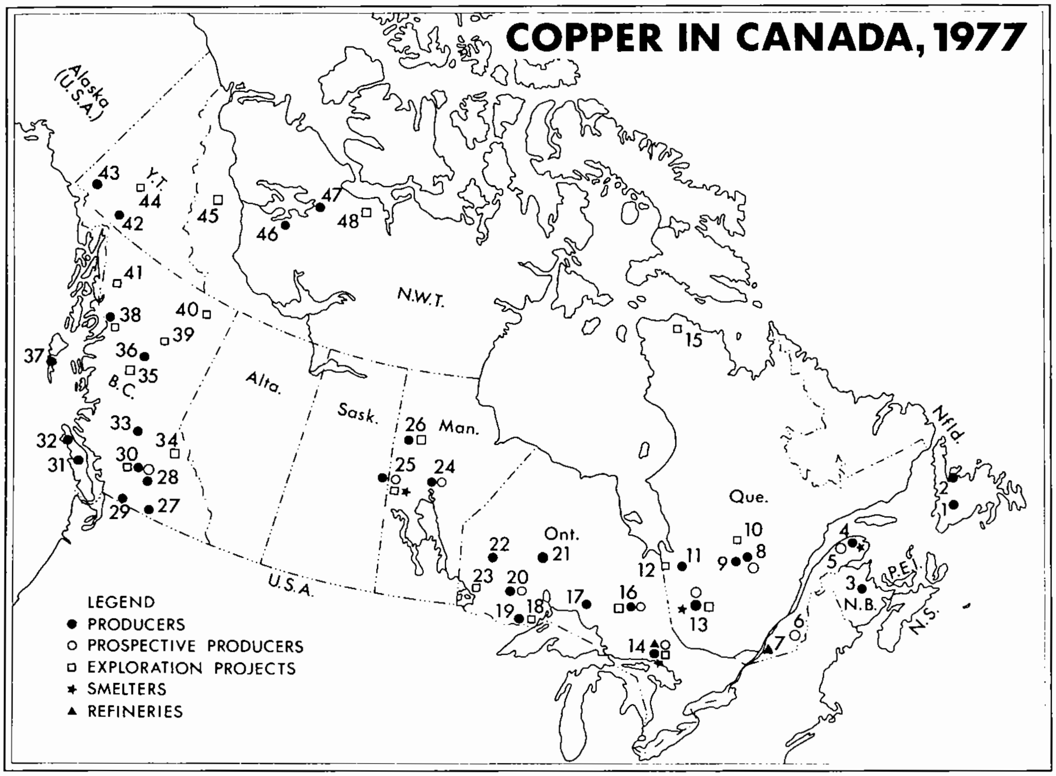
Bethlehem Copper Corporation, Heustis mine, Highland Valley	18 100 (18 100)	0.43 (0.444)	— (—)	— (—)	— (—)	.. (..)	.. (..)	5 554 885 (6 763 881)	.. (68 066)	44.84 (36.74)	20 650 (25 003)	10 (10)
Brenda Mines Ltd., Peachland	21 800 (21 800)	0.190 (0.167)	— (—)	— (—)	— (—)	.. (..)	.. (..)	9 634 483 (10 047 627)	54 838 (51 855)	29.42 (28.08)	16 134 (14 563)	2,10,12 (2)
Craigmont Mines Limited, Merritt	5 170 (4 900)	1.18 (1.29)	— (—)	— (—)	— (—)	— (—)	— (—)	1 884 350 (1 763 569)	77 052 (76 411)	27.97 (28.6)	21 550 (21 827)	10 (10)
Falconbridge Nickel Mines Ltd., Wesfrob Mines Limited, Tasu mine, Tasu Harbour, Q.C.I.	.. (5 300)	0.34 (..)	— (—)	— (—)	— (—)	.. (..)	.. (..)	.. (..)	6 000 (11 960)	.. (19.9)	1 227 (2 380)	10 (10)
Gibraltar Mines Ltd. (N.P.L.), McLeese Lake, Caribou District	36 300 (36 300)	0.38 (0.45)	— (—)	— (—)	— (—)	— (—)	— (—)	12 765 211 (7 672 345)	140 162 (111 090)	28.1 (26.0)	39 364 (28 883)	10 (..)
Granby Mining Corporation, Granisle Mine, Babine Lake	12 700 (12 700)	0.44 (0.42)	— (—)	— (—)	— (—)	.. (2.1)	.. (0.2)	4 538 342 (4 008 247)	54 875 (45 483)	34.96 (32.36)	17 137 (13 913)	.. (10,11)
Phoenix Copper Division, Greenwood	2 600 (2 600)	0.39 (0.50)	— (—)	— (—)	— (—)	5.1 (6.2)	0.5 (0.6)	833 829 (965 851)	10 083 (15 435)	26.35 (27.43)	2 657 (4 232)	9 (9)
Newmont Mines Limited, Granduc mine, Steward	7 300 (6 800)	1.31 (1.26)	— (—)	— (—)	— (—)	.. (..)	.. (..)	1 333 143 (1 315 914)	58 260 (54 107)	.. (..)	16 404 (15 670)	10 (9,10)
Similkameen Division, Ingerbelle pit, Princeton	22 000 (20 000)	0.373 (0.42)	— (—)	— (—)	— (—)	0.64 (..)	0.16 (..)	7 134 400 (6 355 743)	83 667 (84 567)	27.43 (..)	22 948 (23 133)	9,10 (9,10)
Lornex Mining Corporation Ltd., Lornex mine, Highland Valley	43 545 (40 800)	0.481 (0.511)	— (—)	— (—)	— (—)	— (..)	.. (..)	15 480 725 (15 436 996)	204 441 (204 021)	32.36 (33.48)	66 157 (66 094)[6]	9,10,12 (9,10,12)

Table 3. (concl'd)

Company and Location	Mill or mine Capacity	Grade of Ore Milled: Copper	Zinc	Lead	Nickel	Silver	Gold	Ore Milled	Copper Concentrates Produced	Grade of Copper in Concentrates	Contained Copper Produced[1]	Destination of Copper Concentrates[2]
	(tonnes ore/day)	(%)	(%)	(%)	(%)	(gms/ tonne)	(gms/ tonne)	(tonnes)	(tonnes)	(%)	(tonnes)	
British Columbia (concl'd)												
Noranda Mines Ltd., Bell Copper Division, Babine Lake	9 100 (9 100)	0.428 (0.429)	— (—)	— (—)	— (—)	— (..)	0.31 (0.34)	4 408 882 (1 925 259)	59 374 (25 749)	26.76 (25.83)	15 890 (6 639)	2 (2)
Texada Mines Ltd., Vanada	— (4 100)	— (0.24)	— (—)	— (—)	— (—)	— (2.2)	— (0.07)	— (848 483)	— (5 673)	— (21.07)	— (1 195)	— (10)
Utah Mines Ltd., Island Copper Mine, Coal Harbour, V.I.	34 500 (34 500)	0.42 (0.47)	— (—)	— (—)	— (—)	.. (..)	.. (..)	13 110 000 (12 247 000)	202 000 (214 459)	23.0 (23.0)	46 600 (48 988)	10 (10)
Western Mines Limited, Lynx and Myra Falls mines, Buttle Lake, V.I.	700 (700)	1.14 (1.19)	7.58 (7.73)	1.34 (1.42)	— (—)	147.1 (169.3)	2.71 (3.08)	269 069 (269 298)	8 670 (9 012)	27.66 (27.74)	2 857 (2 953)	10 (10)
Yukon Territory												
Whitehorse Copper Mines Ltd., Little Chief mine, Whitehorse	2 300 (2 300)	1.65 (1.69)	— (—)	— (—)	— (—)	0.93 (..)	9.60 (..)	817 790 (726 507)	28 259 (26 937)	42.28 (41.05)	11 947 (11 051)	6 (6)
Northwest Territories												
Echo Bay Mines Ltd., Port Radium	150 (100)	0.9 (..)	— (—)	— (—)	— (—)	1 600 (..)	— (—)	34 270 (35 731)	2 015 (2 407)	13.4 (16.0)	275 (398)	9 (9)
Terra Mining and Exploration Ltd., Silver Bear mine, Great Slave Lake	160 (200)	0.29 (0.2)	— (..)	— (..)	— (..)	1 242 (1 491.4)	— (—)	26 334 (41 812)	.. (..)	.. (..)	69 (64)	.. (..)

Norex mine,	—	0.19	0.6	1.4	—	1 949	—	7 174	..	..	10[e]	..
Great Slave Lake		(—)	(—)	(—)	(—)	(—)	(—)	(—)	(—)	(—)	(—)	(—)

Sources: Company reports and technical press.
[1]Total copper in concentrates. [2]Destination of concentrates: 1. Gaspé Copper Mines, Limited; 2. Noranda Mines Limited; 3. Inco, Sudbury; 4. Falconbridge Nickel, Sudbury; 5. Falconbridge Nickel, Norway; 6. Hudson Bay Mining and Smelting Co. Ltd.; 7. Sherritt Gordon Mines Ltd.; 8. Afton Mines Ltd.; 9. United States; 10. Japan; 11. Germany; 12. Unspecified and other countries. [3]Derived from deliveries not reported directly. [4]Included in the Sudbury total for Falconbridge Nickel Mines Limited. [5]Included in the Copper Cliff total for Inco. [6]Payable copper only.
— Nil; . . Not available; [e]Estimate.



Producers
(numbers correspond to those on map above)

1. ASARCO Incorporated
2. Consolidated Rambler Mines Limited
3. Brunswick Mining and Smelting Corporation Limited (No. 6 and No. 12 mines)
   Heath Steele Mines Limited
   Nigadoo River Mines Limited
4. Gaspé Copper Mines, Limited
8. Campbell Chibougamau Mines Ltd. (Cedar Bay, Henderson, Merrill pit) Patino Mines (Quebec) Limited (Copper Rand, Lemoine mines)
9. Falconbridge Copper Limited, Opemiska Division (Perry, Springer, Cooke mines)
11. Mattagami Lake Mines Limited
    Orchan Mines Limited (Orchan, Norita mines)
13. Falconbridge Copper Limited, Lake Dufault Division (Norbec, Millenbach mines)
14. Falconbridge Nickel Mines Limited (Lockerby, Falconbridge, Hardy, Longvack South, North, Strathcona mines)
    Inco Limited (Coleman, Copper Cliff North, Copper Cliff South, Creighton, Frood Stobie, Garson, Levack, Levack West, Little Stobie, Victoria, Crean Hills mines)
16. Texasgulf Inc. (Kidd Creek mine)
    Pamour Porcupine Mines, Limited
17. Noranda Mines Limited, Geco Division
    Willroy Mines Limited (Willecho, Willroy mines)
19. Inco (Shebandowan)
20. Sturgeon Lake Mines Limited
    Mattabi Mines Limited
21. Union Minière Explorations and Mining Corporation Limited (Thierry mine)
22. Selco Mining Corporation Limited, South Bay Division
24. Falconbridge Nickel Mines Limited (Manibridge mine)
    Inco (Birchtree, Pipe and Thompson mines)
25. Hudson Bay Mining and Smelting Co., Limited (Anderson, Chisel, Flin Flon, Ghost, Osborne, Schist, Stall, White Lake mines and Centennial mine)
26. Sherritt Gordon Mines Limited (Fox and Ruttan mines)
27. Granby Mining Corporation, Phoenix Copper Division
28. Brenda Mines Ltd.

29. Similkameen Mining Company Limited (Ingerbelle and Similkameen deposits)
30. Bethlehem Copper Corporation (Huestis, Iona and Jersey mines)
    Lornex Mining Corporation Ltd.
    Craigmont Mines Limited
    Afton Mines Ltd.
31. Western Mines Limited (Lynx, Myra mines)
32. Utah Mines Ltd. (Island Copper mine)
33. Gibraltar Mines Ltd.
36. Granby Mining Corporation (Granisle mine)
    Noranda Mines Limited, Bell Copper Division
37. Falconbridge Nickel Mines Limited (Wesfrob mine)
38. Newmont Mines Limited (Granduc mine)
42. Whitehorse Copper Mines Ltd. (Little Chief mine)
46. Terra Mining and Exploration Limited
47. Echo Bay Mines Ltd.

Prospective producers*

5. Madeleine Mines Ltd.
6. Sullivan Mining Group Ltd. (Cupra, d'Estrie, Clinton mines)
8. Campbell Chibougamau Mines Ltd. (Gwillim, Original, Grandroy mines)
   Patino Mines (Quebec) Limited (Portage, Jaculet mines)
13. Falconbridge Copper Limited, Dufault Division (Corbet mine)
14. Falconbridge Nickel Mines Limited (Thayer Lindsay, East, Fecunis, South Longvac, Onaping mines)
    Inco (Murray, Totten, Levack East, Clarabelle mines)
16. Texasgulf Inc. (Kidd Creek No. 2 mine)
20. Mattagami Lake Mines Limited (Lyon Lake Division)
24. Inco (Soab, Birchtree mines)
25. Hudson Bay Mining and Smelting Co., Limited (Westarm mine)

Exploration projects**

10. Selco Mining Corporation Limited and Muscocho Exploration Limited
12. Selco Mining Corporation/Moore McCormack Resources Inc. (Detour Project)
13. Noranda Mines Limited (Magusi River property)
14. Falconbridge Nickel Mines Limited (Craig, Onex mines)
    Inco (Cryderman, Whistle mine)
15. New Quebec Raglan Mines Limited
16. Teck Corporation Limited (Montcalm township)
18. Great Lakes Nickel Limited
25. Hudson Bay Mining and Smelting Co., Limited (Hudvam, Rail, Reed, Wim mines, Lost Lake deposit)
    Stall Lake Mines Limited
26. Sherritt Gordon Mines Limited (Lynn Lake)
30. Bethlehem Copper Corporation (J.A., Maggie, Lake zone)
    Highmont Mining Corporation
    Leemac Mines Ltd.
    Valley Copper Mines Limited
34. Noranda Mines Limited (Goldstream River)
35. Equity Mining Corporation (Sam Goosly)
38. Consolidated Citex Resources Inc.
39. Falconbridge Nickel Mines Limited (Sustut deposit)
40. Davis-Keays Mining Co. Ltd.
41. Liard Copper Mines Ltd.
    Stikine Copper Limited
    Texasgulf Inc. (Red Group)
44. Silver Standard Mines Limited and Asarco Exploration Company of Canada, Limited
    United Keno Hill Mines Limited
    Falconbridge Nickel Mines Limited
    Canadian Superior Exploration Limited
45. Shell Canada Limited (Coates Lake)
48. Texasgulf Inc. (Izok Lake)

Smelters

4. Gaspé Copper Mines, Limited
13. Noranda Mines Limited
14. Falconbridge Nickel Mines Limited, Inco Limited
25. Hudson Bay Mining and Smelting Co., Limited

Refineries

7. Canadian Copper Refiners Limited
14. Inco Limited

*Only mines with announced production plans, and mines placed on standby.

**A more complete inventory is available in the publication, *A Survey of Known Mineral Deposits in Canada that Are Not Being Mined,* R.C. Annis, D.A. Cranstone and M. Vallée, Department of Energy, Mines and Resources, Ottawa, 1978.

Table 4. Prospective[1] copper prodcuers

Company and Location	Mill Capacity[2] and Ore Grade	Year Production Expected	Destination of Copper Concentrates	Remarks
New Brunswick				
Brunswick Mining and Smelting Corporation Limited, No. 12 mine, Bathurst	10 000 Cu 0.30 Pb 3.79 Zn 9.22	1979	Murdochville, Noranda	Expanding No. 12 mine to 10 000 tpd from 6 400. Development includes new 8 metre shaft. Pace of development reduced late in 1977.
Quebec				
Orchan Mines Limited, La Gauchetiere Township	700 Zn 4.5 Cu 0.9 Ag 17.14 gms/tonne	1978	Noranda	Deposit acquired from Phelps Dodge Corporation of Canada Limited. Will be developed by decline and 550 metre vertical shaft. Development delayed in 1977 pending completion of all-weather access road.
Ontario				
Texasgulf Inc., Kidd Creek No. 2 mine, Timmins	12 700 Cu 2.70 Zn 5.92 Pb 0.21 Ag 79.19 gms/tonne	1978	Timmins	Construction of 59 000 tpy copper smelter/refinery and mine expansion to 4.5 million tpy deferred in mid-development during 1977.
Falconbridge Nickel Mines Limited				
Thayer Lindsay mine, Falconbridge	— Cu ..	..	Falconbridge	
Fecunis mine	Ni ..		Falconbridge	On standby.
East mine	—	..	Falconbridge	On standby.
Onaping mine	Cu ..	..	Falconbridge	On standby.
Longvack South mine, Sudbury	Ni ..	..	Falconbridge	On standby.
Inco,	—		Copper Cliff	On standby.
Clarabelle	Cu ..	..	Copper Cliff	On standby.
Murray mine	Ni ..	..	Copper Cliff	On standby.
Totten mine		1984	Copper Cliff	New mine.
Levack East Sudbury				
Mattagami Lake Mines Limited, Lyon Lake mine, Sturgeon Lake	— Cu 1.15 Zn 6.66 Pb 0.63 Ag 116.2 gms/tonne	..	..	Development work suspended in Nov. 1977 pending increase in metal prices
Manitoba				
Hudson Bay Mining and Smelting Co., Limited, Westarm mine, Schist Lake	Cu 4.63	1978	Flin Flon	Shaft completed at 580 m and extensive mine development in 1976.

Table 4. (concl'd)

Company and Location	Mill Capacity[2] and Ore Grade	Year Production Expected	Destination of Copper Concentrates	Remarks
Manitoba (cont'd)				
Inco,	—			
Soab mine	Cu ..	..	Thompson	On Standby.
Birchtree mine	Ni ..			
Thompson				
Sherritt Gordon Mines Limited, Ruttan underground mine	9 100 Cu 1.87 Zn 1.02	1982	Noranda Flin Flon	Some production to augment open-pit ore before 1982. Major additions to ore reserves indicated by deep exploration drilling.

Sources: Company reports and technical press.
[1]Only mines with announced production plans and mines placed on standby. [2]Mill capacity in tonnes of ore a day.
— Nil; . . Not available.

Table 5. Canadian copper and copper-nickel smelter, 1977

Company and Location	Product	Rated Annual Capacity	Remarks	Ore and Concentrate Treated	Blister or Anode Copper Produced
		(tonnes)		(tonnes)	(tonnes)
Falconbridge Nickel Mines Limited, Falconbridge, Ont.	Copper-nickel matte	590 000[2]	A smelter modernization program was begun in 1975. Construction is expected to be completed in the spring of 1978. One-third of the estimated $95 million cost had been spent to the end of 1976. Fluid-bed roasters and electric furnaces will replace existing smelting equipment and a 1 180-tonne-a-day sulphuric acid plant will treat roaster gases. Refining of copper-nickel matte is carried out in Norway. In 1977 oxygen enrichment of blast furnace air permitted a one-furnace, two-converter operation throughout the year.	..	19 400[1]
Gaspé Copper Mines, Limited, Murdochville, Que.	Copper anodes	336 000[2]	Mine and smelter expansion program was completed but had start-up problems in 1974. As part of the program, a fluid-bed concentrate roaster, a 272 000-tonne-a-year sulphuric acid plant and plant water recycling facility were added to facilities previously described. Smelter is fed with Gaspé and custom concentrates. Vat leaching of oxide ore to produce copper cement began on a commercial scale in May but was suspended in November due to high iron content of affluent.	297 600 of which 84 400 were custom concentrates	68 800

Table 5. (concl'd)

Company and Location	Product	Rated Annual Capacity	Remarks	Ore and Concentrate Treated	Blister or Anode Copper Produced
		(tonnes)		(tonnes)	(tonnes)
Hudson Bay Mining and Smelting Co., Limited Flin Flon, Manitoba	Blister-copper cakes	522 000[2]	Roasting furnaces, 1 reverberatory furnace, 3 converters. Treats own and custom copper concentrates, along with zinc plant residues, in conjunction with slag-fuming furnaces. A new flue system was completed, including an 825-foot stack. Campaign life in the furnaces extended from 12 to 18 months in 1976. Dampers on furnace uptakes installed in 1977 resulting in a 9 per cent reduction in fuel oil consumption.	358 200 of which 109 000 were purchased concentrates	62 800
Inco Limited	Blister copper, nickel sulphide and nickel sinter for company's refineries; nickel oxide sinter for market, soluble nickel oxide for market	3 630 000[2]	Oxygen flash-smelting of copper sulphide concentrate; converters for production of blister copper. Roasters, reverberatory furnaces for smelting of copper-nickel ore and concentrate; converters for production of copper-nickel Bessemer matte. Production of matte followed by matte treatment, flotation, separation of copper and nickel sulphides, then by sintering to make sintered-nickel products for refining and marketing. Electric-furnance melting of copper sulphide and conversion of blister copper. Also custom smelting.		148 800
Noranda Mines Limited, Noranda, Que.	Copper anodes	1 542 000[3]	Roasting furnaces,[1] hot-charge and 2 green-charge reverberatory furnaces; 5 converters; 1 continuous reactor; one 85-tonne-a-day oxygen plant to supply oxygen-enriched blast. Continuous reactor was modified to produce matte instead of metal.	889 000[4] of which 723 900 were custom concentrates	220 400

Sources: Company reports.
[1]Deliveries. [2]Ores and concentrates. [3]Ores, concentrates and scrap. [4]Excluding flux.

Table 6. Copper refineries in Canada, 1977

Company and Location	Rated Annual Capacity	Output	Remarks
	(tonnes)	(tonnes)	
Canadian Copper Refiners Limited, Montreal East, Quebec	435 000	347 500	Refines anodes from Noranda and Gaspé smelters, blister copper from Flin Flon smelters, and purchased scrap. Copper and nickel sulphate recovered by vacuum evaporation. Precious metals, selenium and tellurium recovered from anode slimes. Produces C.C.R. brand electrolytic copper wirebars, ingot bars, ingots, cathodes, cakes and billets. Start-up of semi-continuous casting of cakes and billets was deferred.
Inco Limited Copper Refining Division, Copper Cliff, Ontario	192 000	148 800	Refines blister copper from Copper Cliff smelter. Precious metals, selenium and tellurium are recovered from anode slimes. Recovers and electrowins copper from Copper Cliff nickel refinery residue. Produces ORC brand electrolytic copper, cathodes, wirebars, cakes, billets, ingots and ingot bars.

Sources: Company reports.

The copper production of Poland also continued to increase at a fast pace. Polish production, from three mines in the Lubin-Polkovice-Rudna area, was projected to reach 400 000 tonnes a year in the 1977-78 period, compared with 248 000 tonnes in 1975 and 72 200 tonnes in 1970. A second oxygen-enriched flash smelter, Glogow II, with a capacity of 150 000 tonnes a year, was scheduled to start up at the end of 1977.

During March, Katangan rebel forces invaded Zaire. Fighting took place in the Province of Shaba, formerly Katanga, the copper-producing area of the country. Although there was no physical interruption of copper production or shipments, the threat posed by these hostilities did have a bullish effect on prices. It also served as a reminder of the extent to which world consumers depend on copper production in southern Africa.

Iran's new mine/smelter complex, Sar Cheshmeh was approaching start-up at year-end. The concentrator was expected to start operating in February and the smelter was expected to come on-stream during the second half of 1978.

Consumption

World consumption of refined copper increased to 8 999 000 tonnes in 1977 from 8 516 100 tonnes in 1976, an increase of 5.7 per cent. The United States, Japan, United Kingdom, France, Belgium and Brazil all recorded increases, while West Germany, Italy, and Canada recorded small decreases.

As a result of this net increase, the previous all-time high for world consumption, that for 1973, was exceeded in 1977 for the first time.

National stockpiles

The Japanese stockpile of refined copper, purchased by the Metallic Mineral Products Stockpiling Association, held 50 000 tonnes by mid-1977. In September it was announced that the Association planned to buy a further 20 000 tonnes, financed by a syndicate of Japanese banks at favourable interest rates. At year-end, the Japanese stockpile had been increased to 55 000 tonnes. Late in 1977, concern over the burgeoning Japanese balance of payments situation led to suggestions in November that Japan should set aside $U.S. 700 million for the purchase of imported commodities, including nonferrous metals. This was followed, in December, by a proposal by the president of Sumitomo Electric Industries Ltd. that Japan should buy and "freeze" about 300 000 tonnes of copper from LME stocks. The cost of a purchase of this magnitude would be in excess of $300 million.

The United States strategic stockpile goals announced by the Ford administration in October 1976 were upheld in substance by the Carter administration in October 1977. This reaffirms a commitment to a $3.5 billion purchase program. The new goal for copper announced in 1976 was 1.2 million tonnes, compared with a present holding of 20 000 tonnes.

Table 7. Canada, consumption of primary copper in manufacture of semifabricated products, 1976 and 1977

	1976	1977
	(tonnes)	
Copper mill products — plate, sheet, strip, bars, rolls, pipe, tubes, etc.	58 729	48 925
Brass mill products — plate, sheet, strip, rods, bars, rolls, pipe, tubes, etc.	15 386	19 459
Wire and rod mill products	113 689	95 795
Miscellaneous	1 102	685
Total	188 906	164 864

Source: Statistics Canada.

A number of bills proposing increased tariffs and purchasing for the strategic stockpile were introduced into the United States House of Representatives during 1977. One of these proposed authorization for the purchase of 227 000 tonnes of copper financed by the sale of 27 000 tonnes of tin from the stockpile.

The French government, expressing fears of a possible shortage of copper over the next few years, also indicated during October that it too may soon become a buyer of copper.

These intentions add up to very substantial new buying power in a market which, in terms of supply and demand, is very close to the point of balance. They can only be seen as a bullish factor in the future price outlook.

International developments

United States copper producers were very active in 1977 in seeking various forms of assistance for their industry from government and its agencies.

A number of protectionist bills were introduced into Congress. Bill S2124, for example, proposed to double the present duty rates on copper and also raise the price below which higher tariffs would come into effect.

Late in the year it became known that United States copper producers were preparing a petition for submission to the United States International Trade Commission, for relief from injury, or threatened injury, from copper imports, under section 201 of the Trade Act of 1974. If such a petition were successful in initiating higher tariffs or import quotas on refined copper it could be a serious blow to Canadian copper producers, who have provided a stable, reliable supply to the U.S. market without disrupting or threatening the U.S. producer pricing.

The chronic instability of world copper prices con-

Table 8. World mine production of copper, 1976-77

	1976	1977p
	(000 tonnes)	
United States	1 456.6	1 377.1
U.S.S.R.	1 130.0	1 140.0
Chile	1 005.2	1 056.2
Canada	730.9	782.2
Zambia	708.9	658.1
Zaire	444.6	498.0
Peru	219.4	320.0
Philippine Republic	238.1	274.0
Poland	267.0	268.0
Australia	214.4	221.0
Republic of South Africa	196.9	216.1
Papua New Guinea	176.5	182.4
Yugoslavia	137.0	139.0
Mexico	89.0	90.0
Japan	81.6	81.4
Indonesia	66.8	56.2
Other communist countries	314.0	316.0
Other non-communist countries	423.4	434.8
Total	7 900.3	8 110.5

Sources: World Bureau of Metal Statistics, April 1978, and Statistics Canada.
pPreliminary.

tinued to receive a great deal of attention in 1977. Many schemes were put forward to alleviate this problem. These schemes included:

- Creation of a producer-consumer consultative body on copper, to operate through improved market transparency and by providing a consultative forum for meetings of producers and consumers.
- Creation of buffer stocks, either national or centrally administered, in some cases with complementary supply restrictions.
- Supply restrictions alone.
- Massive purchasing of copper from the market for national stockpiles, with strategic or economic objectives.
- National and international loan schemes which would establish floor prices, with repayment during subsequent periods of high prices.
- International loan schemes which would make loan payments to producers to withhold exports during oversupply periods, for repayment when the withheld supplies were shipped.
- Worldwide producers' pricing.
- Combinations, through formulae, of free market prices and producer prices.
- Price stabilization around a reference price through universal use of a stabilizing formula for calculating realized prices in copper sales contracts.

Some countries acted unilaterally in applying some of these schemes, for example, Norway with a national loan scheme, and Japan with stockpile purchasing. The majority of the schemes, however, have never passed the conceptual stage but have been the subject of debate in the industry, the press, within governments, at meetings of the Intergovernmental Council of Copper Exporting Countries (CIPEC) and in the United Nations Conference on Trade and Development (UNCTAD) copper discussions.

The process of discussion on copper, involving producing and consuming countries, was continued within the UNCTAD in 1977. Six meetings took place: in February, March, May, August, October and November, all but one of which were meetings of the Intergovernmental Expert Group on Copper, a subgroup set up in September 1976.

A list of studies agreed upon in November 1976 by the expert group were carried out by participating countries and organizations, and were submitted and discussed in detail at the February meeting.

At the August meeting, the expert group commissioned a study by Charles River Associates (CRA) of the feasibility, costs, benefits and financial implications of price stabilization measures involving various combinations of buffer stocks and supply restrictions. The CRA report concluded that with the parameters prescribed, there would have been only a slight lessening of price instability during the period studied. In virtually every simulation, the price broke through the ceiling, although it was generally successful in defending the floor. In many runs, there was an enormous build-up of stocks during certain periods, requiring many billions of dollars of financing.

At the November meeting, a measure of agreement was reached for the first time since March 1976 on the necessity of setting up a consultative organization for copper. A Third Preparatory Meeting on Copper was scheduled to take place early in 1978 to receive the results of the experts' work. It did seem possible at the end of 1977 that a consumer/producer consultative organization might be formed in 1978, at least as an interim step while discussion continues on whether or not to negotiate an international commodity agreement on copper.

CIPEC

The Intergovernmental Council of Copper Exporting Countries (CIPEC) held two ministerial meetings during 1977, one in Paris in June and one in Jakarta in December. CIPEC also participated in the UNCTAD copper talks.

At the February UNCTAD meeting, CIPEC presented a proposal for immediate introduction of an interim remedial price measure. Two possible formulae were suggested as a means to raise prices realized by exporters. The proposal did not meet with a positive

Table 9. World production of refined copper, 1976-77

	1976	1977p
	(000 tonnes)	
United States	1 714.8	1 679.4
U.S.S.R.	1 460.0	1 470.0
Japan	864.4	933.7
Chile	632.0	676.0
Zambia	694.9	640.3
Belgium	425.0	535.1
Canada	510.5	508.8
West Germany	446.6	440.1
Poland	270.1	306.6
Australia	188.8	181.8
Peru	140.1	163.0
Spain	141.9	160.0
Republic of South Africa	95.6	133.0
United Kingdom	137.2	120.5
Yugoslavia	136.5	117.5
Zaire	66.0	98.7
Mexico	83.3	79.0
Sweden	59.5	61.7
Other communist countries	461.1	467.0
Other non-communist countries	320.7	354.8
Total	8 849.0	9 127.0

Sources: World Bureau of Metal Statistics, April 1978, and Statistics Canada.
pPreliminary.

response. CIPEC stated that it was flexible on the price formula to be used, and would make no decision before its June ministerial meeting in Paris.

The Paris meeting, however, failed to reach any agreement on these new pricing methods. At this meeting Yugoslavia was accepted into the organization as a new associate member.

Primarily because of opposition from Chile, CIPEC failed at Jakarta to reach unanimous agreement on production restrictions. In spite of this, a number of countries indicated their determination to seek to reduce world production, with or without Chilean cooperation. Canada, present as an observer, indicated to the meeting that 1978 Canadian mine production of copper was expected to decline by 6 per cent relative to 1977, to a level 10 per cent below the peak production recorded in 1973.

CIPEC also agreed that its newly elected chairman, Mohammad Sadli of Indonesia, should contact government leaders of the European Economic Community, Japan and the United States to work out possible areas of agreement ahead of the UNCTAD Third Preparatory Meeting on Copper to be held in Geneva at the end of January 1978. At the same meeting, CIPEC proposed to put forward for consideration the "Combined Pricing System" for copper devised by the CIPEC secretariat.

Stocks

World stocks of refined copper were relatively stable in 1977. According to the American Bureau of Metal Statistics, stocks for reporting countries were 1.517 million tonnes at the end of December compared with 1.443 million tonnes one year earlier. This compares with reported stocks of 713 000 tonnes at the end of 1974 and 361 000 tonnes at the end of 1973.

Stocks of refined copper on the two major commodity exchanges, the London Metal Exchange (LME) and the New York Commodity Exchange (Comex), taken together, also showed only a small net increase during 1977. LME stocks rose from 603 000 tonnes at the beginning of January to 641 000 tonnes at the end of December. Comex stocks increased during the first four months of 1977 from 182 000 tonnes at the beginning of the year to a peak of 194 000 tonnes at the end of April. Thereafter, Comex stocks declined steadily to a level of 167 000 tonnes at year-end.

Price

Copper prices began 1977 at relatively depressed levels. They increased to a peak level for the year in March, then slumped to the year's low in August, staging only a slight recovery in December.

Average LME cash prices for wirebars were equivalent to U.S. 63 cents a pound in January, U.S. 69 cents in March, 53 cents in August and, 56 cents in December.

United States producer prices for electrolytic wirebars and for cathode opened the year at U.S. 65.625 and 65.00 cents a pound. They increased to U.S. 68.625 and 68.00 cents a pound on January 26, and to U.S. 71.625 and 72.00 cents a pound on March 2. There was a further increase to U.S. 74.625 and 74.00 cents a pound on March 18. Prices were then lowered by 3 cents a pound on May 23, on June 1, and again on July 22. There was a further U.S. 5 cents decrease to U.S. 60.625 and 60.0 cents a pound on August 18. On December 19, most U.S. producers raised prices by 3 cents to 63.625 and 63.00 cents a pound.

Canadian producer prices moved closely in step with United States producer prices but also reflected the steady erosion in the exchange rate of the Canadian dollar against other major currencies. Prices for wirebar and cathode opened the year at 67.125 and 66.5 cents a pound and were changed to 70.00 and 69.375 cents a pound on January 28, 75.125 and 74.50 cents a pound on March 8, 78.375 and 77.75 cents a pound on March 28, 75.125 and 74.50 cents a pound on May 24, 72.625 and 72.00 cents a pound on July 7, 69.625 and 69.00 cents a pound on July 22, 65.125 and 64.50 cents a pound on August 22, and 69.875 and 69.125 cents a pound on December 29.

Table 10. World consumption of refined copper, 1976-77

	1976	1977p
	(000 tonnes)	
United States	1 782.6	2 000.0
U.S.S.R.	1 250.0	1 250.0
Japan	1 050.3	1 131.0
West Germany	744.6	742.0
United Kingdom	457.6	512.0
France	367.1	378.1
Italy	322.0	315.0
Belgium	228.1	295.4
Brazil	179.3	313.7
Canada	206.2	200.4
Poland	174.0	175.0
Yugoslavia	130.0	130.0
Spain	130.5	130.0
East Germany	118.0	118.0
Australia	111.5	112.3
Sweden	87.5	92.2
Other communist countries	550.2	565.0
Other non-communist countries	626.6	638.9
Total	8 516.1	8 999.0

Sources: World Bureau of Metal Statistics, April 1978, and Statistics Canada.
pPreliminary.

Outlook

During 1978 the United States, Japan, and possibly France, may make substantial purchases of refined copper for national stockpiles. While this would not reduce the world inventory position, the copper purchased would probably not be released back into the market for some time and would only be forthcoming in periods of high price or physical scarcity.

In the UNCTAD copper talks, progress towards agreement on some form of international action on the problems of the copper market appears to be leading towards the formation of a producer-consumer consultative organization which could function in much the same way as the International Lead and Zinc Study Group. Discussions on other measures such as buffer stock schemes are also likely to continue.

In spite of the failure of CIPEC to agree unanimously to cut production and exports in 1978 there was a wide measure of support among members for such action. Some cuts will probably be made, and these, together with planned cuts in Canada and other non-CIPEC countries, could have the effect of reversing the four-year trend of rising world copper inventories.

If world inventory levels and holdings by the major commodity exchanges do fall, consumers will increase inventory levels, adding an aspect to demand which has not been present for most of the last four years. Prices should respond positively, but the presence of ample idle production capacity and a large world stock position should prevent any runaway increases. By the end of 1978 it is expected that copper prices should have moved up into the range of U.S. 65 to 75 cents a pound.

Table 11. World copper production and consumption, 1977p

	Mine Production	Refined Production	Refined Consumption
	(000 tonnes)		
United States	1 377.1	1 679.4	2 000.0
U.S.S.R.	1 140.0	1 470.0	1 250.0
Japan	81.4	933.7	1 131.0
CIPEC[1]	3 662.0	2 106.2	434.3
Europe	317.0	1 607.1	2 779.4
Canada[2]	782.2	508.8	200.4
Other communist countries	316.0	467.0	565.0
Other non-communist countries	434.8	354.8	638.9
Total	8 110.5	9 127.0	8 990.0

Sources: World Metal Statistics, April 1978 and Statistics Canada.
[1]Intergovernmental Council of Copper Exporting Countries includes: Australia, Chile, Indonesia, Mauritania, Papua New Guinea, Peru, Yugoslavia, Zaire and Zambia. [2]See footnotes, Tables 9, 10 and 11.
pPreliminary.

Tariffs

Canada

Item No.		GSP[1]	British Preferential	GATT[2]	General
32900-1	Copper in ores and concentrates	Free	Free	Free	Free
33503-1	Copper oxides	Free	Free	15%	25%
34800-1	Copper scrap, matte and blister and copper in pigs, blocks or ingots; cathode plates of electrolytic copper for melting, per pound	Free	Free	Free	1.5c
34820-1	Copper in bars or rods, for manufacture of trolley, telegraph, telephone wires, electric wires and cables	Free	Free	5%	10%
34835-1	Electrolytic copper powder (expires June 30, 1979)	Free	Free	Free	10%
34845-1	Electrolytic copper wire bars, per pound (expires June 30, 1979)	Free	Free	Free	1.5c
35800-1	Anodes of copper	Free	Free	Free	10%

United States

TSUS No.		GSP	GATT
		(¢/pound)	
602.30	Copper ores and concentrates, on Cu content	Free	0.8
612.06	Unwrought copper, on Cu content	Free	0.8
612.10	Copper waste and scrap, on 99.6% of Cu content	Free	0.8

Tariffs (concl'd)

Japan

BTN No.		GSP	GATT
26.01	Copper ores and concentrates	Free	Free
74.01	(1) Matte, cement copper and native copper	Free	Free
	(2) Unwrought copper, other than native copper		
	i) containing not more than 99.8% by weight of copper and used for smelting or refining	Free	8.5%
	ii) Other	Free	24 yen/kg
	(3) Waste and scrap	Free	2.5%

EEC

BTN No.		GSP	GATT
26.01	Copper ores and concentrates	Free	Free
74.01	Copper matte; unwrought copper; copper waste and scrap	Free	Free

Sources: For Canada the Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division; for the United States, Tariff Schedule of the United States Annotated (1978) T.C. Publication 843; for the E.E.C., Official Journal of the European Communities, November 14, 1977; for Japan, Customs Tariff Schedules of Japan, 1977.
[1]GSP — Generalized System of Preferences extended to all, or most, developing countries; some GSP rates are subject to quotas or withdrawal. [2]GATT — General Agreement on Tariffs and Trade.

Fluorspar

G.H.K. PEARSE

Fluorspar, or fluorite in mineralogical nomenclature, is calcium fluoride (CaF_2), an industrial mineral with a broad spectrum of uses. The most important of these are: for the manufacture of hydrofluoric acid and other fluorine chemicals; as a fluxing agent in various metallurgical processes, the most important being steel manufacture; for the manufacture of artificial cryolite, an essential cell ingredient in the electrolytic reduction of alumina to aluminum; in the refining of uranium ores, and in the glass and ceramic industries.

In the past decade, world fluorspar consumption grew rapidly because of increasing demands in the steel, aluminum and chemical industries. Due to a combination of technical, economic and environmental developments, consumption has been stagnant during the present decade. In 1977 world production was an estimated 4.5 million tonnes.* Greater use of the basic oxygen process in steelmaking, which requires about three times as much fluorspar, as a slag thinner, than the more traditional basic open-hearth process, will increase the demand for fluorspar in this sector in spite of the partial use of substitutes. However, slack demand in the steel industry over the last two years has arrested growth in metallurgical-grade fluorspar consumption. Recent concern about concentrations of fluorocarbons in the upper atmosphere has led to legislation by the United States Government banning non-essential uses of these chemicals by December 1978. Aerosol spray products are alleged to be the main offenders.

Production in Canada

Fluorspar is the principal source of the element fluorine. It occurs in many geological environments from low-temperature fracture fillings to high-temperature emplacements and, as a result, it is not restricted to any particular geological province in Canada. In fact, fluorspar is known to occur in all physiographic provinces, with the exception of the interior plains.

In July 1977 Alcan Smelters and Chemicals Limited announced that it would cease fluorspar operations at St. Lawrence, Newfoundland on February 1, 1978. Mine production stopped in the fall of 1977. This operation has been Canada's only producer since the last mine closed at Madoc, Ontario in 1961. Reasons stated for the closure were that operations at St. Lawrence were uneconomic, and that higher-quality, lower-cost material was available on world markets. A study of the mines and plant, funded by federal-provincial authorities, was carried out by B.L. Hodge and Associates of London, England. The findings were that operations could be made economic with changes in mining and processing methods and in management and staffing. Estimated capital expenditure to accomplish the changes was $13 million. A new operator will be sought by government authorities to resume fluorspar operations at this single-industry town of 2,100 people.

The company produced fluorspar from three mines: Director, Tarefare, and Blue Beach, located near the village of St. Lawrence on Newfoundland's Burin Peninsula. The Director mine had been in operation for 35 years. The Tarefare mine commenced production, at about 25 000 tonnes a year of fluorspar concentrate, in 1968. Production from the Blue Beach mine began in 1972 and the mill capacity was increased to 1 200 tonnes of ore a day. Concentrates from these operations were shipped to Alcan's aluminum smelter at Arvida, Quebec, where they were upgraded by flotation and converted to aluminum fluoride for the reduction of alumina to aluminum. Small tonnages were sold from time to time to Newfoundland Steel Company Limited for steel slagging. Developments on new reserves about a mile northwest of St. Lawrence were halted by a strike in 1975. No ore has been mined from the new reserves. Annual concentrate shipments from St. Lawrence varied between 60 000 and 160 000 tonnes, the lower figure essentially reflecting production lost during strikes. Total production from the

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Canada, fluorspar production, trade and consumption

	1976		1977[p]	
	(tonnes)	($)	(tonnes)	($)
Production (shipments)				
Newfoundland	. .	2 934 995	. .	10 180 000
Imports				
Mexico	62 192	4 917 000	60 873	4 982 000
United States	11 009	884 000	23 941	2 208 000
Spain	52 941	4 683 000	23 753	1 560 000
Morocco	9 081	727 000	8 260	701 000
South Africa	—	—	7 072	639 000
Other countries	2 087	184 000	594	76 000
Total	137 310	11 395 000	124 493	10 166 000
	1975		1976	
Consumption[1] (available data)				
Metallurgical flux	21 881	. .	27 404[e]	. .
Foundries	4 273	. .	5 541	. .
Other[2]	175 972	. .	95 408	. .
Total	202 126	. .	128 166	. .

Source: Statistics Canada.
[1] As reported by consumers; breakdown by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa. [2] Includes consumption in the production of aluminum and chemicals, petroleum refining and other miscellaneous uses.
[p] Preliminary; . . Not available; — Nil.

district was more than 6 million tonnes of ore. The fluorspar veins on Burin Peninsula are genetically related to two large stocks of alaskite. Most of this favourable area is obscured by shallow overburden, but innumerable showings and float blocks containing fluorspar are known.

Allied Chemical Canada, Ltd., imports acid-grade fluorspar for the production of hydrofluoric acid at Valleyfield, Quebec and Amherstburg, Ontario. Some of the acid is utilized in the manufacture of various fluorine chemicals. Allied Chemical operates mines in Mexico and the United States to ensure an uninterrupted supply of fluorspar.

Huntingdon Fluorspar Mines Limited, with a plant near North Brook, Ontario, imports metallurgical-grade fluorspar to make five-pound briquettes for foundry use.

International Mogul Mines Limited's barite-fluorite deposits east of Lake Ainslie, Cape Breton Island, Nova Scotia contain indicated reserves of 2.7 million tonnes grading 28 per cent barite and 19 per cent fluorite. Pilot plant testing, with the objective of producing an acid-grade concentrate at an acceptable rate of recovery, has yet to prove successful. From 1940 to 1949, approximately 1 300 tonnes of fluorspar, along with some barite, were recovered from this deposit.

Prior to The First World War, small tonnages of fluorspar were mined from vein-type deposits in the Madoc district of Ontario. As a strategic material of great importance, it showed a marked increase in production during the war. After the war, production decreased substantially, but was stimulated once again during The Second World War by government assistance for exploratory drilling programs and by loans on capital equipment. From 1943 to 1947 some 23 000 tonnes were mined. Fluorspar was mined continuously in the Madoc area up to 1961, when severe underground flooding, lack of export markets and increased mining costs made the operation uneconomic. Altogether, some 140 000 tonnes of fluorspar were mined in the Madoc area, production being derived from 24 separate properties. Most significant producing properties were along a prominent linear vein structure, the southern extension of which could still contain mineable reserves.

The Rock Candy mine, near Grand Forks, British Columbia, was mined intermittently from 1918 to 1942 and is controlled by Cominco Ltd. Substantial reserves probably remain.

Fluorine is being recovered as fluosilicic acid from the processing of phosphate rock by Erco Industries Limited (formerly Electric Reduction Company of

Canada, Ltd.), at Port Maitland, Ontario, and by Cominco Ltd., at Trail, British Columbia.

Other fluorspar occurrences of interest include the Liard River, British Columbia deposits explored a few years ago by Jorex Limited and Conwest Exploration Company Limited; Eaglet Mines Limited's widespread low-grade mineralization near Quesnel, British Columbia and Consolidated Rexspar Minerals & Chemicals Limited's large uranium-bearing, medium-grade fluorspar deposit adjacent to the Canadian National Railway line at Birch Island, about 95 kilometres north of Kamloops.

Uses, markets and trade

Fluorspar is marketed in three grades according to end-use, although, in time of shortage of metallurgical grade, high-grade material is substituted for this normally lower-grade material. These three grades are: acid grade, containing a minimum of 97 per cent CaF_2; metallurgical grade, containing 60 to 80 per cent CaF_2; and ceramic grade, containing 88 to 97 per cent CaF_2.

Acid grade. Roughly 50 per cent of the world's fluorspar requirement is for acid grade, and is used in the manufacture of hydrofluoric acid. Most of this material is beneficiated by flotation to achieve the high CaF_2 content required. In general, two to three tonnes of ore must be mined to produce one tonne of acid grade fluorspar concentrate, and the production of one tonne of hydrofluoric acid requires two tonnes of acid-grade concentrate and almost three tonnes of sulphuric acid. Hydrofluoric acid, produced according to the reaction

$$CaF_2 + H_2SO_4 \rightarrow CaSO_4 + 2\,HF$$

has a variety of uses, but by far the most important is in the aluminum and fluorocarbon industries, which account for some 80 per cent.

About one-quarter of all hydrofluoric acid produced is used by the aluminum industry. Hydrofluoric acid is reacted with a sodium salt and aluminum fluoride to produce artificial cryolite, an essential cell ingredient for fluxing in the electrolytic reduction of alumina to aluminum. In recent years, fluorspar requirements have declined from 65 kilograms (kg) to 25 kg per tonne of aluminum produced as a result of increased cell efficiencies and recycling. Because fluorite is an essential raw material, many primary aluminum producers operate, or participate in the operation of, fluorspar mines to ensure uninterrupted and adequate supplies.

Almost 40 per cent of hydrofluoric acid is consumed in the manufacture of fluorocarbons. Fluorocarbons, which are used in the manufacture of solvents, resins, plastics, films, refrigerants and aerosol propellants, are produced by reacting hydrofluoric acid with carbon tetrachloride, or with chloroform. Fluorocarbons (more specifically, chlorofluorocarbons) are currently under study as potentially harmful atmospheric pollutants. It is alleged that these substances react with the ozone layer in the upper atmosphere which filters out much of the sun's ultraviolet energy. The resulting increase in ultraviolet radiation could increase the incidence of skin cancer.

Table 2. Canada, fluorspar production and shipments, 1965-77

	Mine Production	Finished Production	% CaF_2	Shipments	% CaF_2
	(tonnes)			(tonnes)	
1965	134 130	92 700	75.3	101 500	68.9
1966	112 724	69 400	72.3	76 500	68.6
1967	116 685	66 400	70.9	66 600	68.2
1968	136 418	91 300	66.1	88 100	63.7
1969	181 645	119 400	73.7	92 000	71.6
1970	186 492	124 000	70.1	143 300	69.0
1971	115 491	72 800	67.3	78 700	66.8
1972	217 068	148 900	63.6	143 200	63.9
1973	237 655	157 900	60.9	137 200	61.1
1974	258 502	154 300	62.5	172 700	62.5
1975	90 883	55 100	61.5	—	—
1976	113 061	59 700	64.3	44 400	60.3
1977	95 354	59 500	69.0	122 222	63.5

Source: Compiled by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa, from figures provided by Alcan Smelters and Chemicals Limited.
— Nil.

Fluorspar is used in uranium refining. Uranium dioxide is reacted with anhydrous hydrofluoric acid to form a green salt (UF_4), which is then reacted with elemental fluorine in the form of fluorine gas to form UF_6, the feedstock for plants requiring enriched uranium. For each tonne of uranium processed into uranium hexafluoride, one and two-thirds tonnes of fluorspar are required. This presently minor use is expected to develop rapidly as nuclear energy becomes increasingly important.

Metallurgical grade. Normally, about half of the world's fluorspar output is consumed as a metallurgical fluxing agent (metspar), primarily in the manufacture of steel. Metallurgical-grade fluorspar is used in the steel industry to remove impurities during melting and also to improve separation of metal and slag in the furnace by increasing the fluidity of the slag. Consumption of fluorspar in the steel industry has, over the years, increased substantially because of changing technology. Many steelmakers have shifted from the basic open-hearth process to the basic oxygen process. The latter consumes from 5 to 8 kg of metallurgical-grade fluorspar for each tonne of steel produced, compared with 1.5 to 2.5 kg in the open-hearth process. The electric furnace process consumes from 4 to 5 kg of metallurgical-grade material for each tonne of steel produced. The basic oxygen process substantially reduces production costs, doubles capacity per unit dollar of capital cost and reaches heat much faster than the open-hearth process. Within the next decade, older basic open-hearth furnaces will probably be replaced by more-efficient, new basic oxygen or electric furnaces.

Recessionary demand in this industry has resulted in a drop in metspar consumption from 2 million to about 1.5 million tonnes in the last three years. Part of the reduction has been because of substitution with other materials, and economy measures such as using less fluorspar and longer tap-to-tap time in the furnaces. However, a rise in demand will likely result in use of more fluorspar per unit of production as capacity output is approached. No satisfactory total substitute for fluorspar as a fluxing agent in steelmaking has been found, although research in this area is considerable. Indications are that the growth of metallurgical-grade reserves is not keeping pace with requirements. Consequently, steelmakers may have to switch more and more to higher-grade, higher-cost material, produced as flotation concentrates and converted into pellet or briquette form. Metallurgical-grade fluorspar is also used as a flux in foundries and in the reduction of dolomite to magnesium.

Ceramic grade. Ceramic-grade fluorspar is used as an opacifier in enamels and opal glass. It is also used to a limited extent in the manufacture of clear glass as an active flux, as a contributor to the gloss and as a decolourizer. Much of this grade of fluorspar concentrates can be used for the manufacture of hydrofluoric acid, or as pellets and briquettes for steelmaking. This latter requirement has been provided for in this way during shortages of metallurgical-grade fluorspar.

Canadian consumption and trade

About 80 per cent of the fluorspar consumed in Canada is used in the manufacture of aluminum fluoride for the electrolytic reduction of alumina to aluminum.

In 1977 fluorspar imports were 124 493 tonnes, a decrease of 9 per cent from the previous year. Imports have tended to vary widely from year to year in an inverse relationship to variations in production. Mexico provided 49 per cent of total imports, Spain and the United States each provided 19 per cent, while most of the remainder came from Morocco and the United Kingdom.

Prior to 1957, much of Canadian production was exported to the United States and Europe. In 1958 exports declined abruptly because of the development of alternative low-cost deposits in Mexico by large consumers in the United States.

World review

Rapid growth in fluorspar consumption by the steel, chemical and aluminum industries, coupled with a stagnant ore-reserve situation during the 1960s, raised fears of a shortage towards the end of the decade.

Table 3. World fluorspar production, 1975-77

	1975	1976	1977[e]
	(tonnes)		
Mexico	1 089 000	896 000	998 000
U.S.S.R.	475 000	490 000	500 000
Spain	363 000	275 000	318 000
People's Republic of China	320 000	360 000	320 000
France	245 000	350 000	320 000
Mongolia	270 000	320 000	320 000
Republic of South Africa	202 000	290 000	330 000
United Kingdom	231 000	240 000	260 000
Italy	231 000	210 000	227 000
Thailand	218 000	200 000	163 000
United States	127 000	171 000	163 000
Canada	64 000	73 000	73 000
Other countries	555 000	612 000	641 000
Total	4 390 000	4 487 000	4 633 000

Source: U.S. Bureau of Mines, *Commodity Data Summaries, 1977;* U.S. Bureau of Mines, *Mineral Commodity Summaries, 1978; Mining Annual Review, 1977;* estimates by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
[e] Estimated.

Under the impetus of tightening supply and rising prices, intensive exploration efforts in various parts of the world were successful in substantially augmenting reserves. Expanded and new facilities were brought on stream to meet the expected strong demand. However, coincident with the surge in production came a slackening in demand due to an economic slowdown in the major consuming nations, notably the United States and Japan. Strong growth in consuming sectors in 1974 was met by withdrawals from large inventories, notably in Europe, where output was deliberately cut back. Entry into recession precluded stimulation of production during 1975, 1976 and 1977. World production at 4.6 million tonnes in 1977 is little changed from that of the previous seven years.

Mexico continued to rank as the world's largest supplier, producing 1 million tonnes, or 22 per cent of total output, in 1977. Fluorspar mining began in Mexico prior to The First World War. However, the industry received its greatest stimulus during The Second World War, when the United States government, cut off from European sources, encouraged exploration and development in Mexico. Most production is mined in the State of San Luis Potosi in the Zaragoza area where two major producing mines are located within a mile of each other. The Las Cuevas mine, which is the largest, accounts for over 30 per cent of total Mexican output and is the principal producer of metallurgical-grade fluorspar. This underground operation is an affiliate of Noranda Mines Limited. The rapid growth of fluorspar production in Mexico from 430 000 tonnes in 1963 has paralleled consumption increases in the United States, which relies upon Mexico for most of its import requirements. Similarly, stagnation of production over the last few years reflects the United States demand.

Quimica Fluor S.A.'s hydrofluoric acid plant at Matamoros started up in 1975. It is one of four originally proposed in 1971.

The Mexican Fluorspar Institute, a producer organization, was formed in 1974. This body, backed by the government, formulates policy on sales and prices.

The United States is the world's largest consumer and is heavily reliant on imports to meet demand. In 1977, United States production at 163 000 tonnes, was little changed from that of 1976. Output of fluosilicic acid from phosphate fertilizer plants was equivalent to 98 000 tonnes of fluorspar. Imports for the year (including CaF_2 equivalent of hydro-fluoric acid) totalled 1.1 million tonnes, 73 per cent from Mexico. Most output in the United States comes from the Illinois-Kentucky district and is produced by two companies; Ozark-Mahoning Company (majority interest purchased by Pennwalt Corporation during 1975), and Allied Chemical Corporation, which, through acquisition, took over the former Minerva Oil Company holdings. The mine and mill of Cerro Corporation near Salem, Kentucky, was acquired (95 per cent) by Frontier Resources Inc. of Denver, Colorado, in 1976. A new mine near Hampden, Kentucky is also being evaluated by this company. A new company, Kenspar, was unsuccessful in its scheme to reactivate several properties and the mill at Mexico, Kentucky. Other states producing fluorspar intermittently are: Montana, Colorado, Idaho, Arizona, New Mexico and Utah. Little news of developments at Lost River Mining Corporation Limited's reportedly-extensive deposits near Teller, Alaska was forthcoming during the year. Drilling by United States Borax & Chemical Corporation on its new fluorspar-barite deposit in the Sweetwater district, 65 kilometres southeast of Knoxville, Tennessee, has thus far delineated over 50 million tonnes of 15 to 35 per cent CaF_2 amenable to open-pit mining. Production from this property is unlikely to be commissioned before 1980.

In 1977 Spain produced an estimated 318 000 tonnes. Much of the Spanish production is exported, mostly to the United States and West Germany. Estimated French production was 320 000 tonnes. Italy, also a major producer, shipped an estimated 227 000 tonnes in 1977. Production in Britain was about 260 000 tonnes in 1977.

The U.S.S.R. is the world's second-largest producer of fluorspar, with an output of about 500 000 tonnes in 1977. Domestic supply has fallen short of requirements for some years, and imports in 1977 exceed 300 000 tonnes. The People's Republic of China, North Korea and Mongolia, a rapidly growing producer, together produce approximately 700 000 tonnes a year.

Thailand's output remained substantially below the 1971 figure of 420 550 tonnes. As a result of slack demand, principally in Japan, production in 1977 was an estimated 163 000 tonnes. Reserves are reportedly 11 million tonnes of 60 per cent CaF_2 and large deposits indicated in the upper reaches of the River Kwai have received attention. The limiting factors on production and market development include primitive mining and beneficiation techniques, and costly and difficult transportation from producing areas to points of export. Loading facilities at Bangkok also present a bottleneck to efficient ocean transport. The Thai government has taken an active interest in the industry and is moving to eliminate these drawbacks. A United Nations study and report on these problems was completed during 1975.

The Republic of South Africa's output, which more than doubled between 1968 and 1971 to 235 000 tonnes, was an estimated 330 000 tonnes in 1977. This country has about 25 per cent of the world's measured CaF_2 reserves. Although much of the reserves are well below the generally accepted grade of 35 per cent, its production will likely represent an increasing share of world output over the long term. Namibia (formerly South-West Africa) Kenya, Tunisia and Morocco are all significant producers.

Until recently, South America produced limited quantities of hand-sorted, metallurgical-grade fluorspar. Exploration and development is moving along rapidly in both Brazil and Argentina, and output from this continent has risen to about 120 000 tonnes.

Outlook

The performance of the fluorspar industry necessarily parallels development in the steel, chemical and aluminum industries, which together account for 95 per cent of fluorspar consumption.

A combination of recessionary demand, economies in fluorspar use and environmental constraints has resulted in a seven-year no-growth period in fluorspar consumption. Large producer inventories and declining prices have resulted in mine closures — perhaps the most notable being Canada's last producer — and deferred development plans.

Consumption of fluorspar in the aluminum industry appears to have reached a plateau as requirements per tonne of metal produced have declined. A new aluminum production technology which reportedly reduces consumption of electricity by about 30 per cent and uses chlorine instead of fluorine is in the development stage. Aluminum Company of America (Alcoa) is doubling its Palestine, Texas demonstration plant capacity to 27 200 tonnes and could in the near future construct a world-scale plant. Assuming adoption of the new technology, fluorspar in aluminum manufacture could disappear by the turn of the century. In the short run, however, some growth in fluorspar consumption in the aluminum industry is likely as a result of the current healthy growth in demand for this metal.

Many uncertainties surround the outlook for fluorspar consumption in steelmaking. Demand growth for steel products is tied to performance of the world economy about which no clear trends have, as yet, emerged. There seems little doubt, however, that growth over the next few years will be modest. Nevertheless, any significant increase in steel demand will call forth even greater fluorspar usage to facilitate shorter residence time in the furnaces. Also, conversion to basic oxygen technology will continue, further increasing fluorspar demand. In addition to flux needs, about 160 000 tonnes of acid grade equivalent is consumed as acid in pickling stainless steel.

Consumption in fluorocarbon manufacture is the dominant force in fluorspar usage in the chemical industry at the present time. The imminent ban on "nonessential" fluorocarbon products in the United States, principally aerosol sprays, is also under consideration in other countries. The reduction in fluorspar consumption resulting from such a ban would be about 10 per cent, although growth in other fluorocarbon products is not precluded. Uranium enrichment and oil refining (alkylation) are strong growth segments that will moderate decline in the chemical sector. World consumption of fluorspar (acid grade) for these and other miscellaneous uses presently account for only 2.5 per cent of total fluorspar use, but growth rates in excess of 10 per cent a year over the long term seems likely.

Substitution for fluorspar based acid by byproduct hydrofluoric acid from phosphate fertilizer production has reached approximately 100 000 tonnes fluorspar equivalent in 1977. Output from this enormous source will continue to expand, although at the present time little is being done outside the United States.

In the longer term, the chemical industry would seem to offer the greatest scope for growth in fluorspar consumption. Fluorine, the most electronegative of elements, reacts with almost all organic and inorganic substances and in view of this property, only the surface of its potential as a chemical has been scratched.

In balance, world fluorspar consumption is expected to grow only marginally over the next year or two, but with economic recovery this rate will rise sharply through increased steel and aluminum output. Average growth in consumption is expected to be

Prices

United States fluorspar prices, quoted in "Engineering and Mining Journal" of January, 1978.

(net ton fob Illinois and Kentucky, CaF_2 content, bulk)

	($)
Ceramic, calcite and silica variable, CaF_2	
88-90%	90-100
95-96%	95-106
97%	100-115
In 100-lb paper bags, extra	9
Metallurgical pellets, 70% effective CaF_2	83-91
Acid, dry basis, 97% CaF_2	
Carloads	95-115
Bags, extra	9
Pellets, 88% effective	111
Wet filter cake, 8-10% moisture, sold dry content — subtract approx.	6
European and South African wet filter cake, 8-10% moisture, sold dry content, duty pd., st cif East Coast, Great Lakes and Gulf ports, term contracts	97-102
Mexican	
Metallurgical, 70% effective CaF_2	
Mexican border, fob cars	62.92
Tampico, fob vessel	65.52
Acid, 97% + CaF_2 wet filter cake, bulk, fob	
Mexican border	79.38

around 5 per cent through 1985. Prices for acid-grade and metallurgical-grade fluorspar fob port of export have been at the $90- and $75-a-tonne levels for the last few years, although considerable discounting has been in evidence. Reductions in mine and mill capacity through closures and cutbacks could result in a short term, tight supply situation and substantial price increases upon any significant economic upturn.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
29600-1	Fluorspar	free	free	free	free

United States

Item No.		($/lt)
522.21	Fluorspar, containing over 97% calcium fluoride	2.10
522.24	Fluorspar, containing not over 97% calcium fluoride	8.40

Sources: For Canada, The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division. For United States, Tariff Schedules of the United States, Annotated (1978) T.C. Publication 843.

Gold

J.J. HOGAN

Gold production in Canada in 1977 was estimated at 53 404 000 grams* valued at $268 377 000 compared with 52 621 110 grams in 1976 valued at $208 273 405. The average yearly afternoon fixing prices of gold on the London Gold Market converted to equivalent Canadian dollars for the years 1976 and 1977 were $3.958 a gram and $5.051 a gram. This was the second consecutive year that gold production in Canada has shown a small increase. Lode gold mines recorded a small reduction in output, but this was offset by an increase in byproduct production from base-metal mines. The sharp rise in the gold price was largely responsible for the 28.9 per cent increase in value. The largest gold production in Canada for any year was 1941 when 166 253 668 grams (5 345 179 ounces) were produced.

Canada has been one of the world's leading producers of gold and, since production was first officially recorded in 1858, has produced 6 359 890 kilograms (kg) to the end of 1977, valued at $7 637 million. Although most of the provinces and territories have contributed to total output during that period, the largest producers, in decreasing order of output were Ontario, Quebec, British Columbia, Yukon Territory and the Northwest Territories.

In 1977 lode gold mines in Canada accounted for 70.2 per cent of the country's gold output compared with 72.8 per cent in 1976. At the end of 1977 there were 21 operating lode gold mines in Canada, the ore being treated at 15 mills. One small mine closed in 1977. A small amount of gold was recovered from placer deposits in the Yukon Territory and British Columbia. Ontario continued to be the major gold producing province and accounted for 43.0 per cent of the national total, followed by Quebec with 27.3 per cent, British Columbia, 11.4 per cent and Northwest Territories, 10.9 per cent.

The much-improved gold price in 1977 and the discounted exchange rate of the Canadian dollar in relationship to its United States counterpart reversed the serious problems faced by the Canadian gold industry in 1976, and all mines were able to operate profitably during the year. The mines are still faced with rising production costs related to inflationary pressures and with grade control problems; but, if the increase in the gold price that took place towards the end of 1977 is maintained in 1978, it is expected that all gold mines will continue to operate profitably during the year.

To commemorate the 25th anniversary of Queen Elizabeth II's accession to the throne, Canada issued 179 000 gold coins of $100 legal tender which contained a total of 2 783.76 kg (89 500 ounces) of gold. The coins were minted by the Royal Canadian Mint and are each 22 carat gold, 27 millimetres (mm) in diameter, 2.15 mm in thickness and weigh 16.956 grams, of which 15.552 grams (0.5 troy ounces) are gold and the remainder silver. The gold coins were sold at a price of $140 each, plus handling charges and sales tax where applicable. The reverse side of the coin features provincial and territorial flower emblems.

Canadian developments

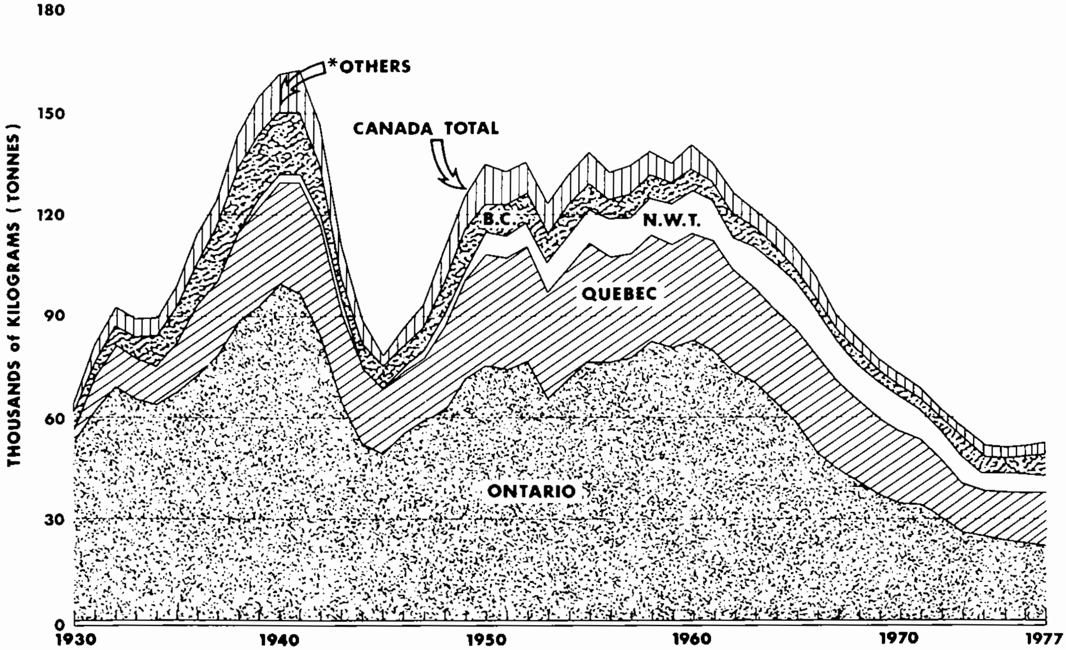
Atlantic provinces. All gold produced in the Atlantic provinces in 1977 was derived as a byproduct of base metal ores. Some exploratory work was carried out on gold prospects in Nova Scotia and Newfoundland.

Quebec. Agnico-Eagle Mines Limited completed the deepening of the shaft at its mine at Joutel from the 550 metre (m) level to the 904 m level. Work is under way to prepare the new levels for production. Long Lac Mineral Exploration Limited completed its exploration program on the Thompson-Bousquet property and decided to sink a shaft to an initial depth of 380 m. Ore produced at this mine will be shipped about 48 kilometres (km) by truck to the East Malartic mill for custom treatment. Shipments are expected to begin in the latter part of 1978.

A drill program was carried out on the Silverstack joint venture project, near Thompson-Bousquet, a property in which Silverstack Mines Ltd. controls 51 per cent and Quebec Mining Exploration Company

*31.10348 grams are equivalent to 1 troy ounce.

GOLD PRODUCTION by PROVINCES



* OTHERS = NFLD., N.S., N.B., MAN., SASK., ALTA., Y.T.
DATA SOURCE: STATISTICS CANADA

(SOQUEM), the exploration arm of the Quebec Government, 49 per cent. Long Lac has a majority interest in Silverstack Mines. An underground exploration program was carried out on the former O'Brien mine in Quebec's Cadillac district by Darius Gold Mines Inc., a private company controlled by Gold Fields American Corporation, a subsidiary of Consolidated Gold Fields Limited. A mill is being built on the property to treat 190 tonnes* of ore a day. A limited amount of exploratory work was carried out on other gold prospects in the province.

Ontario. Total gold production in Ontario in 1977 was 22 985 kg, slightly lower than that of 1976. The lode gold mines operating in the province in 1977 accounted for 91.2 per cent of the provincial total, with the balance derived from base-metal mining.

Campbell Red Lake Mines Limited in the Red Lake district maintained its position as the leading lode gold mine producer in Canada. Pamour Porcupine Mines, Limited is mining a block of low grade ore on the Pamour-Hoyle boundary. Pamour plans to deepen the shaft by 60 to 1 008 m below surface at its Ross mine at Holtyre. In its efforts to ensure continued feed to its two mills in the Timmins area, Pamour is investigating gold prospects in the Timmins-Porcupine district. In the fourth quarter of 1977 Willroy Mines Limited acquired the outstanding shares of Tegren Goldfields Limited from Teck Corporation Limited and Oakdale Mines Limited, a private company, at a reported price of $750 000. The Tegren property adjoins the western boundary of Willroy's Macassa mine and has been worked for a number of years by Willroy under a lease agreement, through deep headings advanced into the Tegren property from Macassa.

Amoco Canada Petroleum Company Ltd. carried out an extensive underground exploration program to evaluate its Detour Lake gold property located about 230 km northeast of Timmins. According to reports, a decline was driven 760 m, and 300 m of crosscutting and drifting was done. Underground diamond drilling amounted to 9 100 m of closely-spaced drillholes. The results of the underground drilling are to be appraised, and samples have been taken for metallurgical testing.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Canada, production of gold, 1976 and 1977

	1976	1977p
	(grams)	
Newfoundland		
Base-metal mines	431 405	435 000
New Brunswick		
Base-metal mines	116 731	218 000
Quebec		
Auriferous quartz mines		
Bourlamaque-Louvicourt	4 363 351	4 292 000
Malartic and Matagami	6 583 984	6 408 000
Total	10 947 335	10 700 000
Base-metal mines	3 523 309	3 888 000
Total Quebec	14 470 644	14 588 000
Ontario		
Auriferous quartz mines		
Larder Lake	5 114 967	5 008 000
Porcupine	8 522 010	8 118 000
Red Lake and Patricia	7 581 659	7 838 000
Total	21 218 636	20 964 000
Base-metal mine	1 783 847	2 021 000
Total Ontario	23 002 483	22 985 000
Manitoba and Saskatchewan		
Base-metal mines	1 929 131	2 084 000
Alberta		
Placer operations	5 163	—
British Columbia		
Base-metal mines	5 357 138	6 034 000
Placer operations	34 214	31 000
Total British Columbia	5 391 352	6 065 000
Yukon		
Base-metal mines	633 951	715 000
Placer operations	477 998	467 000
Total Yukon	1 111 949	1 182 000
Northwest Territories		
Auriferous quartz mines	6 162 252	5 847 000
Canada		
Auriferous quartz mines	38 328 223	37 511 000
Base-metal mines	13 775 512	15 395 000
Placer operations	517 375	498 000
Total	52 621 110	53 404 000
Total value	$208 273 405	$268 377 000[1]
Average price/gram[2]	$3.958	$5.051
Average price/oz[2]	$123.107	$157.098

Sources: 1976, Statistics Canada; 1977, Statistics Canada and company reports. Breakdown by type of operation by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
[1]Value not necessarily based on average gold price for 1977. [2]Average of London Gold Market afternoon fixings in Canadian funds.
pPreliminary; — Nil.

Despite the improvement in the gold price only a minimal amount of exploration was carried out on gold prospects throughout the province.

Prairie provinces. Virtually all gold produced in the Prairie provinces was recovered as a byproduct from the mining of base-metal ores. A small amount of gold was recovered by gravel-washing plants on the North Saskatchewan River, near Edmonton, Alberta. Exploratory work on gold properties was limited.

British Columbia. With the exception of Northair Mines Ltd. virtually all gold produced in British Columbia in 1977 was recovered as a byproduct of base-metal ores. Northair recorded its first full year of production. A lower adit is to be driven at Northair to explore the ore zones at depth. Carolin Mines Ltd. carried out underground exploration on its property near Hope. Also an underground exploration program was carried out on the property of The Mosquito Creek Gold Mining Company Limited in the Cariboo district. A minor amount of exploratory work was done on other gold prospects in the province. Some placer gold was recovered from the placer deposits in the north-central part of the province and the Atlin district.

Yukon Territory. There was considerable activity in all of the older placer districts in the Yukon Territory in 1977. Claymore Resources Ltd. worked its ground near the Alaska-Yukon boundary about 48 km north of the Alaska Highway. Significant quantities of gold were recovered from the copper ores of Whitehorse Copper Mines Ltd.

Northwest Territories. The new deep shaft at the Con mine of Cominco Ltd. in Yellowknife and a 50 per

Table 2. World gold production, 1975 and 1976

	1975	1976[p]
	(grams)	
North America		
Canada	51 433 114	52 621 110
United States	32 728 696	32 597 595
Other countries	13 676 572	20 756 625
Total	97 838 382	105 975 330
South America		
Colombia	9 606 744	9 264 513
Brazil	5 350 980	5 699 992
Chile	4 063 700	4 016 796
Peru	2 450 830	2 510 984
Bolivia	1 655 265	895 687
Other countries	1 835 136	1 760 519
Total	24 962 655	24 148 491
Europe		
U.S.S.R.[e]	233 276 076	239 496 771
Spain	3 874 996	8 397 939[e]
Yugoslavia	5 533 993	5 499 095[e]
Sweden	1 964 993	2 298 547[e]
Other countries	4 450 348	4 661 354
Total	249 100 406	260 353 706
Asia		
Philippines	15 607 507	15 588 969
North Korea[e]	4 976 556	4 976 556
Japan	4 463 442	4 281 985
India	2 825 004	3 131 996
Other countries	5 119 104	5 723 506
Total	32 991 613	33 703 012
Africa		
Republic of South Africa	713 445 952	713 388 971
Southern Rhodesia[e]	24 882 781	24 882 781
Ghana	16 294 769	16 561 762
Zaire	3 210 408	3 199 988
Other countries	2 574 933	2 426 631
Total	760 408 843	760 460 133
Oceania		
Papua-New Guinea	19 015 297	38 212 923
Australia	16 385 965	15 479 983
Fiji	2 138 177	2 045 271
Other countries	110 448	288 516
Total	37 649 887	56 026 693
World total	1 202 951 786	1 240 667 365

Sources: U.S. Bureau of Mines, Mineral Trade Notes, September 1977 and Statistics Canada.
[p]Preliminary; [e]Estimated.

cent increase in the concentrator capacity became operational in 1977. The new shaft will improve the efficiency of the underground operations.

World industry

In 1977 the Republic of South Africa was, by far, the leading gold producing country, followed by the U.S.S.R., Canada and the United States. Other significant producers were Ghana, Papua-New Guinea, Rhodesia, the Philippines and Australia.

Consolidated Gold Fields Limited, which holds a large interest in the Republic of South African gold mining industry, in its report *Gold 1978,* estimated world gold production for 1977 at 1 428.5 tonnes, slightly below 1976 output. South Africa accounted for 49 per cent of the world total output in 1977; U.S.S.R., 31 per cent; and Canada, 3.8 per cent. Gold production in the non-communist world for 1977 was reported to be 964.5 tonnes compared with 971.4 tonnes in 1976. In 1977 gold production in the Republic of South Africa was 699.9 tonnes, 72.6 per cent of the non-communist world total. In 1976 comparable production figures were 713.4 tonnes and 73.4 per cent. Canada is a relatively small world producer and accounted for 5.6 per cent of the non-communist world's gold production in 1977. Reported gold production for the U.S.S.R. by Consolidated Gold Fields for the years 1977, 1976 and 1975 was 440.0 tonnes, 443.6 tonnes and 407.9 tonnes, respectively. Consolidated Gold Fields estimates are considerably higher than those of the United States Bureau of Mines, which reports U.S.S.R. production for the years 1976 and 1975 at 239.5 tonnes and 233.3 tonnes, respectively. The general consensus is that the U.S.S.R. gold output will increase in the next few years.

The world's major centres for the distribution of gold supplies are London, where gold sales are handled through member firms of the London Gold market; and Zurich, Switzerland, where sales are handled through banks. The Republic of South Africa is one of the major suppliers of gold to these centres. Hong Kong is becoming an active gold trading market.

According to *Gold 1978* the world market supply of 1 607 tonnes of new gold in 1977 was appreciably above the 1 453 tonnes of the previous year. New mine production from the non-communist world added 965 tonnes to world supply. Sales from the communist countries were 401 tonnes and net official sales 241 tonnes. Fabrication demand consumed 1 387 tonnes and net private bullion purchases 220 tonnes.

Trading in gold futures was carried out on five commodity exchanges in the United States: the Commodity Exchange Inc. (Comex) of New York and the International Monetary Market (IMM) of Chicago, the two more active exchanges; and the Chicago Board of Trade (CBT), the New York Mercantile Exchange (NYME) of New York and the MidAmerican Commodity Exchange of Chicago. Gold futures are also traded on the Winnipeg Commodity Exchange in 400 and 100 ounce contracts.

Table 3. Canada, gold production, 1960, 1965, 1970 and 1975-77

Year	Auriferous Quartz Mines		Placer Operations		Base-metal ores		Total	
	(grams)	(%)	(grams)	(%)	(grams)	(%)	(grams)	(%)
1960	122 248 048	84.9	2 513 285	1.7	19 213 893	13.4	143 975 226	100.0
1965	92 031 269	82.1	1 387 153	1.2	18 741 680	16.7	112 160 102	100.0
1970	58 591 610	78.2	228 890	0.3	16 094 525	21.5	74 915 025	100.0
1975	37 529 456	73.0	335 077	0.6	13 568 581	26.4	51 433 114	100.0
1976	38 328 223	72.8	517 375	1.0	13 775 512	26.2	52 621 110	100.0
1977p	37 511 000	70.3	498 000	0.9	15 395 000	28.8	53 404 000	100.0

Source: Statistics Canada. Compiled by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
pPreliminary.

Republic of South Africa. In 1977 gold production in the Republic of South Africa was estimated by Consolidated Gold Fields at 699.9 tonnes compared with 713.4 tonnes in 1976. The South African mines have benefited from the increase in the gold price, but this advantage has been partly offset by an increase in cost of production by an estimated 20 to 30 per cent because of increases in labour costs, supplies and power. More workers from the Republic of South Africa are seeking employment in the mines, largely because of the sharp increase in wages since 1972. Also, workers are still being recruited from some of the adjoining countries.

Table 4. Canada, gold production, average value per gram and relationship to total value of all mineral production, 1960, 1965, 1970 and 1975-77

	Total production	Total value	Average value per gram[1]	Gold as per cent of total value of mineral production
	(grams)	($)	($)	(%)
1960	143 975 226	157 151 527	1.09	6.3
1965	112 160 102	136 051 943	1.21	3.7
1970	74 915 025	88 057 464	1.18	1.5
1975	51 433 114	270 830 389	5.27	2.0
1976	52 621 110	208 273 405	3.96	1.4
1977p	53 404 000	268 377 000	5.03	1.5

Source: Statistics Canada.
[1]Value not necessarily based on average gold price for 1977.
pPreliminary.

To offset rising costs the South African mine operators have adopted a policy of increased mechanization wherever possible, but the physical characteristics of ore occurrences eliminates the possibility of adopting much of the technology available for stope mining. The major problems are the narrow widths and faulting of the ore zone.

Three large mines are under development in South Africa and are expected to come into production over the period 1979 to 1981. Construction costs for these three projects have escalated sharply. A project, which is expected to be operative in early 1978, is underway by East Rand Gold and Uranium Company Limited to recover gold, uranium and pyrite for the production of acid from the old mine waste dumps. Gold output from this source is expected to be about 7 000 kg of gold a year.

Gold output in the Republic of South Africa is expected to remain relatively stable or decline slightly until the new mines under development come into production in 1979-80. Production should then increase but is expected to begin declining again by 1985 as older mines exhaust their reserves and suspend operations.

United States. Gold production in the United States was estimated at 31 725 kg in 1977 by the United States Bureau of Mines, a slight decrease from the 32 659 kg produced in 1976. About 33 per cent of the United States domestic gold production comes as a byproduct of base-metal mining, chiefly the copper ores in the western United States. A small amount of gold is recovered from placer operations, and the remainder comes from lode gold mines.

Homestake Mining Company and Carlin Gold Mining Company, an open-pit mine in Nevada, were the major lode gold-producing mines in the United States. Kennecott Copper Corporation was the major contributor to byproduct gold output. There was increased activity in gold exploration, mainly in the western states, with emphasis on types of ore occurrences similar to that of Carlin. It has been reported that some

Table 5. International Monetary Fund, gold auctions, 1977

Date of Sale in 1977	Average bid price or common price[1]	Amount of gold sales
	($U.S./troy ounce)	(troy ounces)
January 28	133.26	780 000
March 2	146.51	524 400
April 6	149.18	524 800
May 4	148.02	524 800
June 1	143.32[1]	524 800
July 6	140.26[1]	524 800
August 3	146.26[1]	524 800
September 7	147.78	524 800
October 5	155.14	524 800
November 2	161.86	524 800
December 7	160.03[1]	524 800
Total gold sales in 1977		6 027 600
Total gold sales in 1976		3 899 200
Total gold sales to end of 1977		9 926 800
Total gold remaining to be sold under present program		15 073 200

Source: *IMF Survey* (International Monetary Fund Publication).
[1]Common price — all successful bidders receive gold at the lowest acceptable bid price.

success has resulted from this activity. Recovery of gold by a heap-leaching process is becoming increasingly important, and research into improvements in the process is meeting with some success.

The United States is one of the major consumers of gold, and imported substantial quantities in 1977 from Canada, Switzerland (mostly of South African origin) and the U.S.S.R. The United States was a major market for the South African krugerrand, a 1-ounce gold coin. Secondary recovery of gold, which amounted to 80 869 kg in 1977, is also an important source of supply for the United States market.

Dominican Republic. In 1977 Rosario Dominicana, S.A., a company in which the Dominican Republic holds 46 per cent interest and Rosario Resources Corporation and J.R. Simplot (both United States companies) each hold 27 per cent interest, maintained its position as the leading gold producer in the western hemisphere.

Gold produced was 10 839 kg. Further exploration work was carried out appraising an underlying sulphide zone, and tests are being carried out to develop an economic method of processing the sulphide ore.

Australia. The increase in the gold price in 1977 reversed the depressed state of the Australian gold industry existing in 1976. Mine production of gold was 19 600 kg in 1977, a five-year high. Increased output from some of the older producers and the start of production at the open-pit Telfer mine, in which Newmont Proprietary Limited has a 70 per cent interest and Dampier Mining Company Limited, a subsidiary of The Broken Hill Proprietary Company Limited, a 30 per cent interest, were the main factors contributing to the increased output. The Tefer mine, located in the northwestern part of Western Australia, produced 3 143 kg of gold in 1977. The Kalgoorlie Mining Associates, a partnership of Kalgoorlie Lake View Pty. Ltd. and Homestake Mining Company of the United States, worked the Mt. Charlotte mine in the state of Western Australia. Work is under way to improve the efficiency of the operation, and it is expected this will result in a substantial increase in output.

Nicaragua. Noranda Mines Limited holds a 60.5 per cent interest in the Empresa Minera de el Setentrion mine in Nicaragua. In 1977, 120 000 tonnes of ore were treated, averaging 13 grams of gold a tonne. Considerable exploratory and development work was done on other gold properties in the country by various companies.

Papua-New Guinea. Papua-New Guinea is a substantial producer of gold, mainly as a byproduct of the treatment of open-pit copper ore of Bougainville Copper Limited. Gold production from this property was 22 297 kg in 1977, equivalent to about 42 per cent of total Canadian output. Some gold is recovered by small operators.

Philippines. Early in 1977 the Philippine government instituted a subsidy program to aid the depressed gold mining industry. The subsidy called for a support price of $U.S. 140 an ounce for mines producing less than 2 333 kg a year and is applicable only to primary domestic producers. The Central Bank of the Philippines completed the construction of a 18 660 kg gold-silver refinery, and it began operations toward the end of 1977. The government will purchase the gold processed at its refinery from the primary producers at the international price of gold. Gold output in the Philippines in 1977 was 17 615 kg, up slightly from 1976.

France. Mines et Produits Chimiques de Salsigne, in which Silver Eureka Corporation of Toronto has controlling interest, operates a gold property in southern France that had mine output in 1977 of 1 270 kg of gold. Arsenic is also recovered. Consolidated Professor Mines Limited of Toronto has a substantial interest in Silver Eureka. Providing the necessary financing is obtained, it is planned to double the mine output.

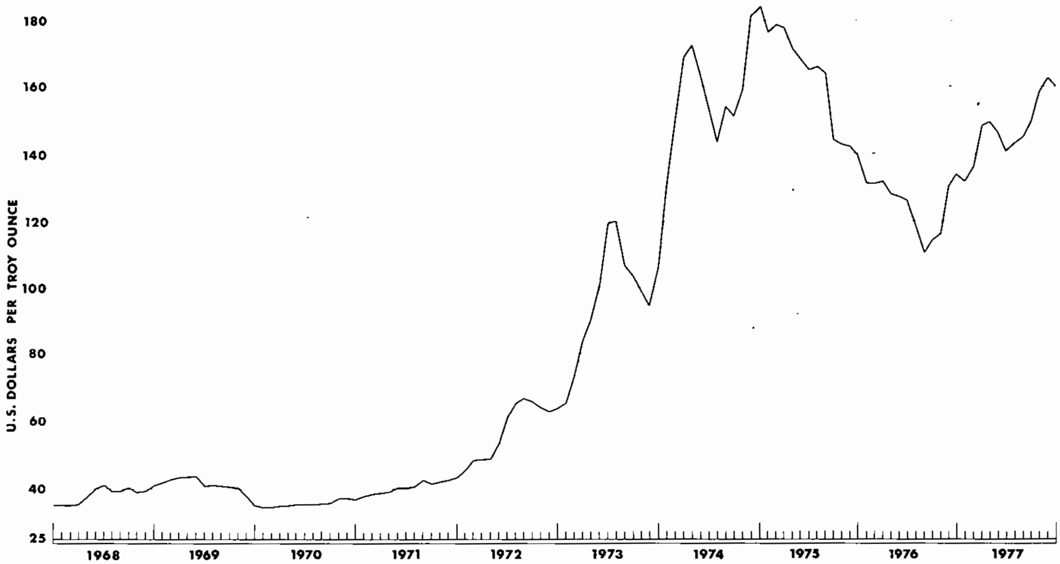
U.S.S.R. Detailed information on the gold industry in the U.S.S.R. is not available. Gold in the U.S.S.R. is recovered from placer gold deposits, mainly in the northeastern area; lode mines, and from base-metal ores, mainly copper ores, as a byproduct. Placer deposits are the largest single contributor to gold output. The consensus is that gold production in the U.S.S.R. will increase over the next few years, but reports of a decline in placer reserves could result in lower product from this source and thereby slow the trend towards increased production.

International Monetary Fund

At the meeting of the 20 finance ministers of the International Monetary Fund (IMF) Interim Committee held in Jamaica on January 7-8, 1976, an agreement was reached on the disposition of part of the IMF's official gold reserves. It was agreed that 777.6 tonnes of gold, one sixth of the IMF's reserves, would be auctioned over a four-year period, and the net proceeds from the sales would go into a trust fund administered by the IMF for the benefit of developing countries. It was also agreed that a further 777.6 tonnes of gold would be restituted over the four-year period to member countries of the IMF in proportion to their quotas in the Fund on August 31, 1975. The restituted gold would be offered at the price of 35 Special Drawing Rights (SDR) an ounce in four equal parts of 194.4 tonnes near the end of each year in which the gold is auctioned.

Gold auctioned by the IMF to the end of 1977 amounted to 308.76 tonnes (9 926 800 ounces), about 40 per cent of the sales program. Details of the sales are shown in Table 5. The auction sales prices were comparatively close to the London Gold Market quoted on the day of the auction. The successful bidders have been mainly European and North American banks and bullion dealers.

LONDON GOLD PRICES
MONTHLY AVERAGE
Afternoon Fixings



DATA SOURCE: SHARPS, PIXLEY LIMITED.

Table 6. Gold reserves of central banks and governments, December 31, 1977

Country	Value in millions of SDR's; gold valued at SDR 35 per fine troy ounce	Tonnes (millions of ounces) of Gold Fine	
		(tonnes)	(million oz)
United States	9 714	8 631.2	(277.5)
West Germany	4 140	3 679.5	(118.3)
France	3 558	3 163.2	(101.7)
Switzerland	2 915	2 590.9	(83.3)
Italy	2 902	2 578.5	(82.9)
Netherlands	1 912	1 698.2	(54.6)
Belgium	1 486	1 321.9	(42.5)
Portugal	844	749.6	(24.1)
United Kingdom	778	690.5	(22.2)
Canada	770	684.3	(22.0)
Japan	757	671.8	(21.6)
Austria	735	653.2	(21.0)
Spain	505	447.9	(14.4)
Venezuela	394	351.5	(11.3)
Republic of South Africa	340	301.7	(9.7)
Lebanon	323	286.2	(9.2)
Other countries	3 337	2 967.3	(95.4)
International Monetary Fund	4 605	4 093.2	(131.6)
Other official agencies	399	354.6	(11.4)
Estimated total world[1]	40 414	35 915.2	(1 154.7)

Source: Value from International Financial Statistics — International Monetary Fund: tonnes of gold (ounces) calculated by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
[1]Excludes holdings of U.S.S.R., other eastern European countries and the Peoples' Republic of China.

Early in 1977, the IMF decided to hold its auction on the first Wednesday of each month until May 1978 and to offer 16.3 tonnes of gold at each sale. At that time about one half of the 777.6 tonnes to be auctioned will have been sold, and the sales procedures will be reviewed. Amendments to Article IV of the IMF's Article of Agreement should be approved by all member countries early in 1978, and at that time central banks will be free to trade in gold.

Table 7. Average annual price of gold, 1965, 1970 and 1975-77

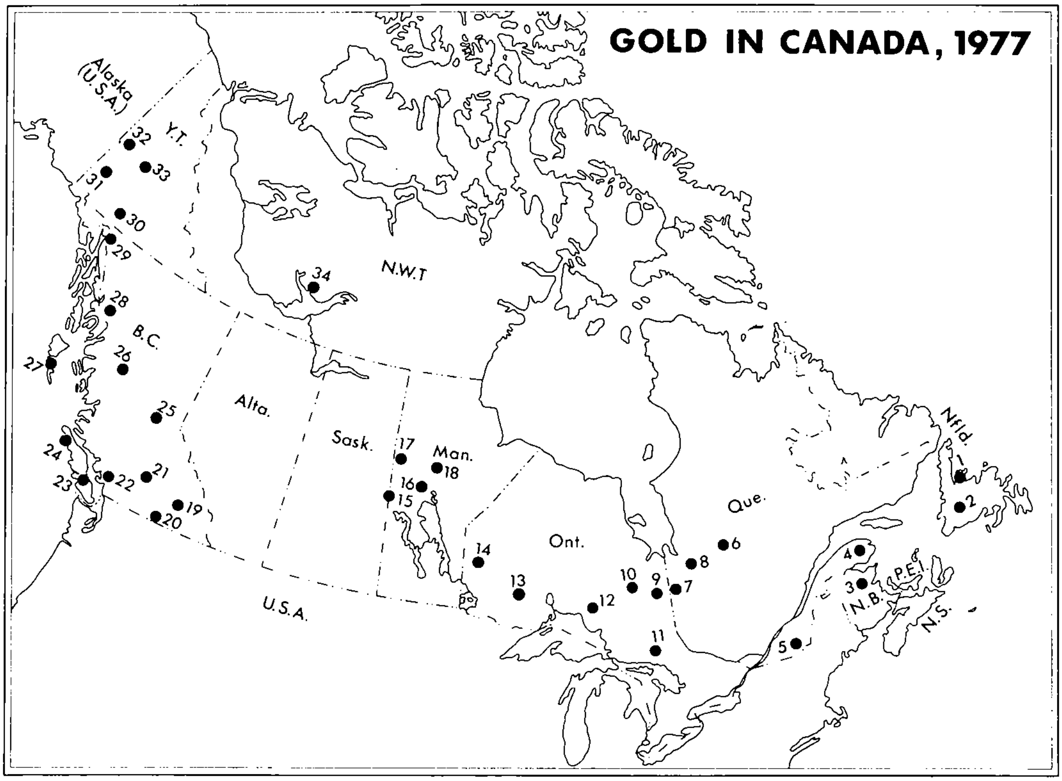
	London Free Market[1]		Royal Canadian Mint[2]
	($U.S.)	(Equiv. $Cdn.) (per troy ounce)	($Cdn.)
1965	37.76	40.82	37.73
1970	35.942	37.523	36.55
1975	161.018	163.804	43.22
1976	124.836	123.101	39.85
1977[p]	147.718	157.098	43.49

[1]Annual average of London Gold Market price, P.M. fixings, as reported by Sharpes Pixley Ltd. [2]Annual average of the Royal Canadian Mint weekly published buying prices.
[p]Preliminary.

The first program of the planned restitution of gold began on January 10, 1977 and was completed by the end of that month. A total of 18 657.2 kg of gold earmarked for 112 member countries was sold. Some countries elected to take advantage of an option whereby they could use their share of gold to purchase their currencies after the IMF's Article of Agreement has been amended. Sales were made only to countries with a net credit position with the IMF Fund in exchange for their currency. Member countries that did not have a credit balance were able to obtain their share of gold through arrangements with members that had a favourable balance with the fund. The second restitution of 19 439.7 kg began in December 1977 and is expected to be completed in January 1978.

Prices

The price of gold on the London Gold Market, with some variation, increased steadily during 1977 and



Gold Producers, 1977
(numbers refer to numbers on map above)

Newfoundland
(1) Consolidated Rambler Mines Limited (a)*
(2) ASARCO Incorporated (Buchans Unit) (a)

New Brunswick
(3) Heath Steele Mines Limited (a)

Quebec
(4) Gaspé Copper Mines, Limited (a)
(5) Sullivan Mining Group Ltd. (a)
(6) Chibougamau district
Campbell Chibougamau Mines Ltd. (a)
Falconbridge Copper Limited (Opemiska Division) (a)
Patino Mines (Quebec) Limited (Copper Rand Division) (a)
(7) Noranda-Rouyn district
Falconbridge Copper Limited (Lake Dufault Division) (a)

Malartic — Val d'Or district
Camflo Mines Limited (b)
East Malartic Mines, Limited (b)
Lamaque Mining Company Limited (b)
Louvem Mining Company Inc. (a)
Sigma Mines (Quebec) Limited (b)
(8) Matagami district
Agnico-Eagle Mines Limited (b)
Mattagami Lake Mines Limited (a)
Orchan Mines Limited (a)

Ontario
(9) Larder Lake Mining Division
Kerr Addison Mines Limited (b)
Pamour Porcupine Mines, Limited (Ross mine) (b)
Willroy Mines Limited (Macassa Division) (b)
(10) Porcupine Mining Division
Dome Mines, Limited (b)
Pamour Porcupine Mines, Limited (Nos. 1, and 3 mines and Timmins property) (b)
Pamour Porcupine Mines, Limited (Schumacher Division, McIntyre mine) (a & b)
(11) Sudbury Mining Division
Falconbridge Nickel Mines Limited (a)
Inco Limited (a)

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*(a) Base metal; (b) Auriferous quartz; (c) Placer.

(12) Thunder Bay Mining Division
Noranda Mines Limited (Geco Mine) (a)
(13) Patricia Mining Division
Falconbridge Copper Limited (Sturgeon Lake) Division (a)
(14) Red Lake Mining Division
Campbell Red Lake Mines Limited (b)
Dickenson Mines Limited (b)
Robin Red Lake Mines Limited (b)

Manitoba
(15) Hudson Bay Mining and Smelting Co., Limited (Flin Flon) (a)
(16) Hudson Bay Mining and Smelting Co., Limited (Snow Lake) (a)
(17) Sherritt Gordon Mines Limited (Fox Lake & Ruttan mines) (a)
(18) Inco Limited (a)

Saskatchewan
(15) Hudson Bay Mining and Smelting Co., Limited (a)

British Columbia
(19) Cominco Ltd. (a)
(20) Granby Mining Corporation (Phoenix Division) (a)
(21) Brenda Mines Ltd. (a)
Similkameen Mining Company Limited (a)
(22) Northair Mines Ltd. (b)
(23) Western Mines Limited (a)
(24) Utah Mines Ltd. (Island Copper Mine) (a)
(25) Small placer operations (c)
(26) Granby Mining Corporation (Granisle Division) (a)
Noranda Mines Limited (Bell Copper mine) (b)
(27) Wesfrob Mines Limited (a)
(28) Newmont Mines Limited (a)
(29) Small placer operations (c)

Yukon Territory
(30) Whitehorse Copper Mines Ltd. (a)
(31) Small placer operations (c)
(32) Small placer operations (c)
(33) Small placer operations (c)

Northwest Territories
(34) Cominco Ltd. (Con mine) (b)
Giant Yellowknife Mines Limited (b)
Lolor Mines Limited (b)
Rycon Mines Limited (b)
Supercrest Mines Limited (b)

closed the year at $U.S. 164.95 an ounce, much above the year's opening price of $U.S. 136.10 an ounce. The average monthly gold prices for January and February were $U.S. 132 and $U.S. 136 an ounce, respectively. The price improved substantially in March to $U.S. 148 an ounce. Over the period from March to September the price varied from $U.S. 141 to $U.S. 149 an ounce. In October the price resumed its upward trend because of increased speculative purchases resulting from the generally poor performance of the world economies and was in the range of $U.S. 160 an ounce for the balance of the year. The low gold price of $U.S. 129.40 an ounce was recorded on January 11 and the high for the year of $U.S. 168.12 an ounce on November 11.

The average gold price for 1977, based on the afternoon fixing on the London Gold Market was $U.S. 147.72 an ounce compared with $U.S. 124.84 in 1976. The equivalent Canadian gold price based on the average currency exchange differential between the United States and Canadian dollar for 1977 was $Can. 157.10 compared with $Can. 123.10 in 1976.

Uses and consumption

Gold has been used traditionally as a monetary reserve by governments and central banks in the settlement of international balances, but since August 1971, when the President of the United States suspended the convertibility of the U.S. dollar into gold, it has not been used for this purpose. When the accord reached in Jamaica on May 8, 1976 on abolishing the official price of gold is finalized, the metal's use as an official reserve will disappear. However, its use as collateral in loans between countries may increase.

The major uses of gold are in the jewellery trade, the electronics industry, dentistry and coinage. In the industrial field, emphasis has been placed on the development of technology leading to a more efficient use of gold, such as a thinner film in gold plating, selective and spot gold-plating, and duplex plating with a high-carat surface on a low-carat base. Other precious metals, mainly silver, platinum and palladium, can be used in place of gold in many of its applications.

A recent development is the use of 24 carat gold as a coating on glass windows in new high-rise office buildings, mainly because of its thermal properties but also for its aesthetic appearance. Gold-coated or "gold-reflective" glass blocks out the sun's heat rays in the summer while admitting the light rays. Consumption of gold for this use varies from a coverage of 37 to 93 m^2 an ounce of gold.

According to figures contained in the Consolidated Gold Field's report the non-communist world consumption of gold for fabrication in 1977 increased from 1 372.9 tonnes in 1976 to 1 386.9 tonnes in 1977. With the exception of gold used in official coins, gold consumption increased in all sectors — jewellery, electronics, dentistry, other industrial and decorative uses, and gold medals, medallions and illegal numismatic gold coins. Gold used in minting official gold coins in 1977 was 136.1 tonnes compared with 183.8 tonnes in 1976.

The use of gold in the jewellery trade largely depends on price and the purchasing power of the public. In the developed countries the price of gold is not the determining factor in gold jewellery purchases, as design, special fashion factors and labour are important factors in the final price. The mark-up on con-

Table 8. Principal gold (mine) producers in Canada, 1977 and (1976)

Company and Location	Mill or Mine Capacity	Gold	Silver	Copper	Combined Lead and Zinc	Ore Treated	Gold Produced	Remarks
		Grade of Ore Treated						
	(tonnes of ore/day)	(grams/ tonne)	(grams/ tonne)	(%)	(%)	(tonnes)	(kilograms)	
Newfoundland								
ASARCO Incorporated, (Buchans Unit), Buchans	1 130 (1 130)	0.75 (0.72)	97.04 (105.60)	0.99 (0.96)	16.88 (16.72)	174 180 (188 694)	102.8 (108.7)	Low ore reserves
Consolidated Rambler Mines Limited, Baie Verte	1 090 (1 090)	2.43 (2.61)	23.07 (21.74)	4.25 (3.68)	— (—)	188 880 (187 284)	402.0 (362.1)	
New Brunswick								
Heath Steele Mines Limited, Newcastle	3 630 (3 630)	0.69 (0.62)	68.23 (77.83)	1.22 (0.99)	5.43 (6.38)	1 150 338 (1 052 568)	265.6 (207.3)	
Quebec								
Agnico-Eagle Mines Limited, Joutel	910 (910)	6.13 (7.06)	. . (. .)	— (—)	— (—)	329 791 (313 467)	1 974.5 (2 001.3)	Shaft deepening to 904 m level completed.
Camflo Mines Limited, Malartic	1 130 (1 130)	6.00 (6.69)	. . (. .)	— (—)	— (—)	428 015 (420 681)	2 715.6 (2 813.6)	Developing lower levels
Campbell Chibougamau Mines Ltd., Cedar Bay, Henderson and Merrill Pit mines, Chibougamau	3 630 (3 630)	1.83 (2.43)	7.51 (8.64)	1.43 (1.62)	— (—)	264 313 (132 996)	432.7 (262.3)	Underground mines worked on single-shift basis.
East Malartic Mines, Limited, Malartic	1 630 (1 630)	3.19 (3.41)	. . (. .)	— (—)	— (—)	561 028 (543 564)	1 738.1 (1 791.1)	Mining approximately 13 600 tonnes a month from Barnet mine
Falconbridge Copper Limited, Lake Dufault Division, Millenbach and Norbec mines, Noranda-Rouyn	1 360 (1 360)	0.78 (0.82)	38.73 (41.49)	3.27 (3.10)	3.74 (3.45)	389 967 (458 447)	238.6 (264.5)	Sinking Corbet shaft. Treatment Norbec stockpile completed

Table 8. (cont'd)

Company and Location	Mill or Mine Capacity	Grade of Ore Treated: Gold	Silver	Copper	Combined Lead and Zinc	Ore Treated	Gold Produced	Remarks
	(tonnes of ore/day)	(grams/ tonne)	(grams/ tonne)	(%)	(%)	(tonnes)	(kilograms)	
Quebec (cont'd)								
Falconbridge Copper Limited, Opemiska Division, Perry, Springer and Cooke mines, Chapais	2 720 (2 720)	1.06 (0.60)	13.89 (12.55)	2.05 (2.01)	— (—)	927 158 (947 053)	849.1 (456.5)	Cooke mine came into production
Louvem Mining Company Inc., Val d'Or	900 (.)	1.03 (.)	41.83 (56.23)	0.12 (.)	6.11 (5.99)	277 842 (258 534)	288.6 (.)	
Lamaque Mining Company Limited, Val d'Or	1 900 (1 900)	4.59 (4.17)	. . (.)	— (—)	— (—)	427 636 (444 965)	1 851.3 (1 933.8)	Developing flats in north end of property
Lemoine Mines Limited, Chibougamau	363 (363)	5.31 (5.18)	100.78 (96.69)	4.67 (4.35)	10.64 (10.40)	110 678 (88 237)	435.4 (378.7)	
Mattagami Lake Mines Limited, Matagami	3 500 (3 500)	0.48 (0.48)	30.9 (31.89)	0.52 (0.55)	6.6 (7.4)	946 343 (1 112 156)	202.0 (219.1)	Exploring mine to depth
Patino Mines (Quebec) Limited, Chibougamau	2 540 (2 540)	3.65 (3.09)	10.63 (10.29)	1.74 (1.72)	— (—)	605 102 (516 356)	1 634.0 (1 229.7)	
Sigma Mines (Quebec) Limited, Val d'Or	1 270 (1 270)	5.55 (5.38)	. . (.)	— (—)	— (—)	450 233 (452 536)	2 413.6 (2 341.6)	
Ontario								
Campbell Red Lake Mines Limited, Red Lake	720 (720)	23.60 (22.94)	. . (.)	— (—)	— (—)	269 663 (272 641)	5 941.7 (5 742.0)	
Dickenson Mines Limited, Red Lake	430 (430)	12.88 (13.98)	. . (1.65)	— (—)	— (—)	78 374 (74 283)	997.9 (963.2)	

Dome Mines, Limited, South Porcupine	1 720 (1 720)	4.71 (5.97)	. . (.)	— (—)	— (—)	622 216 (642 556)	2 931.8 (3 717.0)	
Falconbridge Copper Limited, Sturgeon Lake Division, Sturgeon Lake	1 090 (1 090)	0.89 (0.55)	342.86 (183.42)	3.46 (2.15)	11.70 (10.80)	383 927 (375 433)	214.6 (93.3)	Improved metallurgical recoveries
Falconbridge Nickel Mines Limited, Ontario mine, Sudbury district	11 200 (11 700)	. . (.)	. . (.)	0.74 (.)	— (—)	2 599 318 (2 920 552)	. . (.)	Cutback on production
Inco Limited, Sudbury and Shebandowan districts, Ontario; and Thompson, Manitoba	77 900 (77 900)	. . (.)	. . (.)	1.15 (1.13)	— (—)	14 628 655 (14 949 686)	. . (.)	Cutback on production
Kerr Addison Mines Limited, Virginiatown	594[1] (655)[1]	15.43 (14.40)	. . (.)	— (—)	— (—)	216 882 (239 701)	3 301.3 (3 446.0)	
Pamour Porcupine Mines, Limited, No. 1 mine, Pamour	2 317[1] (2 720)	2.93 (3.31)	. . (.)	— (—)	— (—)	767 351 (758 740)	2 024.7 (2 292.4)	Some ore from No. 2 mine in 1976
Pamour Porcupine Mines, Limited, No. 3 mine, Pamour	262[1] (444)[1]	7.58 (6.14)	. . (.)	— (—)	— (—)	95 739 (162 211)	657.6 (890.4)	Treated at Pamour No. 1 mill, includes Timmins property in 1976
Pamour Porcupine Mines, Limited, Timmins Property, Timmins	562[1] (.)	3.39 (.)	. . (.)	— (—)	— (—)	205 214 (.)	604.4 (.)	Ore treated at Schumacher mill included in No. 3 for 1976
Pamour Porcupine Mines, Limited, Schumacher Division, Schumacher	1 612[1] (1 909)	2.40 (2.06)	. . (3.50)	— (0.44)	— (—)	588 307 (698 449)	1 208.7 (1 250.4)	Gold-copper ore
Pamour Porcupine Mines, Limited, Ross mine, Holtyre	425[1] (393)[1]	4.63 (4.58)	. . (.)	— (—)	— (—)	155 301 (143 628)	613.9 (575.2)	Ore treated at Schumacher mill
Robin Red Lake Mines Limited, Red Lake	106[1] (88)[1]	24.03 (25.47)	. . (1.65)	— (—)	— (—)	38 822 (32 274)	868.9 (762.6)	Ore treated at Dickenson mill

Table 8. (concl'd)

Company and Location	Mill or Mine Capacity	Grade of Ore Treated: Gold	Silver	Copper	Combined Lead and Zinc	Ore Treated	Gold Produced	Remarks
	(tonnes of ore/day)	(grams/ tonne)	(grams/ tonne)	(%)	(%)	(tonnes)	(kilograms)	
Ontario (cont'd)								
Willroy Mines Limited, Macassa Division, Kirkland Lake	450 (450)	18.55 (19.426)	. . (.)	— (—)	— (—)	92 931 (83 682)	1 731.6 (1 555.5)	
Manitoba-Saskatchewan								
Hudson Bay Mining and Smelting Co., Limited, Flin Flon and Snow Lake districts	7 250 (7 700)	1.37 (1.37)	20.6 (20.57)	2.20 (2.30)	3.0 (2.90)	1 652 526 (1 417 617)	1 390.5 (1 146.5)	Building 3 450 tonne concentrator at Snow Lake
Inco Limited, Thompson	16 700 (16 700)	included with figures from Ontario						
Sherritt Gordon Mines Limited, Fox mine, Lynn Lake	2 720 (2 720)	. . (.)	. . (.)	1.46 (1.56)	1.93 (1.68)	807 688 (755 122)	145.0 (.)	
Sherritt Gordon Mines Limited, Ruttan mine, Grand Rapids	9 070 (9 070)	. . (.)	. . (.)	1.13 (1.08)	1.95 (2.14)	2 369 851 (2 413 867)	453.8 (.)	Preparing for underground production
British Columbia								
Grandby Mining Corporation, Granisle mine, Babine Lake	11 800 (11 800)	0.17 (0.17)	2.06 (2.06)	0.44 (0.42)	— —	4 538 342 (4 008 244)	559.6 (115.4)	
Grandby Mining Corporation, Phoenix mine, Greenwood	2 600 (2 600)	0.5 (0.62)	5.08 (6.17)	0.39 (0.50)	— (—)	833 829 (965 850)	265.5 (364.6)	Treated stockpile ore
Newmont Mines Limited, Granduc Operating Division, Stewart	7 260 (7 260)	. . (.)	. . (.)	1.31 (1.26)	— (—)	1 333 143 (1 315 913)	167.0 (152.5)	Mine to close June 30, 1978

Newmont Mines Limited,	22 000	0.16	0.64	0.37	–	7 134 400	1 062.0	
Similkameen Division,	(20 000)	(.)	(.)	(0.42)	(–)	(6 355 738)	(1 107.3)	
Princeton								
Noranda Mines Limited,	9 070	0.31	. .	0.43	–	4 408 882	714.6	Lower production in 1976
Bell Copper Division,	(9 070)	(0.34)	(.)	(0.43)	(–)	(1 925 257)	(296.1)	because of strike
Babine Lake								
Northair Mines Ltd.,	270	14.40	126.5	–	3.57	92 166	1 181.9[e]	First full year of operation
Brandywine area	(270)	(19.88)	(111.75)	(–)	(2.67)	(47 555)	(563.6)	
Utah Mines Ltd.,	34 500	. .	. .	0.42	–	13 110 000	1 500.0	
Island Copper mine,	(34 500)	(.)	(.)	(0.47)	(–)	(12 246 998)	(1 430.8)	
Coal Harbour,								
Vancouver Island								
Western Mines Limited,	1 000	2.71	147.1	1.14	8.92	269 069	632.1	
Buttle Lake,	(1 000)	(3.09)	(169.37)	(1.19)	(9.15)	(269 294)	(695.5)	
Vancouver Island								
Yukon Territory								
Whitehorse Copper Mines Ltd.,	2 300	0.93	9.60	1.65	–	817 790	748.3	
Whitehorse	(2 180)	(.)	(.)	(1.69)	(–)	(726 506)	(577.0)	
Northwest Territories								
Cominco Ltd.,	716	21.17	. .	–	–	142 698	2 889.0	New shaft completed, mill
Con and Rycon mines,	(400)	(21.29)	(.)	(–)	(–)	(137 040)	(2 799.0)	expansion completed
Yellowknife								
Giant Yellowknife Mines Limited,	910[1]	8.71	. .	–	–	356 691	2 729.5	47 per cent of ore treated from
Yellowknife	(910)[1]	(9.15)	(.)	(–)	(–)	(357 186)	(2 904.4)	open-pit mine
Lolor Mines Limited,	19[1]	10.80	. .	–	–	6 952	65.8	Ore treated at Giant mill
Yellowknife	(14)[1]	(8.85)	(.)	(–)	(–)	(5 332)	(42.0)	
Supercrest Mines Limited,	113[1]	14.02	. .	–	–	41 142	506.1	Ore treated at Giant mill
Yellowknife	(71)[1]	(16.32)	(.)	(–)	(–)	(25 897)	(372.7)	

Source: Company reports.
[1]Average daily tonnage milled.
– Nil; . . Not available; [e]Estimated.

tained gold in an item of jewellery in these countries can be over 300 per cent. The market in the developing countries generally demands jewellery of a high carat, usually 22 carat, and the mark-up is low, about 20 to 30 per cent. Gold jewellery sales in these countries is based partly on its aesthetic appearance, but mainly because the gold content is a storehouse of value.

Gold used in jewellery fabrication in the non-communist world in 1977 was estimated by Consolidated Gold Field's at 978.7 tonnes, an increase of 5 per cent over the previous year. Jewellery fabrication is by far the largest industrial use of gold, accounting for about 70 per cent of the total in 1977. Gold consumption in jewellery fabrication increased in most of the developed countries, in the Latin American countries and the Indian subcontinent. It decreased in the Middle East largely because of a significant drop in Turkey's consumption, and in the Far East because of reduced consumption by Japan.

The Gold Institute/L'Institut de l'Or prepared a report on the official gold coinage issued in 1977, which showed that 46 countries issued a total of 87 coins of varying gold content for a total gold consumption of 112.9 tonnes (3 629 750 ounces). The krugerrand, a 1-ounce gold coin of the Republic of South Africa accounted for about 78 per cent of the gold consumed in coinage. Other countries issuing gold coins in 1976, which consumed significant amounts of the metal, were the U.S.S.R., Canada and the United Kingdom.

Outlook

The normal demand-supply relationship that exists for other metals does not apply to gold because of its unique role as a metal consumed by industry and as part of the official monetary reserves of many countries. Gold's position as an official monetary reserve was phased out early in 1978, but because of large gold holdings by many countries the metal will retain a strong unofficial position in these countries' reserves. A major problem encountered in forecasting gold prices is the strong upward pressure on the price of gold as a hedge against any rapid increase in inflation or weakness in currencies, especially the United States dollar, and the actions of speculators in buying or selling gold.

The improvement in the gold price that began in the latter part of 1976 continued into 1978, and by August 1978 the quotation on the London Gold Market was over $U.S. 200 an ounce, much above the gold price of $U.S. 165 an ounce at the end of 1977. A strong market for the industrial usage of gold, especially for jewellery and coins, has developed and this demand, plus investment, hedging and speculative requirements, has readily absorbed the gold produced in 1977 as well as sales by the IMF. The announcement by the United States Treasury in April 1978 that it would auction 1 800 000 ounces of gold from its official reserves caused only a temporary halt in the gold price escalation. The market readily absorbed the early sales.

In the short-term, gold production in the non-communist world is expected to remain near the level of output in 1977. Three large mines now under development in the Republic of South Africa will come into production in 1979 and 1980 and will increase gold output for a short period, but their combined effect will be partly offset by lower production of other South African mines, or mine closures because of ore exhaustion. There are no developments in other parts of the world that could significantly increase gold output. Other sources of gold available to the market are sales of official gold by the United States Treasury and from IMF auctions. The IMF auctions will end in 1980. The U.S.S.R. sells gold to finance purchases of capital goods and wheat, and this contribution to the market cannot be forecast. Sales by other governments from their official sources is possible, but it is considered that sales by them and by the U.S.S.R. will be carried out in such a manner as to be least disruptive to the market. All these factors indicate a continuing strong gold price, and they are also a strong buffer against any sharp decline in the price.

Gold production in Canada in the short-term is expected to show a small decline. The strong gold price will enable most of the gold properties to continue to operate, but many will treat lower-grade ore. Developments on the horizon will not offset the decline in output of the present producers.

Gypsum and Anhydrite

D.H. STONEHOUSE

Gypsum is hydrous calcium sulphate ($CaSO_4 2H_2O$) which, when calcined at temperatures ranging from 250° to 400°F, releases three-quarters of its chemically combined water. The resulting hemihydrate of calcium sulphate, commonly referred to as plaster of paris, when mixed with water, can be moulded, shaped or spread and subsequently dried, or set, to form a hard plaster product. Gypsum is the main mineral constituent in gypsum wallboard, lath and tile. Anhydrite, the anhydrous calcium sulphate ($CaSO_4$), is commonly associated geologically with gypsum.

Crude gypsum is crushed, pulverized and calcined to form stucco, which is mixed with water and aggregate (sand, vermiculite or expanded perlite) and applied over wood, metal or gypsum lath to form interior wall finishes. Gypsum board, lath and sheathing are formed by introducing a slurry of stucco, water, foam, pulp and starch between two unwinding rolls of absorbent paper, which results in a continuous "sandwich" of wet board. As the stucco hardens, the board is cut to predetermined lengths, dried, bundled and stacked for shipment.

Keene's cement is made by converting crushed gypsum to insoluble anhydrite by calcining at temperatures as high as 1 300°F, usually in rotary kilns. The ground calcine, mixed with a set accelerator, produces a harder and stronger plaster product than ordinary gypsum plaster.

Crude gypsum is also used in the manufacture of portland cement where it acts as a retarder to control set. It is used as a filler in paint and paper manufacture, as a substitute for saltcake in glass manufacture and as a soil conditioner.

The use of phosphogypsum, a calcium sulphate byproduct of phosphate fertilizer manufacture, has been of growing interest in Europe and Japan over the past five to ten years. Although large quantities of this material are accumulating in both the United States and Canada, its use in gypsum products manufacture has not developed as might have been expected. A dense board is produced using byproduct gypsum and the preferred industry trend is towards lighter-weight construction materials. A residual radioactivity in gypsum products containing phosphogypsum, carried over from the phosphate rock, is also of concern to gypsum products manufacturers in North America. Technological developments obviating these problems could encourage use of byproduct gypsum, especially in regions where waste disposal costs continue to increase and where natural gypsum is not available close to products plants.

The use of lime or limestone to desulphurize stack gases from utility or industrial plants burning high-sulphur fuel will also result in production of large amounts of waste gypsum sludge, which in itself will present disposal problems if profitable uses are not developed.

Production of gypsum in Canada is closely related to activity in the building construction industry, particularly in the residential building sector, in both Canada and the eastern United States. Between 70 and 75 per cent of Canadian gypsum production normally has been exported to the United States. During the recent period of economic recession in the United States, exports in 1975 were greatly reduced to the lowest level since 1967. Through 1976 and 1977, however, improved construction and building activity in the United States has resulted in greater use of gypsum and exports from Canada have risen accordingly — by over 30 per cent in 1977.

Canadian consumption of gypsum has fluctuated with activity in building construction, and currently is in the 2-million-tonne*-a-year range, which represents 8 to 9 tonnes per housing start. Total construction in Canada in 1977 is estimated to have reached a value of over $34 billion, 60 per cent of which is credited to the building construction sector. Traditionally, one half of building construction expenditures are in the residential category where, in 1977, housing starts decreased 10 per cent to 245 724 units.

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*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Canada, gypsum production and trade, 1976-77

	1976		1977p	
	(tonnes)	($)	(tonnes)	($)
Production (shipments)				
Crude gypsum				
Nova Scotia	4 154 342	14 961 027	4 861 000	18 678 000
Ontario	574 028	2 680 192	685 000	3 677 000
Newfoundland	571 627	2 532 286	661 000	2 880 000
British Columbia	566 449	2 079 181	660 000	2 626 000
Manitoba	100 322	338 447	130 000	465 000
New Brunswick	35 386	176 103	43 000	204 000
Total	6 002 154	22 767 236	7 040 000	28 530 000
Imports				
Crude gypsum				
United States	6 982r	184 000	9 759	312 000
Mexico	47 788	592 000	14 248	252 000
Belgium and Luxembourg	—	—	18	10 000
United Kingdom	—	—	16	1 000
Total	54 770r	776 000	24 041	575 000
Plaster of paris and wall plaster				
United States	25 226	2 234 000	20 812	2 044 000
United Kingdom	387	44 000	291	35 000
West Germany	—	—	153	11 000
Other countries	—	—	35	12 000
Total	25 613	2 278 000	21 291	2 102 000
Gypsum lath, wallboard and basic products	(m^2)		(m^2)	
United States	23 940 279	11 718 000	13 438 330	7 282 000
United Kingdom				
Total	23 940 279	11 718 000	13 438 330	7 282 000
Total imports gypsum and gypsum products		14 772 000		9 959 000
Exports				
Crude gypsum				
United States	3 798 243	13 100 000	4 977 796	19 072 000
Taiwan	—	—	16 501	72 000
Total	3 798 243	13 100 000	4 994 297	19 144 000

Source: Statistics Canada.
pPreliminary; — Nil; rRevised.

Most of the gypsum for export is quarried in Nova Scotia and Newfoundland by Canadian subsidiaries of United States gypsum products manufacturers. Although most of the output from other provinces is used regionally, nearly all the Nova Scotia production is exported in large "in company" shipments to the eastern United States. Production in 1977 increased by 17 per cent to 7 million tonnes.

Canadian industry and developments

Atlantic provinces. During 1977 five companies in Nova Scotia, two companies in New Brunswick and one in Newfoundland produced crude gypsum. Regional consumption of raw gypsum was small compared with the quantity exported to the United States from the Atlantic provinces. Three cement manufacturing plants, two gypsum wallboard manufacturing plants and one plant producing plaster of paris, together used only about 100 000 tonnes. Crude gypsum from Nova Scotia is used by Quebec wallboard plants, and by Quebec and Ontario cement producers, each supplying regional construction industries.

Fundy Gypsum Company Limited, a subsidiary of United States Gypsum Company, Chicago, mines gypsum by open-pit methods at Wentworth and at Miller Creek near Windsor, Nova Scotia, for export to the United States. Crushed and beneficiated crude gypsum is shipped to company-owned processing plants through the port of Hantsport, Nova Scotia.

National Gypsum (Canada) Ltd. produces gypsum from a quarry near Milford, Nova Scotia, and exports most of it through the port of Halifax to east coast United States plants operated by the parent company, National Gypsum Company of Buffalo, New York. Unit-trains of 40 cars each are used to haul gypsum from the quarry site 48 kilometres (km) to Dartmouth. Company-owned, self-unloading ore carriers of up to 30 000 tonnes capacity are loaded at rates as high as 4 500 tonnes an hour through facilities on Bedford Basin. Shipments by water are made to Quebec for use in the manufacture of gypsum products and cement, and by truck to Brookfield, Nova Scotia for use in cement manufacture.

Georgia-Pacific Corporation, Bestwall Gypsum Division, mines gypsum from a quarry near River Denys, Inverness County, Nova Scotia. Crushed rock is transferred by rail to open storage at Point Tupper, 30 km from the quarry, and loaded on chartered vessels through a conveyor and reclaim tunnel system. Shipments are exported mainly to the Georgia-Pacific plant at Wilmington, Delaware.

Little Narrows Gypsum Company Limited, another subsidiary of United States Gypsum Company, produces gypsum from a quarry at Little Narrows, Victoria County, Nova Scotia, for shipments to the United States, Quebec and Ontario, through company shiploading facilities near the plant site.

Domtar Construction Materials Ltd. operates a calcining plant at Windsor, Nova Scotia, for the production of plaster of paris. Gypsum for the plant is supplied from a quarry at MacKay Settlement, under contract.

Many other gypsum occurrences are known in the central and northern mainland of Nova Scotia and on Cape Breton Island.

Gypsum is mined at Flat Bay Station, Newfoundland, 100 km southwest of Corner Brook, by Flintkote Holdings Limited, mostly for export to company plants in the United States. Raw gypsum is supplied to the Corner Brook plant of Atlantic Gypsum Limited for the manufacture of gypsum wallboard products and plaster of paris, and to the cement plant operated by North Star Cement Limited, also at Corner Brook. Exports are made through the port of St. George's from an open stockpile supplied by an aerial cable tramway carrying rock from Flat Bay, 10 km from the shipping site. Other gypsum occurrences are known in the southwestern lowlands, west of the Long Range Mountains.

In New Brunswick, two companies quarry gypsum. Canadian Gypsum Company, Limited, a subsidiary of United States Gypsum Company, produces gypsum for use in the manufacture of plaster and wallboard in the company-owned plant at Hillsborough. Canada Cement Lafarge Ltd. obtains gypsum from the Havelock area, west of Moncton, for use in the manufacture of portland cement at Havelock.

Other gypsum occurrences in the southeastern counties of New Brunswick have been recorded. Many gypsum outcrops occur on the Magdalen Islands in Quebec.

Ontario. Two underground gypsum mines are operated in southwestern Ontario to produce raw material for three gypsum products plants and a number of cement manufacturing plants. Domtar Construction Materials Ltd. mines gypsum at Caledonia, near Hamilton, from a 2.5-metre seam 23 metres below the surface. Crude gypsum is shipped to other consumers as well as being supplied to the company's wallboard plant, at the mine site, where a full range of gypsum building products is manufactured. Domtar plans to double its wallboard capacity at Caledonia with a new plant and is also designing a new underground mining operation.

At Hagersville, southwest of Caledonia, Canadian Gypsum Company, Limited, a subsidiary of United States Gypsum Company, Chicago, produces crude gypsum by room-and-pillar mining methods from a 1.3 metre seam, reached through a 29 metre vertical shaft. Increased production from the mine is planned for 1978 to supply the requirements of the company's wallboard plant, where an expansion is now under way in the form of a third wallboard line.

Westroc Industries Limited, Mississauga, expanded production capability at its wallboard plant by 30 per cent during 1977 with the extension of the wallboard line and the addition of a third continuous calcining kettle and a second Raymond mill. In order to secure a supply of crude gypsum, Westroc has commenced development of an underground mine near Drumbo, in the township of Blandford-Blenheim, Oxford County, Ontario. A shaft-sinking project was completed in October after many problems were experienced with a new shaft-drilling technique. Horizontal drifting at the 122-metre elevation was beginning at year-end and the $5 million program is scheduled for completion in 1978. Reserves are . sufficient to satisfy the company's needs and to supply other growing industrial and agricultural markets for 30 years.

Gypsum has been proven at depths to 60 metres in other parts of southwestern Ontario and under as much as 10 metres of over-burden in the Moose River area south of James Bay.

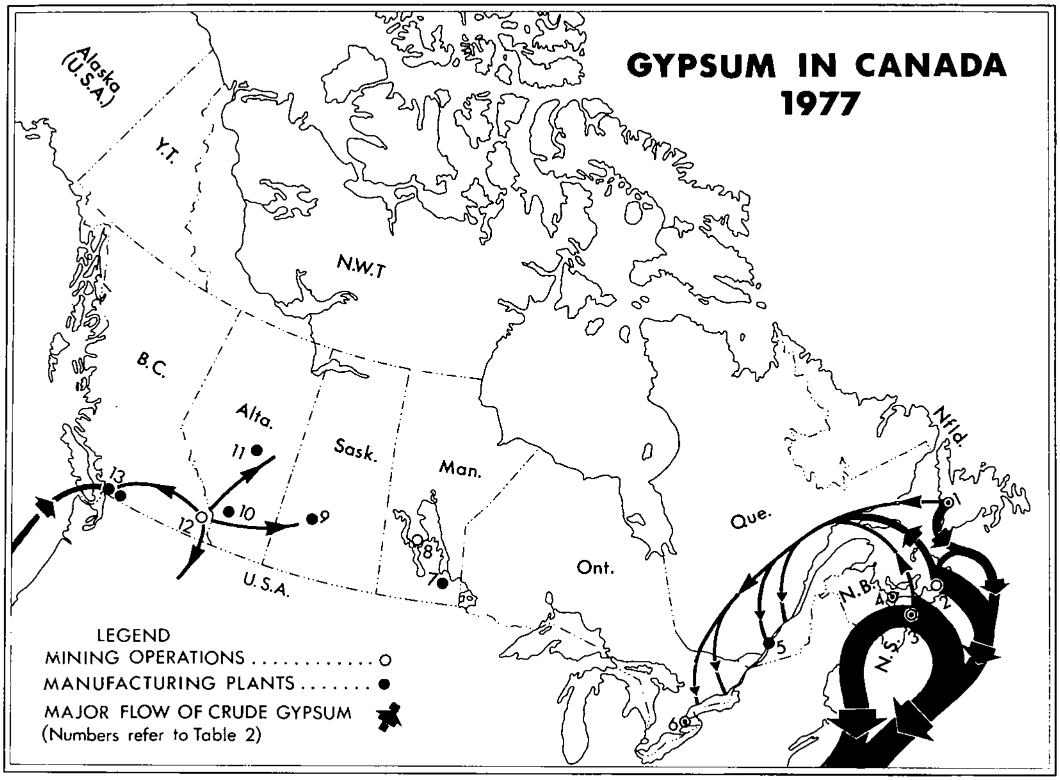


Table 2. Canada, summary of gypsum and gypsum products operations, 1977

Company	Location	Remarks
	(numbers refer to numbers on map above)	
Newfoundland		
1. Flintkote Holdings Limited	Flat Bay	Open-pit mining of gypsum
Atlantic Gypsum Limited	Corner Brook	Gypsum products manufacture
Nova Scotia		
2. Little Narrows Gypsum Company Limited	Little Narrows	Open-pit mining of gypsum and anhydrite
Georgia-Pacific Corporation Bestwall Gypsum Division	River Denys	Open-pit mining of gypsum
3. Fundy Gypsum Company Limited	Wentworth and Miller Creek	Open-pit mining of gypsum and anhydrite
National Gypsum (Canada) Ltd.	Milford	Open-pit mining of gypsum
Domtar Construction Materials Ltd.	MacKay Settlement	Open-pit mining of gypsum
	Windsor	Gypsum plaster manufacture

Table 2. (concl'd)

Company	Location	Remarks
	(numbers refer to numbers on map)	
New Brunswick		
4. Canadian Gypsum Company, Limited	Hillsborough	Open-pit mining of gypsum and gypsum products manufacture
Canada Cement Lafarge Ltd.	Havelock	Open-pit mining of gypsum used in cement manufacture
Quebec		
5. Canadian Gypsum Company, Limited	Montreal	Gypsum products manufacture
Canadian Gypsum Company, Limited	St-Jérome	Gypsum products manufacture
Domtar Construction Materials Ltd.	Montreal	Gypsum products manufacture
Westroc Industries Limited	Ste-Cathérine d'Alexandrie	Gypsum products manufacture
Ontario		
6. Canadian Gypsum Company, Limited	Hagersville	Underground mining of gypsum and gypsum products manufacture
Domtar Construction Materials Ltd.	Caledonia	Underground mining of gypsum and gypsum products manufacture
Westroc Industries Limited	Clarkson	Gypsum products manufacture
	Drumbo	Underground mine development
Manitoba		
7. Domtar Construction Materials Ltd.	Winnipeg	Gypsum products manufacture
Westroc Industries Limited	Winnipeg	Gypsum products manufacture
8. Domtar Construction Materials Ltd.	Gypsumville	Open-pit mining of gypsum
Saskatchewan		
9. Truroc Gypsum Products Ltd.	Saskatoon	Gypsum products manufacture
Alberta		
10. Domtar Construction Materials Ltd.	Calgary	Gypsum products manufacture
Westroc Industries Limited	Calgary	Gypsum products manufacture
11. Truroc Gypsum Products Ltd.	Edmonton	Gypsum products manufacture
British Columbia		
12. Western Gypsum Ltd.	Windermere	Open-pit mining of gypsum
13. Westroc Industries Limited	Vancouver	Gypsum products manufacture
Domtar Construction Materials Ltd.	Vancouver	Gypsum products manufacture
Truroc Gypsum Products Ltd.	Vancouver	Gypsum products manufacture

Source: Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.

Western provinces. Crude gypsum was produced from two surface operations: one in Manitoba, one in British Columbia, providing raw material for ten wallboard manufacturing plants. Imports, mainly from the United States and Mexico, totalled 24 041 tonnes in 1977 and were used principally in the Vancouver region. Early in 1978 Domtar purchased the integrated gypsum - gypsum products facilities of Kaiser Cement & Gypsum Co., including the San Marcos, Mexico quarry, two gypsum ships, a wallboard plant at Long Beach, California and a wallboard paper - producing plant at San Leandro, California.

Domtar Construction Materials Ltd. obtains crude gypsum from its quarry at Gypsumville, 240 km northwest of Winnipeg, Manitoba. The company's gypsum products plant at Winnipeg uses crude from this source.

Westroc Industries Limited mined gypsum from a deposit 33 metres beneath the surface near Silver Plains, 48 km south of Winnipeg, until mid-1975 when an inflow of artesian water from below the orebody forced the closure of the mine. Crushed and screened gypsum had been supplied to company-operated gypsum products plants in Winnipeg and Saskatoon, and to cement manufacturers in Winnipeg, Regina and Saskatoon. This demand is now met with crude gypsum from Gypsumville and from Windermere, British Columbia. Westroc began development of an open-pit gypsum quarry at Amaranth, Manitoba during 1977.

Western Gypsum Ltd., a subsidiary of Westroc Industries Limited, operates an open-pit mine near Windermere in the southeastern part of British Columbia, supplying raw gypsum to its products plant at Calgary and Vancouver, to the Calgary and Vancouver plants of Domtar Construction Materials Ltd., to the Edmonton plant of Truroc Gypsum Products Ltd., to cement manufacturers in the Vancouver area, Kamloops, Exshaw and Edmonton, and to markets formerly supplied from the company's mine at Silver Plains, Manitoba.

Truroc Gypsum Products Ltd., a subsidiary of Genstar Limited, began expansion of its Edmonton, Alberta wallboard plant in 1977 to enable 50 per cent more production.

Gypsum occurs in Wood Buffalo National Park, in Jasper National Park, along the Peace River between Peace Point and Little Rapids, and north of Fort Fitzgerald in Alberta; on Featherstonhaugh Creek, near Mayook, at Canal Flats, Loos, and Falkland in British Columbia; on the shores of Great Slave Lake, the Mackenzie, Great Bear and Slave rivers in the Northwest Territories; and on several Arctic islands.

Markets, trade and outlook

Because gypsum is a relatively low-cost, high-bulk mineral commodity it is generally produced from those deposits situated as conveniently as possible to areas in which markets for gypsum products exist. Exceptions occur if deposits of unusually high quality are available, even at a somewhat greater distance from markets; if comparatively easy and inexpensive mining methods are applicable, or if low-cost, high-bulk shipping facilities are accessible. Nova Scotia and Newfoundland deposits meet all three of these criteria and have been operated for many years by, and for, United States-based companies in preference to United States deposits.

Canadian exports of crude gypsum are mainly to the eastern United States where the demand for gypsum products bears close relation to activity in the

Table 3. World production of gypsum, 1976-77

	1976	1977^{e}
	(000 tonnes)	
United States	10 868	12 610
Canada	6 002	7 040
Iran	6 500	6 895
France	5 850	6 169
Spain	4 199	4 445
United Kingdom	4 000	4 264
West Germany	3 717	3 901
Mexico	1 414	3 810
Italy	3 500	3 719
Other Free World	10 432	11068
Communist countries	8 450	8 890
World Total	64 932	72 811

Sources: United States Bureau of Mines, Commodity Data Summaries, January 1978; and for Canada, Statistics Canada.
^{e}Estimated.

Table 4. Canada, gypsum production, trade and consumption, 1960, 1965, 1970, 1975, 1976 and 1977

	Production[1]	Imports[2]	Exports[2]	Apparent Consumption[3]
	(tonnes)			
1960	4 722 560	54 441	3 877 006	899 995
1965	5 720 370	68 432	4 306 068	1 482 734
1970	5 732 068	35 271	4 402 843	1 364 496
1975	5 719 451	55 338	3 691 676	2 083 113
1976	6 002 154	54 770^{r}	3 798 243	2 258 681
1977^{p}	7 040 000	24 041	4 994 297	2 069 744

Source:Statistics Canada.
[1]Producers' shipments, crude gypsum. [2]Includes crude and ground, but not calcined. [3]Production, plus imports, minus exports.
^{p}Preliminary; ^{r}Revised.

Table 5. Canada, production of gypsum products, 1976-77

Item	1976	1977
	(square metres)	
Wallboard	141 268 952	171 993 085
Lath	7 265 425	x
Sheathing	4 885 696	x
	(tonnes)	
Plaster	57 557	x

Source: Statistics Canada.
xConfidential, to meet secrecy requirements of the Statistics Act.

construction industry. Economic recovery, particularly in the construction industry, has been strong in the United States since 1975, after housing was given a high priority in the current administration's development program. Wallboard production increased from 1.0 billion square metres in 1975 to 1.2 billion in 1976 and to 1.4 billion in 1977. The residential housing sector does not deserve the entire credit for these increases, however. Greater use of gypsum products in non-residential construction has been of major importance to the industry. Its fire-retardant and sound-insulating properties have made it a preferred material for elevator shaft lining, mobile home manufacture and housing rehabilitation.

Crude gypsum, mainly from the Newfoundland port of St. George's and from Halifax and Little Narrows in Nova Scotia, is shipped to the Montreal and Toronto areas for use in gypsum products manufacture and portland cement production. Since the closure of the Westroc Industries Limited mine at Silver Plains, Manitoba, gypsum from Windermere, British Columbia is rail-hauled abnormally long distances to supply the needs of cement producers and the gypsum products industry in the prairie provinces. Raw gypsum is imported on the west coast from Mexico, mainly for cement manufacture. Minor amounts of crude gypsum have been shipped to the mid-United States for agricultural use, and quantities have been exported to the northwestern United States from British Columbia, mainly for use by cement manufacturers.

Gypsum products are not shipped great distances because freight and handling costs represent a major part of the price to the consumer for items that are relatively low-priced and readily available at many locations. However, substantial quantities of wallboard are imported from the United States each year. During 1977 a total of 13.5 million square metres valued at $7.3 million was imported, down from 1976 imports of 24 million square metres at $11.7 million. Ontario, Alberta and Quebec are the leading importing provinces. With modern containerized shipments becoming more popular and with the trend to trade off economic and environmental factors, the establishment of wallboard plants at the raw material source could become attractive.

Construction expenditures in both Canada and the United States are expected to increase. Construction of homes, apartments, schools and offices will continue

Table 6. Imports of gypsum lath, wallboard and basic products by province of clearance

	1974		1975		1976		1977	
	Quantity (000 sq. ft.)	Value $	Quantity (000 sq. ft.)	Value $	Quantity (000 sq. ft.)	Value $	Quantity (000 sq. ft.)	Value $
Newfoundland	286	23 611	150	8 078	3	158	3	169
Nova Scotia	230	12 430	2 405	108 526	55	2 753	–	–
New Brunswick	3 927	227 507	6 429	313 260	11 626	590 009	8 224	447 703
Quebec	12 491	657 508	8 586	419 980	26 426	1 174 003	26 092	1 237 163
Ontario	86 265	3 650 682	68 666	3 088 326	140 013	6 529 046	68 406	3 377 076
Manitoba	2 890	93 797	3 645	142 623	4 833	211 423	3 832	175 800
Saskatchewan	2 811	91 029	4 031	142 726	2 968	113 729	3 114	130 662
Alberta	13 918	560 790	8 518	326 574	63 434	2 768 453	31 875	1 667 434
British Columbia	25 595	890 976	7 385	267 940	8 332	328 823	3 107	245 711
Total	148 413	6 216 430	109 815	4 818 033	257 690	11 718 397	144 653	7 281 718
Avg. value/thousand		41.89		43.87		45.47		50.34

Source: Compiled by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa, from Statistics Canada data.
– Nil.

and the need for gypsum-based building products will rise steadily. Although new construction materials are being introduced, gypsum wallboard will remain popular because of its low price, ease of installation and well-recognized insulating and fire-retarding properties. The present structure of the gypsum industry in Canada is unlikely to change greatly in the near future. Building materials plants either have sufficient capacities to meet the short-term, regional demand for products, or are implementing expansion programs to provide greater capacity. Exploitable deposits in the Prairie region and in Ontario continue to attract attention.

A charge of price fixing, based on activities in all provinces west of, and including, Quebec, was laid September 30, 1976 against four major Canadian gypsum wallboard producers; Domtar Construction Materials Ltd., Westroc Industries Limited, BACM Industries Limited and Truroc Gypsum Products Ltd., following investigation by the federal Department of Consumer and Corporate Affairs. The latter two companies are subsidiaries of Genstar Limited. A preliminary hearing was to have been held in April 1977. The accused waived preliminary hearing and were expected to appear for full trial before a Judge of the Supreme Court of Ontario in January 1978. In May 1978 fines totalling $275,000 were levied against Domtar Inc., Westroc Industries Limited and Genstar Limited.

Canadian Standards Association standards A 82.20 and A 82.35 relate to gypsum and gypsum products.

World review

Gypsum occurs in abundance throughout the world but, because its use is dependent on the building construction industry, developments are generally limited to the industrialized countries. Reserves are extremely large and are conservatively estimated at over 2 billion tonnes. Accumulations of byproduct chemical gypsum (including phosphogypsum) will undoubtedly become attractive as sources of calcium sulphate for both cement and wallboard manufacture in North America, as, indeed, they have already in Europe and Japan. Increasing disposal costs will motivate the use of these products. Stringent regulations regarding the removal of SO_2 from stack gases are not too far in the future and one of the possible products of such emission controls, if the world sulphur system does not require either sulphuric acid or elemental sulphur, would be calcium sulphate. The technology exists to economically utilize chemical gypsum. For example, in Japan in 1976, where total gypsum production was 5 563 000 tonnes, only 150 000 tonnes was natural gypsum, produced from one operating mine, the rest was phosphogypsum (3 228 000 tonnes) and other chemical gypsum (2 185 000 tonnes). Over 65 per cent was used for wallboard and plaster manufacture and about 30 per cent in portland cement manufacture.

Table 7. Canada, house construction, by province

	Starts			Completions			Under Construction		
	1976	1977	% Diff.	1976	1977	% Diff.	1976	1977	% Diff.
Newfoundland	5 709	3 719	−35	5 850	4 292	−27	4 537	2 878	−37
Prince Edward Island	842	824	−2	989	652	−34	183	347	+90
Nova Scotia	7 470	7 495	+1	7 364	7 521	+2	7 307	6 479	−11
New Brunswick	6 772	4 308	−36	7 137	5 313	−26	3 873	2 709	−30
Total (Atlantic Provinces)	20 793	16 346	−21	21 340	17 778	−17	15 900	12 413	−22
Quebec	68 748	57 580	−16	54 301	61 979	+14	43 600	35 366	−19
Ontario	84 682	79 130	−7	80 302	80 717	+1	78 359	75 518	−4
Manitoba	9 339	9 410	+1	8 492	8 720	+3	5 820	6 479	+11
Saskatchewan	13 143	12 825	−2	11 046	11 485	+4	9 319	10 097	+8
Alberta	38 771	38 075	−2	25 858	37 879	+46	29 411	27 305	−7
Total (Prairie Provinces)	61 253	60 310	−2	45 396	58 084	+28	44 550	43 881	−2
British Columbia	37 727	32 358	−14	34 910	33 231	−5	21 877	18 421	−16
Total Canada	273 203	245 724	−10	236 249	251 789	+7	204 286	185 599	−9

Source: Statistics Canada.

The United States is the world's largest single producer of natural gypsum and, together with Canada, brings North American production to about 27 per cent of world output. European production is about 46 per cent of the world total, with France being the largest producer. Asian producers account for about 9 per cent of the world total; the four major producers being Iran, India, the People's Republic of China and Japan. Mexico, Central America, South America, Africa and Oceania each produce significant amounts, with Mexico contributing by far the greatest tonnage of any country in this group.

ANHYDRITE

Production and trade statistics for anhydrite are included with gypsum statistics. Anhydrite is produced by Fundy Gypsum Company Limited at Wentworth, Nova Scotia, and by Little Narrows Gypsum Company Limited at Little Narrows, Nova Scotia. According to the *Nova Scotia Annual Report on Mines*, production of anhydrite in 1977 was 245 100 tonnes. Most of this was shipped to the United States for use in portland cement manufacture and as a peanut crop fertilizer. Cement plants in Quebec and Ontario also used some Nova Scotia anhydrite.

Tariffs

Canada

Item No.		British Preferential Tariff	Most Favoured Nation	General	General Preferential
29200-1	Gypsum, crude	free	free	free	free
29300-1	Plaster of paris, or gypsum calcined, and prepared wall plaster, the weight of the package to be included in the weight for duty per 100 pounds	free	6¢	12½¢	free
29400-1	Gypsum, ground, not calcined	free	free	15%	free
28410-1	Gypsum tile	15%	15%	25%	10%

United States

512.21	Gypsum, crude	free
512.24	Gypsum, ground calcined	59¢ per long ton
245.70	Gypsum or plastic building boards and lath	6% ad val.

Sources: For Canada, the Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1978), T.C. Publication 843.

Indium

D.H. BROWN

Indium occurs as a minor constituent of certain ores of zinc, lead, tin, tungsten and iron. It is commonly associated with sphalerite, the most abundant zinc mineral. Indium becomes concentrated in zinc residues and smelter slags derived from zinc and lead smelting operations. It is recovered at only a few of the world's zinc and lead smelters.

Canadian output of indium in 1977 was 1 157.4 kilograms, (kg) compared with 6 128.7 kg in 1976. Cominco Ltd. is the only Canadian producer of indium, and one of the world's largest producers of the metal.

Other major producers of indium are located in the United States, Japan, West Germany, Australia, Peru and Belgium. Statistical data on output and consumption of indium in these countries are not generally available, although the United States Bureau of Mines estimated 1977 world production at 43 234 kg compared with 46 500 kg in 1976.

Production

Indium was first recovered at Trail, British Columbia in 1941, but the presence of indium in the lead-zinc-silver ores of Cominco's Sullivan mine at Kimberley, British Columbia, had been known for many years. In 1942, 13.6 kg were produced by laboratory methods. After a decade of intensive research and development, production began in 1952 on a commercial scale. At present the potential annual production at Trail is 31 100 kg.

Indium enters the Trail metallurgical plants in the zinc concentrates. In the electrolytic zinc process, indium remains in the zinc calcine during roasting and in the insoluble residue during leaching. The residue is then delivered to the lead smelter for recovery of contained lead and residual zinc. In the lead blast furnaces the indium enters lead bullion and blast furnace slag in about equal proportions. From the slag, it is recovered along with zinc and lead during slag fuming. The fume is leached for recovery of zinc, and indium again remains in the residue, which is retreated in the lead smelter. From the lead bullion, indium is removed in bullion dross. The dross is retreated for recovery of copper matte and lead and, in this process, a slag is produced which contains lead and tin, together with 2.5 to 3.0 per cent indium.

The dross retreatment slag is reduced electrothermally to produce a bullion containing lead, tin, indium, and antimony, which is treated electrolytically to yield a high (20 to 25 per cent) indium anode slime. The anode slime is then treated chemically to give a crude (99 per cent) indium metal, which is refined electrolytically to produce both a standard-grade (99.97 per cent) and a high-purity-grade (approximately 99.999 to 99.9999 per cent) indium. The metal is cast in ingots varying in size from 0.3 kilograms to 10 kilograms. Also produced are various alloys and chemical compounds of indium, such as indium antimonide; and a variety of fabricated forms such as discs, wire, ribbon, foil, sheet, powder, and spherical pellets.

Properties and uses

Indium is a silver-white metal that resembles tin in its physical and chemical properties. Its chief characteristics are extreme softness, low melting point and high boiling point. The metal has a melting point of 156°C; boiling point of 2 000°C; and atomic weight of 114.8. Its specific gravity at 20°C is 7.31, which is about the same as that of iron.

Indium forms alloys with precious metals and many of the base metals, improving their performance in certain applications. Its first major use, and still an important outlet, was in high-speed silver-lead bearings in which the addition of indium increases the strength and corrosion resistance of the surfaces of the bearings. Bearings of this type are used in aircraft piston engines, diesel engines and several types of automobile engines. The standard grade of indium is used in this application.

Indium is used in low-melting-point alloys containing bismuth, lead, tin and cadmium; e.g., a bismuth-tin-cadmium-lead-indium alloy used as a heat fuse contains 19.1 per cent indium and melts at 47°C. Indium is used in glass-sealing alloys containing about equal amounts of tin and indium, in certain solder alloys in which resistance to alkaline corrosion is required, and in gold dental alloys.

Indium is one of several metals that find application in various semiconductor devices. In these, high-purity indium, alloyed in the form of discs or spheres into each side of a germanium wafer, modifies the properties of the germanium. Indium is especially suitable for this purpose because it alloys readily with germanium at low temperatures, and, being a soft metal, does not cause strains on contracting after alloying.

Discovered in 1863, but in commercial use only since 1927 when it was first used as a nontarnish coating on silverware, indium and its compounds are relatively new materials whose potential applications are still being explored. Uses have been found in manufacturing electrical contacts, resistors, thermistors, photoconductors, small lightweight batteries and infrared detectors. Indium can be used as an indicator in atomic reactors because artificial radioactivity is easily induced in the metal by neutrons of low energy (about 1.5 electron-volt). Indium oil was used as a neutron indicator in the uranium-graphite piles of the first atomic bomb project. Silver-cadmium-indium alloys are now used in reactor control rods. Indium compounds added to lubricants have a beneficial anticorrosive effect. Indium is plated as a coating on screws in electrical sockets associated with aluminum wiring and it also has possible applications in decorative plating of jewellery and tableware.

The United States Bureau of Mines estimated that in 1977 the uses of the metal were distributed as follows: solder, alloys and coatings, 40 per cent; instruments, 30 per cent; electronic components, 10 per cent and other uses, 20 per cent.

Foreign trade

Detailed statistics on foreign trade are not available for indium. United States imports of the metal in 1977 were estimated by the U.S. Bureau of Mines at 8 709 kg compared with 9 020 in 1976, 3 234.8 kg in 1975, 15 334 kg in 1974, and 25 224.9 kg in 1973. The sources of imports for the period 1973-76 were: Canada, 36 per cent; U.S.S.R., 7 per cent; Peru, 17 per cent; United Kingdom, 12 per cent and others, 28 per cent.

Prices

The price of indium as quoted by *Metals Week* in the United States at the beginning of 1977 was $10.00 to $10.25 an ounce* delivered for metal having a minimum purity of 99.7 per cent. This quotation represents the announced selling prices of ASARCO Incorporated and the Indium Corporation of America, the only domestic metal producers. Price changes during the year were as follows:

Effective date	U.S. ingots $U.S. per ounce
October 7, 1976	10.00 - 10.25
January 5, 1977	10.00 - 10.50
April 14	10.00
July 21	9.10 - 10.00
August 31	8.50 - 10.00

Year-end quotations continued to reflect the split price for indium in the United States at $8.50 to $10.00 an ounce.

*The term ounce or its abbreviation oz. refers to a troy ounce, equivalent to 31.103 5 grams.

Tariffs

Canada — not specifically enumerated in Canadian tariffs.

United States

Item No.		Rate of Duty January 1, 1977
		%
628.45	Metal, unwrought, waste and scrap[1]	5
628.50	Metal, wrought	9
423.96	Indium compounds	5

Source: Tariff Schedules of the United States Annotated (1976) T.C. Publication 749.
[1]Duty on waste and scrap suspended until June 30, 1978.

Iron Ore

MICHEL A. BOUCHER

Summary of Canadian developments

Important events in 1977 in the Canadian iron ore industry included: a price increase of iron ore products; higher net earnings in 1977 as compared to 1976 for several Canadian iron ore producers and their respective holding companies; the start-up of Sidbec-Normines Inc. pellet plant at Port Cartier, the start-up of Sidbec's second Midrex direct reduction plant at Contrecoeur; a mine production cutback at Mount Wright near Fermont, Quebec by Quebec Cartier Mining Company; the closure of the Hilton mines, at Shawville Quebec and Lac Jeannine mine near Gagnon, Quebec; the temporary closing at year-end of Wesfrob Mines Limited at Tasu, B.C.; the announcement by Youngstown Sheet and Tube Company of the United States that its shares in Wabush Mines and in the Iron Ore Company of Canada were for sale; the completion of a drilling program and the production of experimental pellets by James Bay Development Corporation; the completion of a feasibility study by Steep Rock Iron Mines Limited on its Bending Lake property; the announcement of the closure of the Marmora mine in Ontario in early 1978, and a proposed toll increase by the St. Lawrence Seaway Authority for the Montreal-Lake Erie section of the Seaway, and for the Welland canal.

Summary of international developments

Important international events included a strike at most United States mines that lasted from August to December; the signing of a major contract for iron ore products between Japanese steel companies and Cia. Vale do Rio Doce (CVRD); the announcement of CVRD that its Carajas project was being scaled down; the sale of United States Steel Corporation's share of CVRD; a meeting of l'Association des Pays Exportateurs de Fer (APEF), followed by a United Nations Conference on Trade and Development (UNCTAD) meeting on iron ore.

Overview

As a result of a continuing depressed demand for steel in Western Europe, the United States and Japan, world iron ore production at 852 million tonnes* in 1977, was down by 2.6 per cent compared with 1976. In Europe, Sweden and France experienced the worst difficulties, and production in these countries is expected to decline in the future in view of strong competition from Brazil and West Africa. Production was down in Canada, Liberia, Brazil, Mauritania, Venezuela and the United States. In South Africa, Peru and India production increased, but only marginally. Generally, the year 1977 was characterized by the cutting back of several mine expansion programs, and by delayed and cancelled projects.

Canadian developments

Preliminary figures indicate that in 1977 Canadian iron ore production shipments were 51 754 000 tonnes, valued at $1 360 163 000. This compares with 55 416 346 tonnes valued at $1 223 002 567 in 1976, and 44 892 530 tonnes valued at $918 064 741 in 1975. These figures indicate an average annual tonnage growth of about 7 per cent from 1975 to 1977. However, Canada's total iron ore production capacity in 1977 was in the order of 75 million tonnes a year, which means that only 69 per cent of plant capacity was utilized.

The ability of the Canadian iron ore industry to maintain shipments at reasonable levels since 1975, even in a period of recession in the world steel industry, results from the following factors: shipments of iron ore to United States markets increased steadily since 1975, and particularly in 1977, as a result of a prolonged strike by all major iron ore producers in the United States that lasted from August 1 to the end of December; the Canadian steel industry, which consumes some 25 per cent of the iron ore produced in Canada, performed relatively well; and finally, a large part of our exports to Japanese and European markets

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Canada, iron ore production and trade, 1976-77

	1976		1977p	
	(tonnes)[1]	($)	(tonnes)[1]	($)
Production (mine shipments)				
Newfoundland	26 756 991	631 272 638	24 556 000	722 184 000
Quebec	17 323 304	324 607 902	16 285 000	329 583 000
Ontario	10 080 772	252 317 984	10 404 000	299 838 000
British Columbia	1 255 279	14 804 043	509 000	8 558 000
Total[2]	55 416 346	1 223 002 567	51 754 000	1 360 163 000
Imports				
Iron ore				
United States	2 822 560	75 802 000	2 091 596	64 596 000
Brazil	144 170	3 961 000	376 068	10 412 000
Sweden	38 281	1 319 000	36 599	1 191 000
Belgium and Luxembourg	—	—	786	59 000
Peru	—	—	142	16 000
South Africa	15 116	432 000	—	—
Mexico	3	. . .	—	—
Total	3 020 130	81 514 000	2 505 191	76 274 000
Exports				
Iron ore, direct shipping				
United States	2 837 853	47 923 000	2 665 014	39 745 000
Italy	571 023	9 721 000	344 140	4 902 000
United Kingdom	336 396	5 037 000	97 046	1 431 000
Japan	395 469	6 431 000	—	—
Belgium and Luxembourg	225 853	3 844 000	—	—
Netherlands	32 615	353 000	—	—
Total	4 399 209	73 309 000	3 106 200	46 078 000
Iron ore concentrates				
United States	6 228 848	115 293 000	5 326 319	113 858 000
Netherlands	3 642 757	51 844 000	4 137 561	58 482 000
Japan	4 472 032	46 554 000	4 193 186	51 822 000
United Kingdom	2 912 381	40 667 000	3 095 752	48 104 000
West Germany	2 061 869	31 118 000	1 066 085	17 484 000
Italy	1 272 223	17 330 000	1 112 352	17 436 000
France	877 470	11 645 000	1 125 897	16 213 000
Belgium and Luxembourg	—	—	303 704	4 449 000
Philippines	—	—	426 067	4 361 000
Yugoslavia	—	—	252 627	4 227 000
Spain	146 436	2 269 000	125 245	2 287 000
Portugal	51 088	1 125 000	97 384	1 893 000
Australia	29 239	686 000	27 052	684 000
Other countries	176 762	2 808 000	—	—
Total	21 871 105	321 339 000	21 289 231	341 300 000

Table 1. (concl'd)

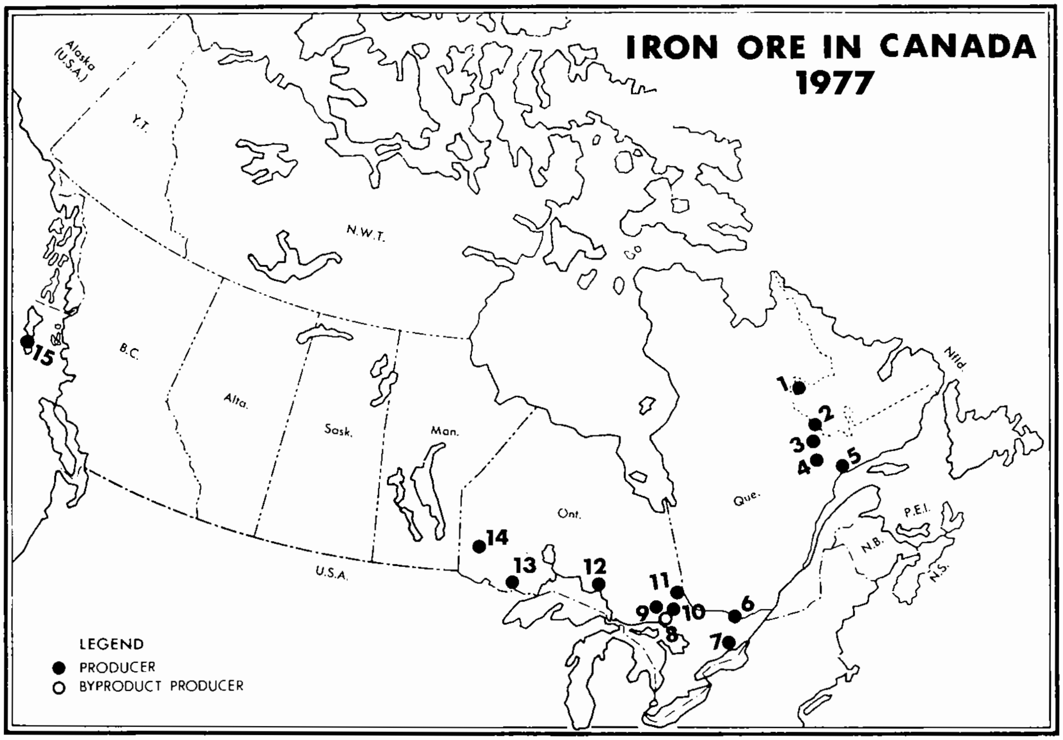
	1976		1977p	
	(tonnes)[1]	($)	(tonnes)[1]	($)
Iron ore, agglomerated				
United States	15 238 406	434 400 000	18 193 141	596 179 000
Netherlands	1 243 876	35 957 000	999 848	32 149 000
Italy	304 032	8 924 000	471 602	15 122 000
Spain	590 407	16 993 000	310 512	10 217 000
West Germany	312 201	8 897 000	208 959	6 624 000
United Kingdom	265 686	7 706 000	173 011	5 704 000
Japan	220 510	6 268 000	76 305	2 253 000
Belgium and Luxembourg	44 636	1 318 000	53 616	1 768 000
Total	18 219 754	520 463 000	20 486 994	670 016 000
Iron ore, not elsewhere specified				
United States	194 800	5 352 000	177 732	6 528 000
Total exports, all classes				
United States	24 499 907	602 968 000	26 362 206	756 310 000
Netherlands	4 919 248	88 154 000	5 137 409	90 631 000
United Kingdom	3 514 463	53 410 000	3 365 809	55 239 000
Japan	5 088 011	59 253 000	4 269 491	54 075 000
Italy	2 147 278	35 975 000	1 928 094	37 460 000
West Germany	2 374 070	40 015 000	1 275 044	24 108 000
France	877 470	11 645 000	1 125 897	16 213 000
Spain	736 843	19 262 000	435 757	12 504 000
Belgium and Luxembourg	270 489	5 162 000	357 320	6 217 000
Philippines	—	—	426 067	4 361 000
Yugoslavia	—	—	252 627	4 227 000
Portugal	51 088	1 125 000	97 384	1 893 000
Australia	29 239	686 000	27 052	684 000
Other countries	176 762	2 808 000	—	—
Total	44 684 868	920 463 000	45 060 157	1 063 922 000
Consumption of iron ore at Canadian iron and steel plants	13 694 489	. .	14 170 500	. .

Source: Statistics Canada.
[1]Dry tonnes for production (shipments), by province; wet tonnes for imports and exports. [2]Total iron ore shipments include shipments of byproduct iron ore.
pPreliminary; — Nil; . . Not available.

is sold on long-term contracts, and consequently exports were only partially affected by the steel recession.

In order to cover increases in the costs of energy, new capital equipment, supplies and transportation, The Cleveland-Cliffs Iron Company announced a 4.5 per cent price increase on all its iron ore products in January 1977. The increase was followed immediately by the other major merchant-ore mining firms, namely, The Hanna Mining Company and Pickands Mather & Co.

Net income of Iron Ore Company of Canada (IOC) and Steep Rock Iron Mines Limited was $44.9 million and $4.566 million, respectively, in 1977; these figures compare with net incomes of $19.2 million and $185 000 in 1976.



PRODUCERS

(numbers refer to numbers on map above)

1. Iron Ore Company of Canada, Knob Lake Division (Schefferville)
2. Iron Ore Company of Canada, Carol Division, (Labrador City)
2. Scully Mine of Wabush Mines (Wabush)
3. Quebec Cartier Mining Company (Mount Wright)
4. Sidbec Normines Inc. (Gagnon, Fire Lake)
5. Iron Ore Company of Canada, Sept-Iles Division (Sept-Iles)
5. Pointe Noire Division of Wabush Mines (Pointe Noire)
6. The Hilton Mines (Shawville)
7. Marmoraton Mining Company, Division of Bethlehem Chile Iron Mines Company (Marmora)
9. National Steel Corporation of Canada, Limited (Capreol)
10. Sherman Mine of Dominion Foundries and Steel, Limited (Temagami)
11. Adams Mine of Dominion Foundries and Steel, Limited (Kirkland Lake)
12. Algoma Ore Division of The Algoma Steel Corporation, Limited (Wawa)
13. Caland Ore Company Limited (Atikokan) Steep Rock Iron Mines Limited (Atikokan)
14. The Griffith Mine (Bruce Lake)
15. Wesfrob Mines Limited (Moresby Is.)

BYPRODUCT PRODUCERS

8. Inco Limited (Copper Cliff)

A significant portion of IOC's net income in 1977 reflected gains on foreign exchange. However, the company also benefited from higher prices paid for iron ore products and from improved operating performances by its plants. Steep Rock benefited from higher iron ore shipments, higher prices for iron ore, tax credits carried forward and gains on foreign exchange.

Net income of Labrador Mining and Exploration Company Limited and Hollinger Mines Limited in 1977 was $19.4 million and $19.666 million respectively compared with net income of $14.566 and $13.718 million in 1976. Additional net income in 1977 reflected increased royalties from IOC, increased investment revenue from IOC and gain on foreign exchange.

Activity in the Canadian iron ore industry during the year took place largely in Quebec. Sidbec-Normines reported that mining developments at its Fire Lake mine were almost completed. Also, construction of the company's 6-million-tonne-a-year pellet plant at Port Cartier, located some 400 kilometres (km) south of the mine, was nearly completed. On November 29, the first pellets for blast furnace feed were produced, and production to December 31 totalled 118 000 tonnes. Production of low-silica pellets for direct-reduction plants is expected to start in March 1978. Total cost of the Fire Lake mine development, together with modifications to the Gagnon concentrator, purchase of railroad cars and construction at Port Cartier of the pellet plant, secondary concentrator and handling equipment; plus the purchased cost of the Fire Lake mine, the Lac Jeannine concentrator and Gagnon townsite facilities from Quebec Cartier Mining, is about $630 million, including interest during construction. The pellet plant alone cost more than $200 million. Some 2.5 million tonnes a year of pellets averaging 65.5 per cent Fe and 5.5 per cent silica for blast furnace feed will be taken by British Steel Corporation, and 0.5 million tonnes a year by United States Steel Corporation. Of the remaining 3 million tonnes a year of pellets with 68 per cent Fe and less than 2.0 per cent silica for use in direct reduction plants, about 1.5 million tonnes a year could be used initially by Sidbec's two Midrex plants at Contrecoeur, leaving 1.5 million tonnes to be disposed of on world markets.

The second Midrex direct reduction plant of Sidbec began operations successfully on August 5. The 650 000-tonne-a-year sponge iron unit is the largest of its size in the world. The plant soon reached full capacity, bringing Sidbec's total capacity of high-quality sponge iron to about one million tonnes a year. Due to a combination of low scrap prices and a soft demand for steel, Sidbec operated only one of its two units at any one time during the year. Also, for the same reasons, the two other direct-reduction plants in Canada; the SL-RN plant owned by The Steel Company of Canada, Limited (Stelco) located at the Griffith mine near Red Lake, Ontario, and the Allis Chalmers Controlled Agglomeration and Reduction (ACCAR) plant of Sudbury Metals Company at Falconbridge, Ontario were idle all year. Unless there is a strong increase in demand for steel in Canada it is unlikely these two plants will be operating in 1978.

The cif cost of scrap purchased by steel producers reached an all-time high, averaging about $88 to $92 a tonne in 1974. Prices have been deteriorating since, and in 1977 scrap prices were down to an average of about $58 to $63 a tonne. Not much improvement is expected in 1978.

As a consequence of poor demand for steel in the United States and Western Europe, Quebec Cartier's production at Mount Wright was only 14 045 000 tonnes in 1977. The Mount Wright concentrator has a production capacity of 18 million tonnes a year and this could be increased to 23 million tonnes.

Two mines closed in April, the Hilton mine near Shawville, Quebec, some 64 km northwest of Ottawa, and the Lac Jeannine mine near Gagnon. The Hilton mine, owned by Stelco, Jones & Laughlin Steel Corporation and Pickands Mather & Co., started operating in 1958 and some 4 million tonnes of magnetite, grading 21 per cent Fe, were mined annually for the production of about 1 million tonnes of pellets. Fifteen million tonnes of pellets have been produced by this plant to date. The mine's closure resulted in a layoff of some 300 employees.

The Lac Jeannine mine, owned by Quebec Cartier Mining, a subsidiary of United States Steel Corporation, began operating in 1961. Specular hematite grading 35 per cent Fe was mined and concentrated in an 8-million-tonne-annual-capacity concentrator. Some 116 million tonnes of concentrate had been produced from this mine to April, 1977, when operations were terminated. Gagnon and the concentrator are now the property of Sidbec-Normines and the facilities will be used to concentrate the ore from Sidbec's new Fire Lake mine, located some 64 km northeast of Gagnon. Due to soft markets for iron ore, full production of 6 million tonnes a year at the Fire Lake mine will not be reached until 1979. In 1977 combined production at the two mines was 2.312 million tonnes.

Wesfrob Mines Limited, a wholly-owned subsidiary of Falconbridge Nickel Mines Limited, closed its mine temporarily at the end of October 1977 as the result of a prolonged strike at Oregon Steel Corporation, Portland, Oregon. The mine supplies some 250 000 tonnes a year of pellet feed concentrate to Oregon Steel and some 360 000 tonnes of pellet feed concentrates to Mitsubishi Corporation for resale to Kawasaki Steel Corporation and Kobe Steel of Japan. The mine is expected to resume production early in 1978.

Youngstown Sheet and Tube Company, a subsidiary of Lykes Corporation, owns a 6 per cent interest in Iron Ore Company of Canada and 15.6 per cent interest in Wabush Iron Co. Limited. In August, Youngstown reported it was considering selling its interests in both companies as a result of the closure of most of its

Table 2. Canada, iron ore production, 1975, 1976 and 1977

Company and location	Ore mined	Product shipped	1975	1976	1977
			(000 tonnes)		
Adams Mine, Kirkland Lake, Ont.	Magnetite	Pellets	1 153	1 197	1 218
Algoma Ore Division of The Algoma Steel Corp. Ltd., Wawa, Ont.	Siderite	Sinter	1 518	1 865	1 771
Caland Ore Co. Ltd., Atikokan, Ont.	Hematite and Goethite	Pellets	701	860	1 027
		Concentrate	818	729	477
Griffith Mine, Bruce Lake, Ont.	Magnetite	Pellets	1 471	1 579	1 565
Hilton Mines, Ltd., Shawville, Que.	Magnetite	Pellets	785	657	177
Iron Ore Company of Canada Schefferville, Que.	Hematite, goethite and limonite	Direct shipping	4 134	4 125	3 069
Carol Lake, Lab.	Specular hematite and magnetite	Concentrate	6 462	7 301	6 435
		Pellets	9 161	10 085	11 158
Sept Iles, Que.	Schefferville "treat ore"	Pellets	3 005	3 585	4 552
Marmoraton Mining Co., Marmora, Ont.	Magnetite	Pellets	486	462	611
National Steel Corporation, Capreol, Ont.	Magnetite	Pellets	673	627	582
Quebec Cartier Mining Company, Mount Wright, Que.	Specular hematite	Concentrate	8 266[1]	14 137[2]	13 169
Sidbec-Normines Inc., Fire Lake and Lac Jeannine, Que.	Specular hematite	Concentrate	–	–	297
Sherman Mine, Temagami, Ont.	Magnetite	Pellets	1 116	1 093	1 109
Steep Rock Iron Mines Ltd., Atikokan, Ont.	Hematite	Pellets	1 122	1 363	1 433
Texada Mines Ltd., Texada Island, B.C.	Magnetite	Concentrate	312	388	100

Table 2. (concl'd)

Company and location	Ore mined	Product shipped	1975	1976	1977
Wabush Mines, Wabush, Lab.	Specular hematite and magnetite	Pellets	3 258	5 487	5 640
Wesfrob Mines Limited, Queen Charlotte Islands, B.C.	Magnetite	Sinter concentrate	411	344	—
		Pellet concentrate	610	564	366
Byproduct producers					
Inco Limited, Sudbury, Ont.	Pyrrhotite	Pellets	517	485	649
Quebec Iron and Titanium Corp., mine at Lac Tio, Que., electric smelter at Sorel, Que.	Ilmenite-hematite	Pig iron	421	467	508
Total			46 400	57 400	55 905

Sources: Statistics Canada and personal communication.
[1]All shipments originated from Lac Jeannine mine. [2]Includes preliminary shipments of Fire Lake mine. In 1975 and 1976 the Lac Jeannine and Fire Lake mines were operated by Quebec Cartier Mining.
— Nil.

steelmaking facilities at the Campbell Works, Youngstown, Ohio. Youngstown sent letters to its partners in Wabush asking whether they would be interested in acquiring Lykes' share, but at the end of the year no firm offer had been announced.

James Bay Development Corporation (JBDC) completed its drilling program at Lac Albanel, north of Chibougamau. JBDC has delineated over one billion tonnes of iron ore reserves and has indicated that production of 9 million tonnes a year of pellets and/or concentrates would be justified for a period of 30 years. Crushing, concentration and pelletization tests are under study. JBDC intends to start production between 1985 and 1990.

During the year, Steep Rock Iron Mines Limited completed the feasibility study of its Bending Lake iron ore deposit. A decision regarding the development of this property, located 25 km northwest of Atikokan, Ontario, will be taken in early 1978. The ore at Bending lake consists of magnetite grading 20 per cent Fe, and reserves are adequate to maintain a mining operation for 20 years at a rated capacity of 2.5 million tonnes of pellets a year. The ore would be mined as an open pit, concentrated at Bending Lake, and transported by railway or pipeline to Atikokan for pelletizing at Steep Rock's existing pellet plant. The major problem facing the development of Bending Lake is the lack of markets, particularly in the Great Lakes region, since most Canadian and United States steel companies have a short- to medium-term surplus of iron ore.

Bethlehem Steel Corporation announced the permanent closure of its Marmoraton Mining Company Ltd., Marmora mine, near Marmora, Ontario, effective March 31, 1978. About 275 employees will be affected. Reasons for the shutdown include overall business conditions and a reduction of Bethlehem's requirements for iron ore. For the same reasons, Bethlehem closed its Grace mine, near Morgantown, Pennsylvania in July. Bethlehem suffered heavy financial losses in 1977.

Table 3. Origin and destination of iron ore by shipping port in Canada in 1976

Port Cartier to:	Tonnes
Clyde-Glasgow, U.K.	60 071
Port Talbot, U.K.	567 824
U.K. nes	1 557 428
Finland	98 638
Emden, W. Germany	225 768
France	591 155
Hamburg, W. Germany	321 131
W. Germany nes	744 593
Taranto, Italy	858 566
Rotterdam, Netherlands	2 278 884
Netherlands nes	373 572
Portugal	51 078
Spain	140 735
Gary, U.S.	3 094 205
Conneaut, U.S.	2 046 091
Mobile, U.S.	628 963
Morrisville, U.S.	416 314
Philadelphia, U.S.	263 314
Sept Iles to:	Tonnes
American Lake Erie ports nes	26 412
American Lake Ontario ports nes	25 904
Baltimore, U.S.	3 423 926
Houston, U.S.	147 857
Mobile, U.S.	128 504
Morrisville, U.S.	4 528 985
Philadelphia, U.S.	577 455
Clyde-Glasgow, U.K.	83 153
U.K. nes	1 275 037
Antwerp, Belgium	210 633
Belg. and Lux. nes	54 329
Emden W. Germany	25 396
France nes	407 925
W. Germany	653 587
Genoa, Italy	563 966
Taranto, Italy	511 991
Italy nes	38 165
Amsterdam, Netherlands	87 299
Rotterdam, Netherlands	908 545
Netherlands nes	1 835 626
Spain	569 776
Osaka-Kobe, Japan	152 376
Japan nes	3 815 233
Chicago, U.S.	42 576
Indiana Harbour, U.S.	21 768
Detroit, U.S.	2 677 985
L&RST Clairports nes	22 140
Ashtabula, U.S.	510 840
Buffalo, U.S.	919 810
Cleveland, U.S.	1 866 186
Sept Iles to:	Tonnes
Conneaut, U.S.	14 222
Erie, U.S.	14 222
Huron, U.S.	296 885
Lackawana, U.S.	941 807
Lorain, U.S.	128 442
Toledo, U.S.	240 911
Pointe Noire to:	Tonnes
Taranto, Italy	120 757
Italy nes	116 773
Chicago, U.S.	224 524
Indiana Harbour, U.S.	971 356
Detroit, U.S.	19 322
Ashtabula, U.S.	468 845
Buffalo, U.S.	319 650
Cleveland, U.S.	21 877

Table 3. (concl'd)

Pointe Noire to: (cont'd)	Tonnes
Conneaut, U.S.	100 425
Huron, U.S.	264 700
Lackawana, U.S.	75 243
Lorain, U.S.	61 858
Toledo, U.S.	81 491
Philadelphia, U.S.	39 833
Contrecoeur to:	**Tonnes**
Buffalo, U.S.	92 003
Cleveland, U.S.	347 688
Hamilton, Canada	108 096
Port Colborne, Canada	6 850
Montreal to:	**Tonnes**
U.K. nes	14 175
Hamilton, Canada	9 000
Depot Harbour to:	**Tonnes**
Detroit, U.S.	537 798
Buffalo, U.S.	71 254
Cleveland, U.S.	38 098
Little Current to:	**Tonnes**
Chicago, U.S.	180 282
Detroit, U.S.	33 559
Cleveland, U.S.	165 410
Picton to:	**Tonnes**
Buffalo, U.S.	432 619
Thunder Bay to:	**Tonnes**
Chicago, U.S.	1 015 360
Indiana Harbour, U.S.	513 293
Huron, U.S.	77 362
Toledo, U.S.	84 330
Tasu to:	**Tonnes**
Japan nes	685 514
Australia nes	29 234
Portland, U.S.	176 603
Texada to:	**Tonnes**
Japan nes	298 182
Sydney from:	**Tonnes**
Brazil	35 781
Sept Isles, Canada	348 823
Contrecoeur from:	**Tonnes**
Rotterdam, Netherlands	15 200
Sweden	38 274
Liberia	446 076
Brazil	488 936
Sept Isles, Canada	28 322
Pointe Noire, Canada	172 049
Trois-Riviers from:	**Tonnes**
Philippines	8 390
Hamilton from:	**Tonnes**
Duluth, U.S.	118 721
Superior, U.S.	120 820
Taconite, U.S.	1 088 273
Escanaba, U.S.	407 860
Sept Isles, Canada	109 304
Pointe Noire, Canada	2 574 529
Thunder Bay, Canada	1 435 945
Port Colborne from:	**Tonnes**
Marquette, U.S.	95 930
Michipicoten Harbour, Canada	15 578
Thunder Bay, Canada	12 295
Sault Ste. Marie from:	**Tonnes**
Marquette, U.S.	954 459
Silver Bay, U.S.	53 454
Toledo, U.S.	12 445
Michipicoten Harbour, Canada	56 194
Thunder Bay, Canada	

Source: Statistics Canada, Catalogue 54-207, Shipping Report.
nes Not elsewhere specified.

In order to help cover operating costs, the St. Lawrence Seaway Authority has proposed to gradually increase tolls on the Montreal-Lake Ontario section of the Seaway and on the Welland canal. Tolls are to be increased over a period of three years, starting in 1978. Effective 1978, the charge per gross registered tonne (GRT)* will increase from 4¢ to 7¢ and will remain the same thereafter on both sections of the Seaway. The Welland canal toll which has until now been a flat rate of $100 a lock for each of its eight locks, will be eliminated and replaced by a toll of 19.8¢ in 1978, increasing to 30.9¢ by 1980. The proposed toll schedule is as follows:

*This is a rating for ships based on the volume of enclosed space and not related to cargo tonnage.

Tolls Schedule
(¢ per tonne)

Year	Montreal to or from Lake Ontario	GRT
1977	44.1	4¢
1978	49.6	7¢
1979	61.7	7¢
1980	68.3	7¢
	Lake Ontario to or from Lake Erie (Welland Canal)	GRT
1977	$100/lock	Nil
1978	19.8	7¢
1979	24.2	7¢
1980	30.9	7¢

Based on a GRT of 15 000 and an average cargo of 21 000 tonnes of iron ore, the total toll cost of transporting the ore from Montreal to Lake Erie in 1977 was 50.77¢ a tonne, determined as follows:

$$\frac{(0.441 \times 21\,000) + (0.04 \times 15\,000) + (100 \times 8)}{21\,000} = 50.77¢$$

In 1980 the total cost will be $1.09 a tonne.

Traffic on St. Lawrence Seaway (1977)

Section	Total	Iron ore	Per-cent
	(million tonnes)	(million tonnes)	
Montreal-Lake Ontario	61.6	21.2	34.4
Welland	69.3	21.7	31.3
Total	130.9	42.9	32.8

Source: St. Lawrence Seaway Authority.

International developments

On August 1, 1977, some 15 000 mine workers at 12 iron mines in Minnesota and Michigan went on strike. The main issue related to differences in incentive payments between iron ore miners and steel mill employees; other issues included seniority, health and safety. At the time of the strike inventories were high (about four months) and steel demand was low. At the end of the year the strike was over at all mines with the exception of some of the mines owned by U.S. Steel.

During the year, Cia. Vale do Rio Doce (CVRD) of Brazil signed an agreement with a group of Japanese steel mills for the sale of 376 million tonnes of iron ore having a sales value of $6.7 billion at current prices. The iron ore products will be delivered over a period of 15 years, commencing in 1977. The sale, considered the largest ever in the international iron ore market, includes the supply of 285 million tonnes of direct-shipping ore having a value of $4 billion, and a contract for the sale of 91 million tonnes of iron ore pellets valued at $2.7 billion. Some 40 per cent of the quantities sold will be transported by Docenave, the shipping subsidiary of the CVRD group, for an additional $1 billion in maritime freight receipts. The Japanese industry consumes about 140 million tonnes of iron ore a year, of which Brazil supplies about 12 per cent. With the signing of the new contract, Brazil will be supplying approximately 25 per cent of total Japanese iron ore requirements by 1980.

United States Steel Corporation has decided to pull out of the Carajas project. The move resulted from disagreements on questions of control, financing and timing of the project. Under the remittance law in Brazil, U.S. Steel could only take out of the country what it brought into the project. CVRD has accepted to receive $50 million from U.S. Steel for its 49 per cent share in the project. Some other partners were being sought as a result of U.S. Steel's withdrawal. Later in the year CVRD announced that work would begin in 1978 on its Carajas iron ore mining project. Originally CVRD planned to produce some 50 million tonnes of iron ore from Carajas by 1980 but because of a lower-than-expected demand for steel, combined with financial problems associated with the development of Carajas, production has been scaled down to 20 million tonnes a year by the mid-1980's. The Carajas deposit has reserves of 15.7 billion tonnes of iron ore with a 67 per cent Fe content, and 2.1 billion tonnes of iron ore with a 61 per cent Fe content. The project is estimated to cost some $2 billion.

A meeting of l'Association des Pays Exportateurs de Fer (APEF) was held in Geneva September 21-22, 1977. Delegates from Algeria, Australia, India, Mauritania, Peru, Sweden and Venezuela attended the meeting. In addition to the regular members of the group, Canada, Brazil and the UNCTAD Secretariat were invited to send observers, who for technical reasons were called "Special Invitees". The group agreed upon three specific issues that they believed should be explored further by APEF's own secretariat. These issues were: trends in shipping costs over the next four or five years; trade in iron ore by the member countries, and amount of trade based on long-term contracts country by country; and finally, a study of the benefits of further processing.

The first UNCTAD preparatory meeting on iron ore was held in Geneva October 24-25, 1977. Some 48 countries including Canada were represented, as well as representatives from the World Bank, International Monetary Fund (IMF) and the General Agreement on Tariffs and Trade (GATT). The meeting was aimed at developing a dialogue between producers-exporters and consumers of iron ore and at determining areas of

Table 4. Production and capacity of pig iron and crude steel at Canadian iron and steel plants, 1976-77

	1976	1977p
	(tonnes)	
Pig iron		
Production	9 800 524	9 660 927
Capacity at December 31[1]	10 495 000	10 871 000
Steel ingots and castings		
Production	13 289 550	13 631 243
Capacity at December 31	17 457 503	17 984 393

Source: Statistics Canada.
[1]In blast or in use.
pPreliminary.

Table 5. Receipts, consumption and stocks of iron ore at Canadian iron and steel plants, 1976-77

	1976	1977p
	(tonnes)	
Receipts imported	3 262 743[1]	2 604 502[2]
Receipts from domestic sources	10 057 878[3]	11 198 509[4]
Total receipts at iron and steel plants	13 320 621	13 803 011
Consumption of iron ore	13 694 489[5]	14 170 500[6]
Stocks of ore at iron and steel plants, December 31	4 383 340	3 940 556
Change from previous year	+54 270	−442 784

Source: American Iron Ore Association.
[1]Compared with 3 020 130 tonnes in Table 1. [2]Compared with 2 505 191 tonnes in Table 1. [3]Compared with domestic shipments of 10 448 190 tonnes compiled by Statistics Canada. [4]Compared with 11 513 316 tonnes compiled by Statistics Canada. [5]Compared with 13 697 452 tonnes compiled by Statistics Canada for blast furnace consumptions. [6]Compared with 13 618 732 tonnes compiled by Statistics Canada for blast furnace consumption.
pPreliminary.

the iron ore industry that require further attention in order that the problems of the industry be more clearly understood and corrective measures applied. The meeting recommended that the following areas be further studied: costs of production and prices of iron ore and steel, and their relationship; transport arrangements for iron ore; iron ore stocks, including their geographical distribution and factors influencing variations in their volume; the costs and benefits of the further processing of iron ore in the producing countries. The second preparatory meeting on iron ore will be held in April 1978.

Other developments which may affect future developments in the iron ore industry include the creation of a "Common Fund" and the establishment of "Reference Price" schemes for a large number of steel product imports in both the United States and western Europe.

The first UNCTAD meeting on the Common Fund was held in March 1977. The purposes of the common fund are to help stabilize markets (prices and quantities), stimulate domestic development, increase international trade and increase the transfer of resources (technology, equipment, management) from industrialized countries to developing countries. The fund would cover 18 commodities including bauxite, copper, phosphate, iron ore and agricultural products. Two modes of financing the fund have been suggested at the March meeting. Industrialized countries, including Canada, recommended a "pooling" concept. Under this concept international commodity agreements (ICA's) would first be negotiated by producers and consumers on a commodity-by-commodity basis. Then the ICA's would pool a portion of their assets to form a common fund. The major problem in this concept is pricing the commodity to a level acceptable to both producers and consumers.

Developing countries recommended a "source" fund, largely financed by governments, and by commercial loans which would be guaranteed by governments. Under this concept, industrialized countries would be expected to contribute a large portion of the funds; however, a major concern to the industrialized countries is that their control in the use of the fund may not be in proportion to their contributions.

In order to deal more effectively with dumping of steel, both the United States and the European Economic Community (EEC) announced plans in late 1977 to introduce in early 1978 "reference prices" or "base prices" for steel imports. Imports would be closely monitored, and accelerated antidumping actions taken if any imports were priced lower than the accepted minimums. These plans, and other protectionist actions around the world affecting steel trade, could affect several iron ore-producing countries, and particularly Australia and the United States.

International trade of iron ore

In 1960, 520 million tonnes of iron ore were produced in the world, of which 154 million tonnes were exported. In 1970 these figures were 758 million and 320 million respectively. By 1975, production had reached 846 million and exports 389 million. These figures indicate that while production grew at 3.3 per cent a year from 1960 to 1975, trade increased at 6.25 per cent a year. 'During that period, Australia, and

Table 6. Canadian consumption of iron-bearing materials at integrated[1] iron and steel plants, 1977

	In Sinter Plants	In Direct Reduction Plants	In Iron and Steel Furnaces: In the Production of Pig Iron	In Iron and Steel Furnaces: In Steel Furnaces	In Iron and Steel Furnaces: Total in Furnaces
			(tonnes)		
Iron Ore					
Crude and concentrates	221 163	—	424 111	24 942	449 053
Pellets	78 671	490 687	10 966 148	59 145	11 025 293
Sinter	100 119	—	1 675 292	—	1 675 292
Sinter produced at steel plant	—	—	985 806	—	985 806
Direct-reduced iron	—	—	—	312 008	312 008
Other iron-bearing materials					
Flue dust	87 639	—	—	—	—
Mill scale, cinder, slag	521 015	—	412 484	444	412 928

Source: Company data.
[1]Dominion Foundries and Steel, Limited, Hamilton, Ont.; Sidbec-Dosco Limited, Contrecoeur, Que.; Sydney Steel Corporation, Sydney, N.S.; The Algoma Steel Corporation, Limited, Sault Ste. Marie, Ont.; The Steel Company of Canada, Limited, Hamilton, Ont.
— Nil.

more recently Brazil, emerged as major producers and exporters of iron ore. Canada's position has remained relatively stable in terms of its share of total world production (3.8 per cent in 1960 and 5.3 per cent in 1975). France in 1960 was the third largest producer after the U.S.S.R. and the United States, but in 1975 it ranked sixth. Also, Sweden in 1960 ranked fifth and in 1975 it ranked tenth. It is likely that production of iron ore from France and Sweden will decrease with time, in view of strong competition from Brazil and West Africa.

As shown in Table 11, Brazil's share of iron ore imports by the industrialized countries has increased considerably from 1970 to 1975 and this at the expense of Sweden. The table also shows that Brazil has replaced India as the second-largest supplier of iron ore to Japan.

Steel production in many of the industrialized countries remained at the same level, or even decreased, since the early 1970s. However, steel production increased steadily during that time in developing countries such as Brazil, Venezuela, India, Mexico, South Africa, South Korea and the Middle East countries. Because of the importance of energy it is likely that much of the new additional steel capacity will be installed in energy-rich countries, which in most cases have access to nearby iron ore suppliers. This indicates that the growth rate of world iron ore trade in terms of tonnes-kilometres may be reduced in the future.

Table 7. Sourcing patterns of major Canadian steel producers, 1976-79

Mine	Ownership in 1976 (%)	Capacity in 1976 (million tonnes/ year)	Product	Share of Capacity and/or Regular Supplies in 1976	Notes
Stelco					
Griffith	100	1.36	pellets	1.36	
Wabush	26	5.53	pellets	1.45	
Hilton	50	0.91	pellets	0.45	Depleted early 1977
Erie	10	9.34	pellets	0.93	
Tilden[1]	10	4.00	pellets	0.40	Expansion to 8.0 million tonnes a year in 1979
Eveleth[2]	nil	2.40	pellets	nil	Expansion to 6.0 million tonnes a year in 1977
Hibbing[3]	10	5.40	pellets	0.54	Expansion to 8.1 million tonnes a year in 1979
Dofasco					
Wabush	16	5.53	pellets	0.91	
Sherman	90	1.00	pellets	0.91	
Adams	100	1.00	pellets	1.00	
Eveleth[4]	nil	2.40	pellets	nil	Expansion to 6.0 million tonnes a year in 1977
Algoma					
Algoma ore	100	1.63	sinter	1.63	
Steep Rock[5]	nil	1.27	pellets	1.27	Depleted in 1979
Inco	nil	0.36	pellets	0.36	
Tilden[6]	30	4.00	pellets	1.20	Expansion to 8.0 million tonnes a year in 1979
Bending Lake[7]	nil	nil	pellets	nil	Expected start-up in 1979 at a capacity of 2.2 million tonnes a year.
Sidbec					
Sidbec-Normines	50	6.00	pellets	3.0	Start-up in 1977

Source: Compiled from personal communication and various publications.
Note: Sydney Steel does not have any ownership share in any iron ore mine, and purchases its iron ore requirements (pellets) mainly from Iron Ore Company of Canada. [1] 15% of total capacity in 1979. [2] 23.5% of expansion capacity. [3] 6.67% of total capacity in 1979. [4] 16% of expansion capacity. [5] Canadian Pacific Investment Ltd. owns 51% of Algoma and 68% of Steep Rock. [6] 30% of total capacity in 1979; will also purchase 600 000 tonnes a year from Tilden. [7] Owned by Jones & Laughlin and optioned to Algoma.

Table 8. Lake Erie base price of selected ores[1], year-end 1964 to year-end 77

Ore Type	1964-69	1970	1971	1972	1973	1974	1975	1976	1977
					($U.S. per tonne)				
Mesabi Non-Bessemer	10.38	10.63	10.99	10.99	11.72	15.50	18.21	19.94	20.84
Mesabi Bessemer (+ phos. premium)	10.53	10.78	11.14	11.14	11.87	15.65	18.35	20.09	20.09
Old Range Non-Bessemer	10.63	10.87	11.24	11.24	11.97	15.75	18.45	20.18	21.09
Pellets (per tonne natural iron unit)[2]	0.248	0.262	0.275	0.275	0.289	0.399	0.464	0.522	0.546

Sources: Skillings' Mining Reviews, 1977.
[1]51.5 per cent of iron natural, at rail of vessel, lower lake ports. [2]Equals 1 per cent of a tonne. A 60 per cent iron ore, therefore, has 60 units.

Transportation

Iron ore is by far the largest nonfuel mineral commodity transported on the oceans. In 1974 some 320 million tonnes of iron ore were shipped by sea, followed by: coking coal, 100 million tonnes; bauxite, 30 million; manganese, 11 milion; nickel ore and concentrate, 4 million; copper concentrate, 2 million and lead/zinc concentrate, 2 million.

Table 9, which follows, shows average costs in 1976 including "voyage"* and "time"* charter, but excluding "owned"** vessels, for transporting iron ore concentrates from mines to steelmills.

This table shows that transportation costs from Canadian and United States mines to steelmills in Hamilton are about the same, although costs vary considerably in the United States, depending upon the location of the mine. Transportation costs are also similar from Canadian and United States mines to steelmills located in the Pittsburgh area of the United States. Transport costs from Canadian mines to mills in Europe are less than from Canadian mines to Canadian mills. Transport costs from Canadian mines to EEC mills are less than transport costs from Brazilian mines to EEC mills. Finally, transport costs from Australian mines to Japan are lower than transport costs from United States and Canadian mines to U.S. and Canadian steelmills. Handling charges per tonne-kilometre of iron ore transported in Canada or in the United States are higher than in Japan and in EEC mills.

*Rates vary with market conditions.
**Rates do not vary with market conditions in the short term, but reflect operating costs in the long term.

In 1976, comparative average cif costs at steel plants in $U.S. per tonne, for all iron ore purchased by the respective countries were as follows*: Canada, 28.85; United States, 29.40; Japan, 17.50 and EEC 16.67. Most of the iron ore purchased in Canada and in the United States is in the form of pellets, while in the EEC and Japan most of the iron ore purchased is in the form of sinter fines.

Given two iron ore products of the same quality, it is important for a producer wanting to compete in the ECSC market to meet the above cif prices. Given that transportation costs from Swedish mines to Rotterdam are the lowest, all other iron ore producers must adjust their fob prices to $13.17 ($16.67 to $3.50) and absorb transportation costs if necessary. The same applies to producing countries such as Brazil that compete with Australia in the Japanese market.

By far the cheapest mode of transporting iron ore is by ocean. Costs* in 1975 varied from about 0.3 to 0.75 mills per tonne-kilometre (one mill is one tenth of a cent), according to reported charter prices. Cost of barge service to shippers is the cheapest form of inland mineral transport (2 to 2.5 mills per tonne-kilometre) followed by rail (10 to 11 mills) and trucks (50 mills).

Products and markets

Most iron ore deposits in the United States and Canada consist of low-grade, fine-grained ore. In order to liberate the iron and upgrade the ore, considerable grinding is necessary. Very fine-grained ore is more amenable to pelletization than to sintering. Therefore,

*Sources same as for Table 9.

Table 9. Approximate mine-to-steelmills iron ore transport costs[1], 1976

From	To	Cost
		($U.S./tonne)
Quebec-Labrador	Hamilton	6.20 - 6.57
U.S. mines		
(Marquette range)	Hamilton	5.47
(Mesabi range)	Hamilton	8.36
Quebec-Labrador mines	Pittsburgh	10.90 - 11.28
U.S. mines (Empire mine)	Pittsburgh	10.57
U.S. mines (Mesabi range)	Pittsburgh	12.61
Quebec-Labrador mines	U.S. East Coast (Northern Harbours)	4.29 - 4.66
U.S. mines (Marquette range)	Chicago	4.33
U.S. mines (Marquette range)	Lower lakes	4.92
Quebec-Labrador mines	Lower Lakes	6.75 - 7.10
Sweden	Rotterdam	3.50
Brazil	Rotterdam	7.38
Quebec-Labrador mines	Rotterdam	4.58 - 4.92
Sierra Leone	Rotterdam	4.62
Australia	Yokohama	5.17
Brazil	Yokohama	8.36

Sources: *Skillings Mining Reviews*, 1977; The Cleveland Cliffs Iron Co.; Canadian Transport Commission; Department of Industry, Trade and Commerce, Ottawa.
[1]Excludes unloading (except to rail of vessel).

Table 10. World iron ore production, 1975-77

	1975	1976^p	1977^e
	(000 tonnes)		
U.S.S.R.	232 803	239 000	244 000
Australia	97 365	92 400	93 000
Brazil	88 493	90 000	87 000
United States	81 351	81 200	58 000
People's Republic of China	51 000	50 000	56 000
Canada (mine shipments)	44 893	55 416	52 000
India	40 271	41 400	43 000
France	50 142	45 543	42 000
Sweden	30 867	30 526	26 000
Liberia	36 500	35 000	16 000
Venezuela	24 104	23 000	15 000
South Africa	11 191	15 684	. .
Chile	11 070	10 500	. .
Mauritania	8 500	8 000	. .
Spain	8 617	7 700	. .
Peru	7 753	7 000	. .
North Korea	8 200	6 100	. .
United Kingdom	4 490	4 583	. .
Other countries	58 212	51 664	120 000
Total	895 822	874 716	852 000

Sources: For Canada, Statistics Canada. For other countries, *Metal Bulletin*. For 1977, U.S. Bureau of Mines, Mineral Commodity Summaries, 1978.
^{p}Preliminary; ^{e}Estimated; . . Not available.

because of the nature of the ore deposits in these countries, most of the iron ore consumed by North American steelmills is in the form of pellets.

The domestic iron ore industry in Europe has been traditionally based on sedimentary iron ores. Due to the large amounts of siderite (20 to 25 per cent) contained in these deposits, the ores were more amenable to sintering than to pelletization. Also, most of the EEC countries had ample supplies of cheap coal available for sintering in close proximity to domestically-produced iron ore, while oil was very costly. Because of the already-established sintering plants in Europe, most of the iron ore consumed there is still in the form of sinter.

In Japan, almost all the iron ore consumed by steelmills since the late 1950s has been imported from Australia. A large portion (some 60 per cent) of these imports was in the form of lumps, with the remaining being fines and concentrates. Long-distance transportation from Australia resulted in more fines from the lumps, thereby creating a need for the establishment of sintering plants. Today, 40 per cent of Japanese imports is in the form of lumps and 50 per cent is in the form of sinter fines and concentrates. However, some 70 per cent of iron ore consumption is in the form of sinter.

Prices

Table 12 indicates that pellets are by far the most expensive iron ore product, followed by concentrates and sinter fines. Also, pellet prices have increased faster than sinter fines or concentrate during the period 1972-77. The table also shows that the Japanese and the Europeans pay the least for their iron ore products, although sinter prices are not known because the product is not traded commercially.

Direct reduction

At the end of 1976 there were 34 direct-reduction plants in the world with a total production capacity of

Table 11. World iron ore trade

Importing Countries	Total Imports	Exporting Countries						
		Brazil	Sweden	Australia	Venezuela	Liberia	Canada	India
					(million tonnes)			
United States								
1975	48.2	8.6	0.2	0.8	13.1	2.5	19.4	0.2
1970	45.6	2.0	0.2	0.6	13.2	1.9	24.2	—
Japan								
1975	135.5	26.2	—	62.7	2.6	0.5	3.9	17.6
1970	102.0	6.8	—	36.6	7.7	2.4	2.2	16.4
West Germany								
1975	45.2	11.0	5.8	6.4	1.9	6.2	4.1	1.0
1970	47.9	6.4	11.5	1.0	3.0	8.2	3.7	0.4
Belgium and Luxembourg								
1975	25.7	2.0	5.0	2.3	0.3	0.9	0.1	0.1
1970	29.6	1.6	8.5	0.5	0.8	1.5	0.6	0.3
United Kingdom								
1975	16.6	2.2	3.0	0.9	1.8	0.5	3.1	—
1970	19.2	1.2	3.3	0.6	1.7	2.0	5.0	—
France								
1975	13.3	3.5	1.6	1.7	0.4	2.0	0.5	—
1970	9.7	2.2	1.4	0.7	0.1	1.6	0.3	0.07
Italy								
1975	15.6	3.1	1.07	2.1	2.2	2.8	2.0	—
1970	10.8	1.1	0.20	0.8	1.1	2.8	1.6	—
Netherlands								
1975	9.9	1.8	3.9	0.7	0.3	1.1	0.9	0.1
1970	5.4	0.3	0.6	0.2	—	1.6	1.5	—

Source: Compiled by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa, from various publications.
— Nil.

6.0 million tonnes a year. In 1977, 17 new direct-reduction plants were under construction, adding another 8.3 million tonnes of production capacity. These figures indicate that much larger plants are now being built. Most of these plants are constructed in developing countries where energy, in the form of gas and oil, is abundant and low-priced. Because of their small size, (about half a million tonnes a year), generally only products such as squares, reinforcing bars, light structurals, wire and sheets are produced at the adjoining mills. Output originally is expected to be for the domestic market, with the surplus exported. Worldwide, the bulk of steel production in terms of tonnage consists of flat products such as sheets and plates, and heavy sections, tubes and rails that are produced by the large mills in the industrialized countries. In the short term there appears to be no serious threat that the developing countries will displace domestic markets in the industrialized countries for rebars and similar low-cost products through low-priced imports. In the medium term there will be increased pressure from these countries to export low-cost product once their domestic markets are satisfied; transportation costs, however, will probably limit exports. In the longer term (1990 to 2000) the steelmaking facilities will have expanded, and there will be more pressure toward exporting products that will be more sophisticated and thus less sensitive to transportation costs.

Planned direct-reduction plants for the period 1981 to 1985 indicate an average size of close to 1 million tonnes a year as compared to an average size of some 500 000 tonnes in 1976. The main advantages gained by the developing countries in building direct-reduction plants are: steelmaking facilities can be established

Table 12. World iron ore prices (cents/tonne iron unit)

		North American market (cif Lake Erie ports)	European market (cif Rotterdam)	Japanese market[1] (fob Australia)
Concentrates	1977	32.08	30.0	. .
	1972	16.64	18.0	. .
Average annual growth rate (%)		14	10.5	. .
Pellets	1977	54.61	45.0	38.87
	1972	27.16	25.0	20.17
Average annual growth rate (%)		15	12.5	14.0
Sinter fines	1977	. .	26.0	19.05
	1972	. .	17.0	11.07
Average annual growth rate (%)		. .	9	11.5
Lump Ores	1977	. .	. .	22.34
	1972	. .	. .	14.46
Average annual growth rate (%)		. .	. .	9

Sources: *Skillings' Mining Review.*
United Nations TD/B/IPC/Iron Ore/2/Add. 1/8 August 1977
Tex Report Co. Ltd.
[1]Add 7-8 cents a tonne iron unit for cif prices to Japan.
. . Not available.

at relatively low cost, steel can be produced at competitive prices, small production capacity can be added in response to increased demand, and imports of steel can be reduced.

In terms of 1976 dollars the investment costs of direct reduction plants are in the order of $U.S. 95-125 a tonne for a 400 000-tonne-a-year sponge iron plant whether it be a shaft furnace or a rotary kiln furnace. This compares with $170-190 a tonne for a blast furnace built in North America or in Western Europe with an annual capacity of 3 million tonnes of pig iron. Assuming the use of pellets with 67 per cent Fe, and a supply of 1 540 kg necessary to produce 1 000 kg of Fe in the form of sponge iron, after taking into consideration losses during transportation and reduction, production costs for countries with captive iron ore mines and reducing agents are between $U.S. 80 and 90 a tonne of sponge iron. These costs would apply to countries such as Canada, Venezuela and South Africa. In areas where either iron ore or reducing agents only are available, the sponge iron production costs lie between $U.S. 97 and 100 a tonne, depending on the transportation costs of raw materials. Under unfavourable conditions where the prices of iron ore pellets and reductant are high, sponge iron may cost $110 to 115 a tonne. These conditions would apply to most European countries.

Currently, the common practice by producers is to increase the quantity of scrap in their electric furnaces when scrap prices are low, and use more sponge iron when scrap prices are high. The optimum value of sponge iron in the charge is between 20 and 60 per cent. A higher percentage of sponge iron increases melting time as a result of high gangue content of sponge iron, and, therefore, productivity is lowered. The use of sponge iron which is free of tramp elements allows it to be blended with scrap of low, cheap quality to produce steel of the same or better quality than would be obtained with a 100 per cent prime scrap charge. In other words, the additional cost of using sponge iron can be lowered or entirely eliminated.

Table 13 is a resumé of the direct reduction plants in Canada. With the exception of Sidbec, none of the plants operated in 1977, the major reason being that scrap prices were low, averaging about $58 to $63 a tonne.

Even though scrap prices have been generally low in Canada since the steel boom of 1973-74, the government of Saskatchewan is considering building a direct-reduction plant in Regina in view of an expected strong demand for steel in the western provinces during the next decade. The plant would have a capacity in the order of 600 000 tonnes of sponge iron a year, with most of the output expected to be used by Interprovincial Steel and Pipe Corporation Ltd. (IPSCO) steel plant at Regina. The Government of Saskatchewan, Steel Alberta Ltd. and Slater Steel Industries Limited, are the major shareholders of IPSCO. Other markets for sponge iron would likely be the Manitoba Rolling Mills Division of Dominion Bridge Company, Limited at Selkrirk and Western Canada Steel Limited at Calgary. Production would not begin before the early 1980s. Possible sources of iron ore include producers of the Mesabi Range in the United States, Steep Rock from its Bending Lake deposit, or Sidbec-Normines from its Fire Lake mine.

Table 14 lists scrap processing plants in Canada. Fers et Métaux Recyclés Ltée, owned jointly by Intermetco Ltd. and Stelco, is the only scrap processing plant in Canada where the nonferrous (Cu, Zn, Al) portion of scrapped automobiles is recovered.

Uses

About 90 per cent of the iron ore produced in the world is transformed into pig iron for use by the steel industry and, to a lesser extent, by the foundry industry.

Iron ore is also used in the cement industry and as a fluxing agent in nonferrous smelting. The higher-purity type is used in the manufacture of pigments. The purest type is used in the manufacture of ferrites for the electrical and electronics industries. Lump magnetite ore is used for heavy aggregate in concrete and as a shielding material in nuclear power plants. Finely ground magnetite (95 per cent — 325 mesh) is used as a heavy media for the treatment of metallurgical coal in coal preparation plants. Consumption of magnetite in coal preparation plants is between 1.0 and 2.0 kg per tonne of clean coal produced. Initial magnetite requirements to create a media of 1.5 (which is between that of coal and its ash) in a tank capable of processing 350 tonnes of raw coal an hour is approximately 70 tonnes.

Canadian consumption of iron ore in the form of pyrite and iron oxide by the cement industry is about 10 kg/tonne of cement.

The manufacture of iron pigment requires about 1.3 tonnes of hematite to produce one tonne of pigments.

Outlook

New labour contracts were signed at the end of the year at most United States iron ore mines and negotiations will start in March 1978 for iron ore workers of the Quebec-Labrador region. New labour contracts are also expected to be signed at most Ontario mines between April and August, 1978. Wage settlements will be governed by the Anti-Inflation Board guidelines from the period March 1978 to February 1979. However, in view of the world oversupply situation in the iron ore industry, there is a strong possibility that production will be interrupted temporarily at several mines in Canada during 1978. Mine production oriented to export markets such as Europe and Japan may be particularly affected. For the same reason, some of the small iron ore mines in Ontario may close earlier than anticipated.

As a result of capital expenditures for recent mine expansions in the United States, and wage increases for iron mine workers in Canada and the United States, the Lake Erie base prices for iron ore products are expected to be increased early in 1978.

Table 13. Direct reduction capacity in Canada, 1977

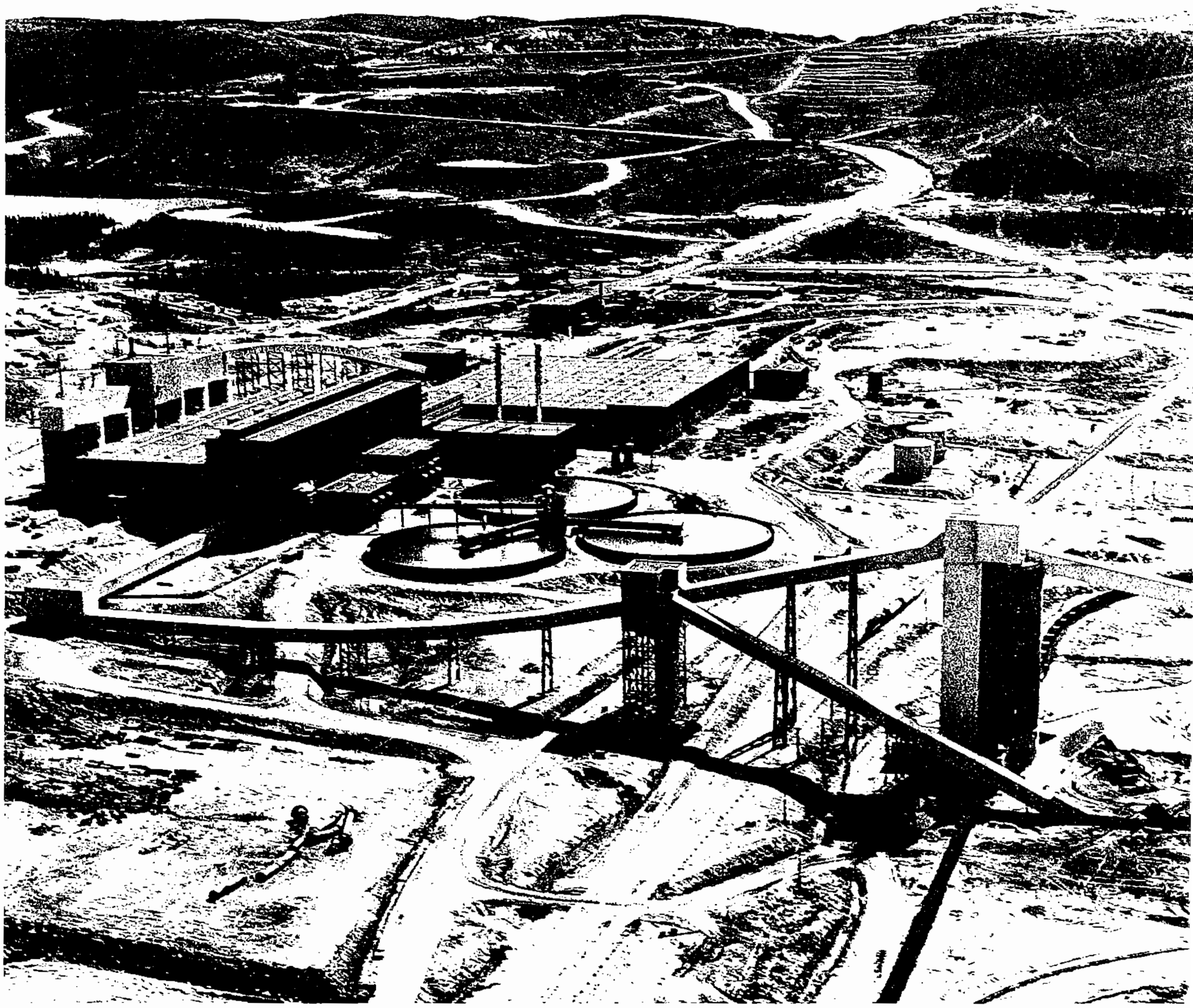
Company	Owner	Location	Process	Reductant	Capacity	Start-Up	% Fe Pellets	Iron Ore Suppliers
					(tonnes/ year of sponge)			
Sidbec-Dosco	Sidbec	Contrecoeur, Que.	Midrex	Gas	400 000	1973	68.0	Sidbec-Normines
Stelco	Stelco	Bruce Lake, Ont.	SL-RN	Coal	350 000	1975	66.2	Griffith Mine
Sudbury Metals Company	National Steel Corp. and Allis Chalmers Corp.	Sudbury, Ont.	ACCAR	Fuel Oil and Gas	300 000	1976	65.7	Inco
Sidbec-Dosco	Sidbec	Contrecoeur, Que.	Midrex	Gas	650 000	1977	68.0	Sidbec-Normines
Total capacity					1 700 000			
Pilot plants								
Niagara Metals Ltd.	Allis Chalmers Corp.	Niagara Falls, Ont.	ACCAR	Coal/Oil Gas	30 000	1971		
Stelco	Stelco	Hamilton, Ont.	SL-RN	Coal	10 000			

Source: Compiled by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa, from various publications.

Table 14. Compilation of automobile shredders in Canada, 1977

Province	City	Company	HP	Capacity*	Year Installed
				(tonnes/ year)	
Alberta	Calgary	Navajo Metals Ltd.	1 500	36 000	1968
British Columbia	Richmond	Richmond Steel Recycling Ltd.	5 000	70 000	1972
Manitoba	Winnipeg	General Scrap & Car Shredder Ltd.	1 500	36 000	1969
Ontario	Hamilton	International Iron & Metal Company	2 500	54 000	1966
Ontario	Ottawa	Baker Brothers Iron & Metal Ltd.	2 000	48 000	1970
Ontario	Toronto	International Iron & Metal Company	500	15 000	1966
Ontario	Toronto	Industrial Metal Co. of Canada	4 000	100 000	1968
Ontario	Windsor	Zalev Brothers Limited	2 500	54 000	1971
Quebec	Contrecoeur	Sidbec-Feruni Inc.	4 000	100 000	1975
Quebec	Laprairie	Fers & Métaux Recyclés Ltée.	2 000	48 000	1975
Quebec	Côte Ste-Catherine	Associated Steel Industries Ltd.	2 000	60 000	1975
Quebec	Longueuil	Sidbec-Feruni Inc.	2 000	48 000	1969
Saskatchewan	Regina	Native Auto Shredders	3 000	72 000	1974
New Brunswick	Moncton	Cyclomet	2 000	48 000	1977
Total					

Source: *Scrap Age*, March, 1977.
*Eight-hour shift, 5-day week.



The concentrator of the Mount Wright development of Quebec Cartier Mining Company, shown above with the open-pit mine in the background, has the capacity to process 18 million tonnes of iron ore a year. This operation is located near Fermont, Quebec. *Quebec Cartier photo*

Iron and Steel

MICHAEL K. McMULLEN

Production of crude steel in Canada increased by 2.6 per cent in 1977 to 13.6 million tonnes* even though economic activity exhibited only modest growth. Steel product shipments from plants of rolled steel products increased from 9.8 million tonnes to 10.3 million tonnes, about 5.2 per cent, due to better deliveries in Canada (up 2.7 per cent) and higher exports (up 21.2 per cent), mainly to the United States. Apparent consumption of steel products rose to 10.3 million tonnes. However demand for steel products was uneven for most of 1977 and for certain products was quite poor.

The consumer goods sector was buoyant throughout the year, due in particular to strong sales of North American automobiles. Thus, demand for flat-rolled products showed a strong gain over 1976. On the other hand, the capital goods and construction markets remained depressed. Demand for structurals, rods and bars was poor. This indicated a lack of investment and reflected the uncertainty of many manufacturers concerning the short- and medium-term outlook for the performance of the Canadian economy.

The variation in steel product demand resulted in variable production and financial performances for Canadian steel companies because of specialization in certain product lines. Those strongly orientated to flat-rolled products experienced good years. Dominion Foundries and Steel, Limited (Dofasco), which produces mainly flat-rolled products in response principally to automobile industry demand, had an excellent year. The Steel Company of Canada, Limited (Stelco), with a wide range of steel products, benefited chiefly from its sales of flat-rolled products. Interprovincial Steel and Pipe Corporation Ltd. (IPSCO) had a good year as its markets for pipes and tubes remained buoyant. On the other hand, The Algoma Steel Corporation, Limited (Algoma), which is heavily orientated to structural steels, was adversely affected by continuing poor conditions in the capital goods and construction sector although it improved its product mix over 1976. The activity of many regional producers such as Sidbec-Dosco Limited and Sydney Steel Corporation, which produce mainly long products, i.e., rods and bars,remained at depressed levels.

Exports increased, mainly due to regional marketing opportunities in the United States and because of the depreciation of the Canadian dollar. Imports rose by roughly 12.5 per cent over 1976. Low-priced imports led to several dumping complaints by Canadian producers. Three cases were heard by the Anti Dumping Tribunal in November, which subsequently ruled that material injury had been caused to domestic producers in the three cases and that dumping levies would be applicable on imports of affected steel products.

In September, Canada and the United States signed an agreement to build a pipeline across Canada to transport natural gas from Alaska to United States markets. This followed approval by the National Energy Board for the Alcan-Foothills pipeline project through the Yukon. It is estimated that about 1.3 million tonnes of steel pipe will be required for the Canadian section (approximately 3 000 kilometres (km)) of this project. In addition, associated services and infrastructure will require steel. Although the pipe specifications will probably not be finalized until mid-1978 it is expected that a large portion, if not all, of the pipe requirements for the Canadian section will be supplied from Canadian mills. Over a three-year period the requirements would have a beneficial effect on the steel industry in general and a considerable impact on the plate market in particular. Stelco, with its pipe mill at Welland, and IPSCO of Regina are the two major suppliers capable of making large-diameter, Arctic-grade pipe.

Internationally, sluggish economic performance in most industrialized countries left steel markets characterized by an over-capacity in steelmaking, poor demand, falling prices and international trade problems. Trade problems were leading to many dumping cases, and toward protectionist policies. Many firms were encountering adverse financial results due to poor capacity utilization. Without firming demand conditions, it appeared that many of these problems would continue into 1978.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Canada, general statistics of the domestic primary iron and steel industry, 1975, 1976 and 1977

		1975	1976	1977[p]
Production				
Volume indexes				
Total industrial production	1971 = 100	114.8	120.5	124.5
Iron and steel mills[1]	1971 = 100	113.5	117.1	123.1
		($ million)	($ million)	($ million)
Value of shipments, iron and steel mills[1]		3 202.9	3 420.9	3 753.1
Value of unfilled orders, year-end, iron and steel mills		556.9	449.5	586.9
Value of inventory owned, year-end, iron and steel mills		920.9	998.4	1 049.2
Employment, iron and steel mills[1]		number	number	number
Administrative		10 620	10 462	10 911
Hourly rated		40 930	39 251	38 769
Total		51 550	49 713	49 680
Employment index, all employees	1961 = 100	149.9	144.6	144.6
Average hours per week, hourly rated		39.7	39.7	39.4
		($)	($)	($)
Average earnings per week, hourly rated		240.58	278.36	305.28
Average salaries and wages per week, all employees		265.25	295.15	322.52
Expenditures, iron and steel mills[1]				
		($ million)	($ million)	($ million)
Capital: on construction		111.0	108.6	79.9
on machinery		430.7	334.2	314.1
Total		541.7	442.8	394.0
Repair: on construction		26.9	29.8	32.2
on machinery		341.1	378.0	405.6
Total		368.0	407.8	437.8
Total capital and repair		909.7	850.6	831.8
Trade, primary iron and steel[2]				
Exports		666.8	703.5	897.7
Imports		820.4	604.9	755.1

Source: Statistics Canada.
[1]S.I.C. Class 291 — Iron and Steel Mills: covers the production of pig iron, steel ingots, steel castings, and primary rolled products, sheet, strip, plate, etc. [2]Includes pig iron, steel ingots, steel castings, semis, hot and cold-rolled products, pipe and wire. Excludes sponge iron, iron castings and cast iron pipe. Compiled by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
[p]Preliminary.

Outlook

The market for steel products in Canada in 1978 is expected to improve, due, in part, to various economic stimulations being provided to the Canadian economy by provincial and federal governments. It is forecast that economic activity in Canada will increase at a rate between 3.5 and 4.5 per cent and, consequently, this should provide growth in demand for steel products in 1978. However, high levels of unemployment and inflation, large trade deficits, increasing energy costs, concerns over availability and the cost of capital, declining productivity and the situation of the Canadian dollar in the international money market are problems overhanging the Canadian economy, and thus the demand for steel. Nevertheless, the Canadian steel industry should do better than those of many industrialized countries around the world.

The demand for steel from the automobile industry is expected to remain firm in 1978. Increased activity in the construction and capital goods market is hoped for, although the prospects do not appear particularly bright. However, energy-related projects will continue to be an important market for steel. It is expected that total crude steel production will increase by about 3.5 per cent to some 14.1 million tonnes. Producer shipments and apparent steel consumption should increase accordingly.

Table 2. Canada, pig iron production, shipments, trade and consumption, 1975-77

	1975	1976	1977p
		(tonnes)	
Furnace capacity, January 1[1]			
Blast	10 001 711	11 607 429	10 495 000
Electric	612 350	612 350	612 350
Total	10 614 061	12 219 779	11 107 350
Production			
Basic iron	8 587 470	9 166 807	9 099 157
Foundry iron[2]	562 525	633 717	561 770
Total	9 149 995	9 800 524	9 660 927
Shipments			
Basic iron	83 203	106 571	91 441
Foundry iron[2]	500 252	589 900	611 898
Total	583 455	696 471	703 339
Imports			
Tonnes	4 078	8 836	11 913
Value ($000)	884	1 652	2 268
Exports			
Tonnes	406 272	281 557	505 275
Value ($000)	78 202	45 918	83 649
Consumption of pig iron			
Steel furnaces	8 495 093	8 971 013	8 908 191
Iron foundries	269 402	289 454	263 947
Consumption of iron and steel scrap			
Steel furnaces	6 612 201	6 548 070	6 846 791
Iron foundries	1 122 809	1 288 016	1 306 331

Sources: Statistics Canada; *Primary Iron and Steel* (monthly); *Iron and Steel Mills* (annual); *Iron Castings and Cast Iron Pipes and Fittings* (monthly).
[1]The capacity figures as of January 1 in each year take into account both new capacity, and obsolete capacity anticipated for the year. [2]Includes malleable iron.
pPreliminary.

Trade outlook is unclear due to the uncertainty of the effect on world trade for steel of the various programs being formulated by many countries to lessen the impact of low-priced imports, *i.e.*, "reference pricing" by the United States and "basic pricing" by the European Economic Community (EEC), and the response to be taken by export-oriented countries like Japan. The depreciation of the Canadian dollar *vis-a-vis* the major world currencies and the results of the recent steel dumping cases in Canada should tend to lessen the threat of a major flood of steel imports into Canada during 1978. Exports should increase due to the value of the Canadian dollar and because of an apparent favourable situation regarding the United States reference price system due to lower transportation costs from central Canadian steel mills to traditional markets in the United States. The expiration of the contracts between the United Steelworkers of America and Algoma and Stelco in mid-1978 will probably stimulate some hedge buying early in the year if there is anticipation of a strike. Any benefits to be derived from the Alcan-Foothills pipeline will probably not be felt until 1979.

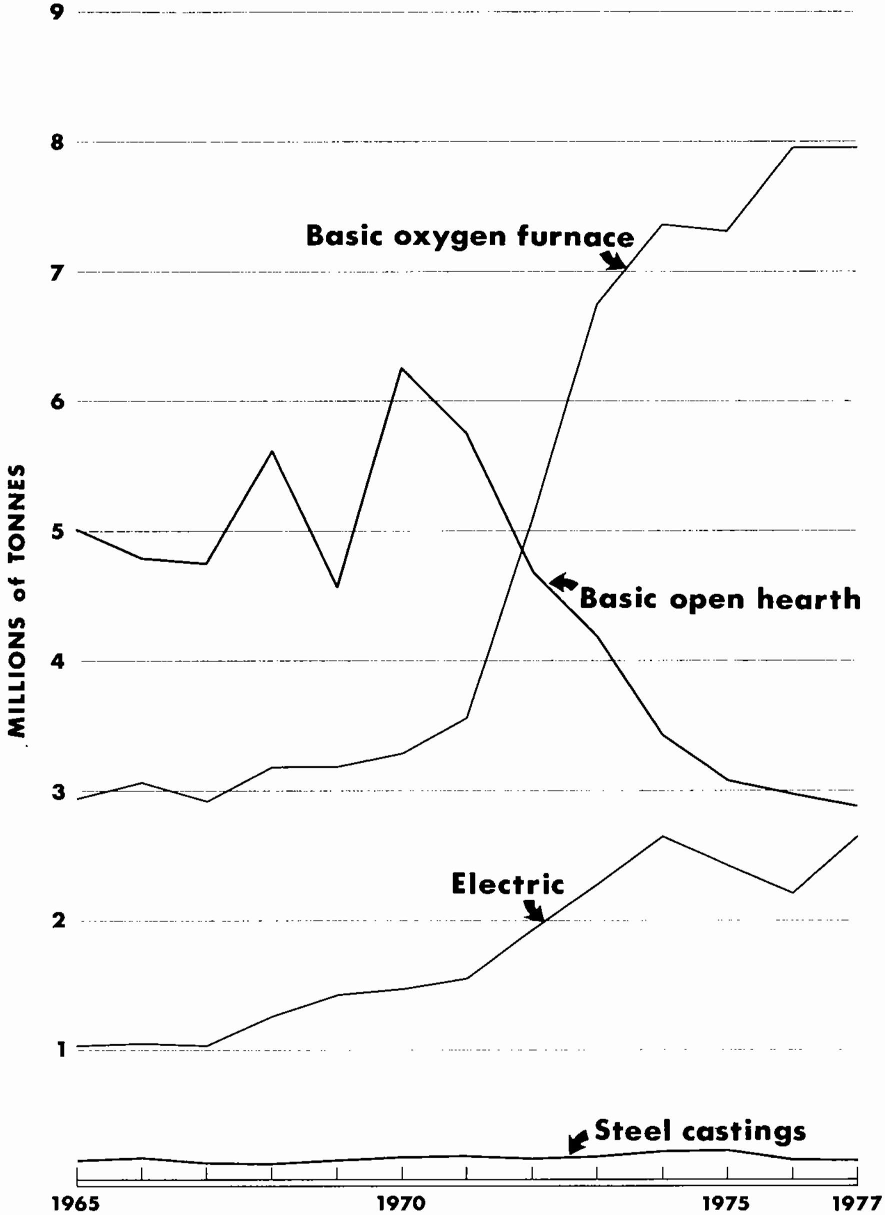
Although there will be growth in steel demand in the medium- to long-term, it now appears that the growth rate will be significantly less than had been generally forecast in the early 1970s. For example, the trend to smaller and lighter automobiles will dictate less steel per unit than is presently the case. Steel requirements will be less than estimated if investment for new plant and equipment continues to lag or stabilize at a lower level of activity than in the 1960s. The period to 1985 will probably see crude steel production in Canada grow at an annual average rate of

Table 3. Canada, crude steel production shipments, trade and consumption, 1975, 1976 and 1977

	1975	1976	1977p
		(tonnes)	
Furnace capacity January 1[1]			
Steel ingot			
Basic open-hearth	3 742 137	3 742 137	3 742 137
Basic oxygen converter	9 186 153	9 267 799	9 523 626
Electric	3 719 457	3 894 997	3 745 767
Total	16 647 747	16 904 933	17 011 530
Steel castings	360 606	418 938	445 973
Total furnace capacity	17 008 353	17 323 871	17 457 503
Production			
Steel ingot			
Basic open-hearth	3 079 115	2 971 118	2 879 758
Basic oxygen	7 304 920	7 945 811	7 952 828
Electric	2 423 740	2 206 095	2 649 559
Total	12 807 775	13 123 024	13 482 145
Continuously cast in total	1 739 124	1 687 365	2 169 047
Steel castings[2]	217 101	166 526	149 098
Total steel production	13 024 876	13 289 550	13 631 243
Alloy steel in total	1 247 038	1 591 361	1 691 580
Shipments from plants			
Steel castings	195 048	156 861	133 866
Rolled steel products	9 481 983	9 820 728	10 327 360
of which steel ingots are	362 488	453 965	587 658
Total	9 677 031	9 977 589	10 461 226
		(000 tonnes)	
Exports, equivalent steel ingots	1 167.6	1 855.2	2 230.6
Imports, equivalent steel ingots	1 712.9	1 368.1	1 511.5
Indicated consumption, equivalent steel ingots	13 570.2	12 802.5	12 911.8

Source: Statistics Canada.
[1]The capacity figures as of January 1 in each year take into account both new capacity, and obsolete capacity anticipated for the year. [2]Produced mainly from electric furnaces.

CANADA, PRODUCTION of STEEL by METHOD 1965–1977



Source: Statistics Canada

around 3.0 per cent. On this basis, production in 1985 would be in the order of 17.5 million tonnes.

Production, shipments and consumption

Crude steel production increased 2.6 per cent to 13.6 million tonnes in 1977. Basic oxygen furnace production accounted for about 58 per cent of this total, with production up fractionally (some 7 000 tonnes), to 7 953 000 tonnes. Open-hearth production was off about 91 000 tonnes to 2.9 million tonnes, continuing its diminishing role in steelmaking in Canada. Output from electric steel furnaces increased to 2.6 million tonnes, a gain of 20 per cent. Steel castings, mainly produced by electric furnaces, declined to 149 098 tonnes from 166 526 tonnes in 1976.

Steelmaking capacity, which stood at 17.3 million tonnes at the beginning of 1976, rose fractionally to 17.5 million tonnes due principally to more basic oxygen furnace capacity. Average steel furnace capacity utilization during 1977 was 78.1 per cent. This compares to 76.7 per cent in 1976 and 76.6 per cent in 1975. Basic oxygen furnaces averaged the highest rate at 83.5 per cent of capacity, wheras steel furnace castings averaged only 33.4 per cent.

Pig iron production (hot metal) decreased 1.5 per cent to 9.7 million tonnes, reflecting somewhat the decrease in blast furnace capacity. Several blast furnaces were temporarily taken out of service during 1977 because of oversupply conditions. The bulk of the pig iron is produced and consumed by the integrated steelmakers. About 7 per cent, some 703 000 tonnes, were cast and shipped, mainly to foundries. Consumption of pig iron decreased by about 1 per cent to 9.2 million tons, while ferrous scrap consumption increased by 4 per cent to 8.2 million tonnes.

Producer shipments of rolled steel in 1977 amounted to 10.3 million tonnes, an increase of 5.2 per cent compared with 1976. Shipments were up for most groups, including 29.5 per cent for ingots and semis, 20.9 per cent for structural shapes, 11.9 per cent for cold finished bars and 7.9 per cent for galvanized sheet and strip. Rails declined 9.9 per cent and track material 6.7 per cent.

Domestic disposition of rolled steel products increased by 2.7 per cent to 8.8 million tonnes. The consumer market remained firm, particularly due to strong automobile and truck sales. Steel consumption for automotive and aircraft use increased by 9.3 per cent to 1.7 million tonnes. Steel for appliances and utensils fell, however, by 17.5 per cent to 148 000 tonnes. The Canadian Appliance Manufacturers Association announced that about 2.7 million appliances were sold in Canada during 1977, down 3.6 per cent. Although the automotive market fared well, other segments of the transportation sectors, such as shipbuilding and railways, reduced their steel needs during 1977.

Disposition by wholesalers and steel service centres increased by 11.6 per cent to 1.4 million tonnes. Pipes and tubes, another large market for steel increased by 6.9 per cent to 1.3 million tonnes, chiefly because of the strong activity in oil and gas exploration in western Canada. The capital goods and construction sectors remained soft, reflecting lagging investment for business expansion. Steel for construction was down, although structural steel fabricators use increased by 10.2 per cent to 784 000 tonnes. The Canadian Institute of Steel Construction announced that new bookings of fabricated structural steel, joists and platework by its members declined by 12 per cent to some 240 000 tonnes in 1977.

Table 4. Producer shipments[1] of rolled steel[2], 1976 and 1977

	1976	1977	Growth
	(000 tonnes)		(%)
Ingots and semis	454.0	587.7	+29.5
Rails	352.7	317.9	−9.9
Wire rods	729.4	783.7	+7.4
Structural shapes	619.0	748.6	+20.9
Concrete reinforcing bar	484.7	495.1	+2.2
Other H.R. bars	918.0	996.7	+8.6
Track material	73.0	68.1	−6.7
Plate	1 072.0	1 136.9	+6.1
Hot-rolled sheet and strip	2 450.0	2 441.4	−0.4
Cold finished bars	76.2	85.3	+11.9
Cold reduced sheet, strip, other and coated	1 764.8	1 774.0	+0.5
Galvanized sheet and strip	826.9	892.0	+7.9
Total	9 820.7	10 327.4	+5.2
Alloy steel in total shipments	699.7	759.2	+8.5

Sources: Statistics Canada; *Primary Iron and Steel* (monthly).
[1]Includes producer exports. [2]Includes ingots and semis, but not steel castings; comprises both carbon and alloy steels.

Investment and corporate developments

Expenditures by the Canadian steel industry for capital and repair declined by about 2 per cent to $831.8 million in 1977. Repair expenditures of $437.8 million increased by over 7 per cent; however, capital expenditures decreased by 11 per cent to $394 million (See Table 1). The decline in capital spending was due in part to the completion of major projects, but also to cutbacks in spending and to the lengthening of certain expansion schedules due to changing marketing conditions. The major projects under way in 1977, but not completed, were Stelco's $1.2 billion Greenfield project at Nanticoke, Ontario, and Dofasco's new melt shop at Hamilton. Major expansion programmes were completed by Atlas Steels Division of Rio Algom Limited and Sidbec-Dosco Limited during the year.

Stelco, the largest producer in Canada, continued with its Greenfield steel complex at Nanticoke on Lake Erie during 1977. Initial capacity will be 1.2 million t with startup scheduled for April 1980. A 4 500-tonne-a-day blast furnace, a BOF steel furnace and a slab caster make up this first phase of development. Eventual capacity at the Nanticoke site is expected to be 5.4 million t. Initially, only slabs will be produced and these will be trucked to Hamilton for finishing into steel products. With adequate supplies of iron at the Hilton Works in Hamilton, Stelco shut down its small "B" blast furnace in early 1977. The furnace will be back in operation when demand warrants. Due to the general availability of scrap at low prices, Stelco did not operate its SL-RN direct-reduction plant at Bruce Lake in northwestern Ontario. This plant is designed to produce pre-reduced iron for Stelco's electric furnace plants at Edmonton and Contrecoeur.

As in 1976, the markets for Algoma's structural steel products remained depressed. As a reflection of this, Algoma reduced pig iron production by suspending operations at its Canadian Furnace Division at Port Colborne in March and by banking its No. 5 blast furnace at Sault Ste. Marie for about three months late in the year. Also, due to adequate levels of coke production, the schedule of rebuilding the No. 9 coke battery has been stretched out to mid-1978 for completion. Plans to build another new coke battery have been cancelled in favour of rebuilding the No. 5 battery when necessary. In order to reduce the transportation cost of shipping steel products to the west coast, Algoma is experimenting with shipping via the Panama Canal. A 6 400-tonne cargo of steel products was sent to Vancouver via the Panama Canal in mid-December as an alternative to overland rail transportation.

Dofasco continued with its expansion program during 1977. A new hot-strip slitting facility was brought on line to slice coils into narrow widths, and a new, modern line to produce high-grade silicon steel came into production. The major project underway during the year was the construction of Dofasco's No. 2 basic oxygen steel-making shop on its Bayfront property. The new melt shop, with about 910 000 tonnes of capacity, is scheduled for operation in May 1978. The site has been designed so that capacity can be increased in stages to about 4 million tonnes. Also in 1978 Dofasco will commission its new No. 6 coke battery which will have an annual capacity of some 420 000 tonnes of coke and add eight new soaking pits with a total capacity of about 270 000 tonnes a year.

Table 5. Disposition of rolled steel products[1], 1976 and 1977

	1976	1977	Growth
	(tonnes)		(%)
Wholesalers, warehouses and steel service centres	1 217 397	1 357 969	+11.6
Automotive and aircraft	1 540 514	1 683 989	+9.3
Agricultural	231 812	171 948	−25.8
Contractors — building	522 832	492 843	−5.7
Construction — public and utility	38 646	33 127	−14.3
Structural steel fabricators	711 720	784 258	+10.2
Containers	514 962	508 650	−1.2
Machinery and tools	309 475	276 901	−10.5
Wire, wire products and fasteners	687 894	679 617	−1.2
Natural resources and extractive industries	217 449	208 325	−4.2
Appliances and utensils	179 171	147 753	−17.5
Other metal stamping and pressing	634 949	651 543	+2.6
Railway operating	318 478	298 823	−6.2
Railroad cars and locomotives	85 025	75 392	−11.3
Shipbuilding	19 114	15 235	−20.3
Pipes and tubes	1 223 031	1 307 824	+6.9
Miscellaneous	74 670	65 078	−12.9
Total domestic shipments	8 527 139	8 759 275	+2.7
Producer exports[2]	1 293 589	1 568 085	+21.2
Total producer shipments	9 820 728	10 327 360	+5.2

Source: Statistics Canada: *Primary Iron and Steel* (monthly).
[1]Includes ingots and semis, but excludes steel castings, pipe and wire. [2]Total rolled steel exports amounted to 1 440.9 and 1 759.7 million tonnes in 1976 and 1977, respectively.

Table 6. Canada, trade in steel by product[1], 1975-77

	Imports			Exports		
	1975	1976	1977^p	1975	1976	1977^p
	(000 tonnes)					
1. Steel castings (including grinding balls)	17.1	13.4	21.5	26.8	22.7	16.9
2. Ingots	60.7	10.4	52.2	1.1	36.0	88.8
3. Semi-finished steel blooms, billets, slabs	45.9	12.0	9.1	34.1	94.0	151.0
4. Total (1+2+3)	123.7	35.8	82.8	62.0	152.7	256.7
5. Finished steel						
A) Hot-rolled						
Rails	56.2	18.8	19.7	127.9	162.1	122.5
Wire rods	236.6	157.6	175.8	86.4	166.4	195.3
Structurals	190.7	231.1	225.2	90.3	138.7	207.0
Bars	123.6	134.0	105.7	39.4	43.0	83.8
Track material	11.3	5.4	6.4	2.3	3.6	15.1
Plate	346.2	214.3	225.0	154.0	165.5	226.6
Sheet and strip	96.8	68.8	116.0	141.7	317.3	269.9
Total hot-rolled	1 061.4	830.0	873.8	642.0	996.6	1 120.2
B) Cold-rolled						
Bars	22.7	14.2	19.7	7.3	6.6	11.2
Sheet and strip	36.9	40.6	51.8	23.5	84.8	55.5
Galvanized	17.2	48.8	42.0	59.0	107.0	154.0
Other[1]	85.5	92.2	112.8	119.5	115.9	179.0
Total cold-rolled	162.3	195.8	226.3	209.3	314.3	399.7
6. Total finished steel (A+B)	1 223.7	1 025.8	1 100.1	851.3	1 310.9	1 519.9
7. Total rolled steel (2+3+6)	1 330.3	1 048.2	1 161.4	886.5	1 440.9	1 759.7
8. Total steel (4+6)	1 347.4	1 061.6	1 182.9	913.3	1 463.6	1 776.6
9. Total steel (raw steel equivalent)[2]	1 712.9	1 368.0	1 511.5	1 167.6	1 855.2	2 230.6
10. Fabricated steel products						
Steel forgings	10.9	8.3	7.5	31.8	42.5	42.2
Pipe	196.1	169.7	203.1	325.9	280.1	263.1
Wire	80.5	77.5	88.3	40.3	45.6	63.6
11. Total fabricated	287.5	255.5	298.9	398.0	368.2	368.9
12. Total castings, rolled steel and fabricated (8+11)	1 634.9	1 317.1	1 481.8	1 311.3	1 831.8	2 145.5

Source: Statistics Canada: Exports and Imports by Commodities.
[1]Includes steel for porcelain enamelling, terneplate, tinplate and silicon steel sheet and strip. [2]Calculation: finished steel (Row 6) divided by 0.77, plus steel castings, ingots and semis (Row 4).

Sidbec-Dosco Limited commenced operation of its second Midrex direct-reduction unit in August 1977. The 600 000-tonne-capacity plant increased Sidbec's prereduction iron capacity to about 1 million tonnes annually. Sidbec also completed installation of one 136-tonne electric furnace and another is scheduled for early 1978, along with one continuous casting machine for billets. A continuous casting machine for slabs will be brought on stream in 1978. This expansion will more than double Sidbec's steelmaking capacity to about 1.5 million tonnes a year. In September, Sidbec purchased the Questeel mill of bankrupt QSP Ltd. at a creditors' auction for $27.1 million. Questeel, with a raw steel capacity of some 270 000 tonnes a year and a rolling mill capacity of 245 000 tonnes, had been in operation since 1974. Large capital costs associated with its development, coupled with a market deterioration for its steel products, led to the severe financial difficulties which caused its closing. IPSCO of Regina, the largest pipe producer in Canada with annual capacity of about 500 000 tonnes, carried out investigations relative to an expansion of pipe-producing capacity in 1977. The motivating factor is the potential market for large-diameter, Arctic-grade pipe.

The Atlas Steels Division of Rio Algom Limited, Canada's largest producer of stainless and specialty steels, completed its new melt shop at Welland during 1977. The new plant has two 54-tonne and one 23-tonne electric arc furnaces and a vacuum refining system for stainless steels.

Sydney Steel Corporation (Sysco) of Sydney continued to have production and marketing difficulties. However, during the year Sysco secured a contract to supply rails to Venezuela over a five-year period beginning in 1978, and entered into a sales arrangement with Titan Industrial Corporation of New York for the marketing of slabs. In December the Government of Canada, through the Department of Regional Economic Expansion, and the Government of Nova Scotia agreed to provide Sysco with $19.5 million in financial aid. The bulk of these funds will be used for capital expenditures to improve production capability.

Cansteel Corporation, a Crown corporation of the Government of Nova Scotia, and four steel companies: Estel NV Hoesch-Hoogovens and Thyssen International of Europe, National Steel Corporation of the United States and Dofasco, completed a feasibility study for the development of a new steel plant at Gabarus Bay, Cape Breton Island. It was announced late in the year that the 2.5-million-tonne-a-year "semis" project would not go ahead at this time due mainly to the uncertain condition of the international steel market. However, the consortium will continue to monitor the potential for such a steel plant.

Prices

Nominal steel product prices increased during 1977 in line with response to market factors, and under Anti-Inflation Board guidelines. Discounting was particularly noticeable in certain regional markets. Effective changes basically reflected increased costs of production. Some typical mill basic selling prices by year-end, per tonne of product, were approximately $300 for hot-rolled sheet, $340 for cold-rolled sheet, $380 for galvanized sheet, $505 for tinplate, $300 for plate and $280 for large structurals. Merchant pig iron was selling for just under $180 a tonne.

Prices of raw materials increased during the year, due principally to higher costs of production. Coking coal was generally in an excess supply situation for the year, consequently spot market prices were soft. However most coal under long-term contracts increased slightly in price due to annual escalation clauses. At year-end, Canadian medium-volatile coking coal was selling at about $56 a tonne fob Vancouver. In the United States, low-volatile coking coal was priced at approximately $U.S.67 a tonne, fob Hampton Roads. Notwithstanding the "wildcat" strikes at many United States coking coal mines during mid-year, and the United Mineworkers of America (UMW) coal miners' strike which commenced in early December, coking coal was readily available. Iron ore prices increased as the Lake Erie base price increased by 4.5 per cent. Iron ore pellets were selling at approximately $U.S.33 a tonne at rail of vessel, lower lake ports. Although the iron ore miners in Upper Michigan and Minnesota were on strike for nearly five months, the North American steel industry was not greatly affected by the interruption in production because of high stocks of iron ore at the plants. Scrap prices were depressed for much of 1977. The United States composite price for No. 1 heavy melting fell from $75 a tonne in March to $48 in late November. However, demand suddenly picked up in December, and the price rose to $70 a

Table 7. Canada, value* of trade in steel castings, ingots, rolled and fabricated products, 1975-77

	Imports			Exports		
	1975	1976	1977^p	1975	1976	1977^p
			($000)			
Steel castings	22 320	16 616	21 832	18 811	17 091	13 724
Steel forgings	22 261	16 339	17 450	36 234	49 076	56 960
Steel ingots	9 672	2 413	8 641	649	6 212	11 871
Rolled products						
Semis	12 603	4 503	4 412	9 858	17 833	26 852
Other	503 790	373 844	460 204	285 781	386 220	514 521
Fabricated						
Pipe and tube	183 052	130 853	169 308	210 480	151 987	146 644
Wire	65 787	58 635	71 020	26 811	29 152	43 453
Total steel	819 485	603 203	752 867	588 624	657 571	814 025

Source: Statistics Canada: Exports and Imports by Commodities.
*Note: The values in this table relate to the tonnages shown in Table 6.

Table 8. Canada, trade in steel[1] by country, 1975-77

	Imports			Exports		
	1975	1976	1977^p	1975	1976	1977^p
	(000 tonnes)					
United States	685.9	476.1	490.8	940.4	1 219.2	1 781.8
ECSC[2] countries	501.5	253.3	380.6	61.3	305.0	98.5
Japan	330.3	414.1	392.3	0.2	0.3	0.1
Other	117.2	173.6	218.1	309.4	307.3	265.1
Total	1 634.9	1 317.1	1 481.8	1 311.3	1 831.8	2 145.5

Source: Statistics Canada: Exports and Imports by Commodities (monthly).
[1]Comprised of steel castings, ingots, semis, finished steel, forgings, pipe and wire [2]European Coal and Steel Community (Belgium, France, Italy, West Germany, Luxembourg, Netherlands, Britain, Denmark and Ireland).

Table 9. Canadian crude steel supply and demand, 1960, 1965, 1970, 1975-77

	Crude steel production	Imports[1]		Exports[1]		Indicated consumption[2]	
		A[3]	B[4]	A[3]	B[4]	A	B
	(000 tonnes)						
1960	5 253	1 059	1 227	849	902	5 463	5 578
1965	9 134	2 238	2 624	990	1 120	10 382	10 638
1970	11 200	1 524	1 986	1 696	2 086	11 028	11 100
1975	13 025	1 713	2 194	1 168	1 721	13 570	13 498
1976	13 290	1 368	1 819	1 855	2 382	12 803	12 727
1977^p	13 631	1 512	2 021	2 231	2 766	12 912	12 886

Source: Statistics Canada.
[1]Trade of Canada, adjusted to equivalent crude steel by Mineral Policy Sector. [2]Production plus imports, less exports, with no account taken for stocks. The two columns of figures depend on the two sets of values for trade. [3]Calculations: total finished steel (all hot and cold-rolled steel but excluding wire, steel, pipe and tube) divided by 0.77 plus steel castings, ingots and semis. See Table 6. [4]Calculations: total hot and cold-rolled steel, steel forgings, wire, and steel pipe and tube divided by 0.75 plus steel castings (piston ring castings), ingots, semis and ingot moulds and stools.

tonne. In Hamilton, No. 1 heavy melting scrap was selling for $48 a tonne in November. Demand was so poor at that time that several dealers were laying off employees.

Prices for oil and gas increased during the year due mainly to the federal and provincial policies on oil and gas pricing. The domestic oil price was increased by $1.00 a barrel on July 1, 1977 to $10.75, with another increase due Jan. 1, 1978. Natural gas prices rose on August 1 and will increase again on February 1, 1978. The Toronto city gate price of $1.68 a million cubic feet will rise to $1.85 on February 1. Graphite electrodes, used by electric steel producers, will increase by an average 9.5 per cent to 76.5 U.S.¢ a pound effective January 3, 1978.

Trade

Total exports of steel by Canadian producers increased by 17.1 per cent in 1977 to 2.1 million tonnes. Consequently, for the second year in succession exports exceeded imports. The value of exports rose by approximately 23.8 per cent to $814 million. Semi-finished steel (castings, ingots, blooms, billets, slabs) increased to 256 700 tonnes from 152 700 tonnes in 1976. Finished steel (hot- and cold-rolled products) increased by 15.9 per cent to 1.5 million tonnes with hot-rolled wire rods, bars and structurals, and cold-rolled galvanized products showing large gains. Fabricated steel products remained roughly the same, at 368 900 tonnes. Approximately 83 per cent of total export trade went to the United States, Canada's traditional foreign market, as shipments increased by over 500 000 tonnes to nearly 1.8 million tonnes. Exports to the EEC, which amounted to 238 500 tonnes in 1976, dropped back to a more normal amount of 68 200 tonnes during 1977.

Imports rose by 12.5 per cent to nearly 1.5 million tonnes, with value increasing by 24.8 per cent to $752.9 million. Increases were exhibited by both the United States and EEC countries. Shipments from Japan declined to 392 300 tonnes from 414 400 tonnes in 1976. Most product lines showed increases, with only hot rolled bars and structurals showing noticeable decreases.

Early in the year there was concern about the increasing level of steel imports being sold in Canada at distressed prices. Although shipments in most cases were not large, the prices were having an erosion effect on prices of Canadian producers and were altering the market towards increasing levels of imports. Consequently, several companies initiated formal complaints

Table 10. World raw steel production, 1976 and 1977

	1976	1977p
	(million tonnes)	
Soviet Union	144.8	147.0
United States	116.3	113.1
Japan	107.4	102.4
West Germany	42.4	39.0
China	21.0	23.4
Italy	23.5	23.3
France	23.2	22.1
United Kingdom	22.5	20.4
Poland	15.3	18.0
Czechoslovakia	14.7	15.0
Canada	13.3	13.6
Rumania	11.0	12.2
Belgium	12.1	11.3
Brazil	9.3	11.2
Spain	11.0	11.1
India	9.4	10.0
Australia	7.8	7.3
South Africa	7.1	7.3
East Germany	6.7	6.8
Mexico	5.3	5.5
Netherlands	5.2	4.9
Luxembourg	4.8	4.3
South Korea	3.5	4.2
Austria	4.5	4.1
Sweden	5.1	4.0
Hungary	3.7	3.7
Yugoslavia	2.8	3.2
North Korea	3.0	3.2
Argentina	2.4	2.7
Bulgaria	2.5	2.6
Finland	1.6	2.2
Turkey	2.0	1.8
Taiwan	1.6	1.8
Others	10.0	10.3
Total	676.8	673.0

Source: International Iron and Steel Institute.
pPreliminary.

of dumping. Three cases involving wide flange shapes, bar angles and several types of stainless steels were heard by the Anti-Dumping Tribunal in early November.

In late December dicisions were announced for the first two cases. The first ruled that certain wide flange shapes were being dumped in Canada by producers from the United Kingdom, France, Japan, South Africa and Luxembourg, and that material injury was being caused to the only Canadian producer of these products (The Algoma Steel Corporation, Limited). The second decision, involving certain sized, hot-rolled bar angles, ruled that dumping and material injury had been caused to five Canadian producers (Lake Ontario Steel Company Limited, Questeel Ltd., Burlington Steel Division of Slater Steel Industries Limited, Sidbec-Dosco Limited, and The Steel Company of Canada, Limited) by bar angle products being dumped in Canada by Japanese producers. In early January 1978 the Anti-Dumping Tribunal ruled that imports of stainless steel plate from South Africa and Japan were being dumped in Canada and that material injury was being caused to the only Canadian producer of this product, Atlas Steel Company Limited of Welland, Ontario. The tribunal also ruled that injury is likely to occur to Atlas from dumping of stainless steel sheet produced in West Germany and Japan. As a result of these anti-dumping decisions, provisional levies imposed in September-October 1977 would be maintained.

World review

The sluggish nature of economic performance throughout the world, together with undesirable levels of inflation and unemployment continued to affect the iron and steel industry in virtually all market economies during 1977. Demand for most steel products remained poor, particularly for capital and construction goods. Total world crude steel production decreased fractionally by 0.5 per cent to 673 million tonnes as capacity utilization in many countries remained poor. The only significant bright spot was the automobile market. Late in 1977, Japan was operating at 70 per cent, and West Germany as low as 50 per cent, of capacity. Most countries were in the 60- to 70-per-cent range. As a result, most firms were having severe financial problems, and layoffs or short workings were more prevalent.

Many countries, particularly those with large state involvement, have tried to stabilize production in order to maintain employment. This has been translated into increased efforts for the marketing of export products, which has led to serious international trade problems; the main problem being accusation of dumping. Many of these cases allege products being sold at prices not only less than those prevailing in the countries of origin, but even below the cost of production.

In countries such as Canada and the United States formal dumping procedures were pursued. Earlier, the United States imposed quotas on stainless and specialty steel. Some countries such as Japan have sought arrangements of voluntary restraints for orderly marketing. In western Europe, several steel industry associations formed a lobby group called "Eurofer" to work with the European Commission in establishing voluntary production quotas, setting minimum prices and implementing the so-called "Simonet Plan". The latter was replaced in mid-1977 by the "Davignon Plan" named after Commissioner Viscount Davignon. While the long-term objective of the Davignon Plan is aimed at stabilizing and modernizing the EEC steel industry it has a short-term goal of getting price levels above the costs of production in member countries, which in turn would help overcome the problem of steel imports.

By year-end, the EEC and the United States felt that more drastic actions were needed to effectively deal with imports in their respective market and both announced special measures in respect of most imported steel products. Essentially these measures, through the use of "reference pricing or basic price" mechanisms, should enable authorities to establish more orderly pricing in their respective domestic markets and to apply antidumping duties more expeditiously if required.

In the United States its "reference price" or "trigger price" system, which is based on recommendations of the Soloman Task Force, is to become effective in late February 1978. Mr. A.M. Soloman of the United States Treasury Department was appointed by the president of the United States in late 1977 to make recommendations on steel, particularly in regard to imports. Under this scheme, prices for virtually all steel products imported into the United States would be based on the lowest cost producer (presently thought to be Japan) with adjustments for such factors as overhead, profit and transportation to the United States. If an import from any country is priced lower by more than 5 per cent from this reference price, a dumping complaint would automatically be triggered, with a finding to be made within 60 to 90 days. Reference prices will be

Table 11. Capital expenditures of selected Canadian companies in 1977 and plans for 1978

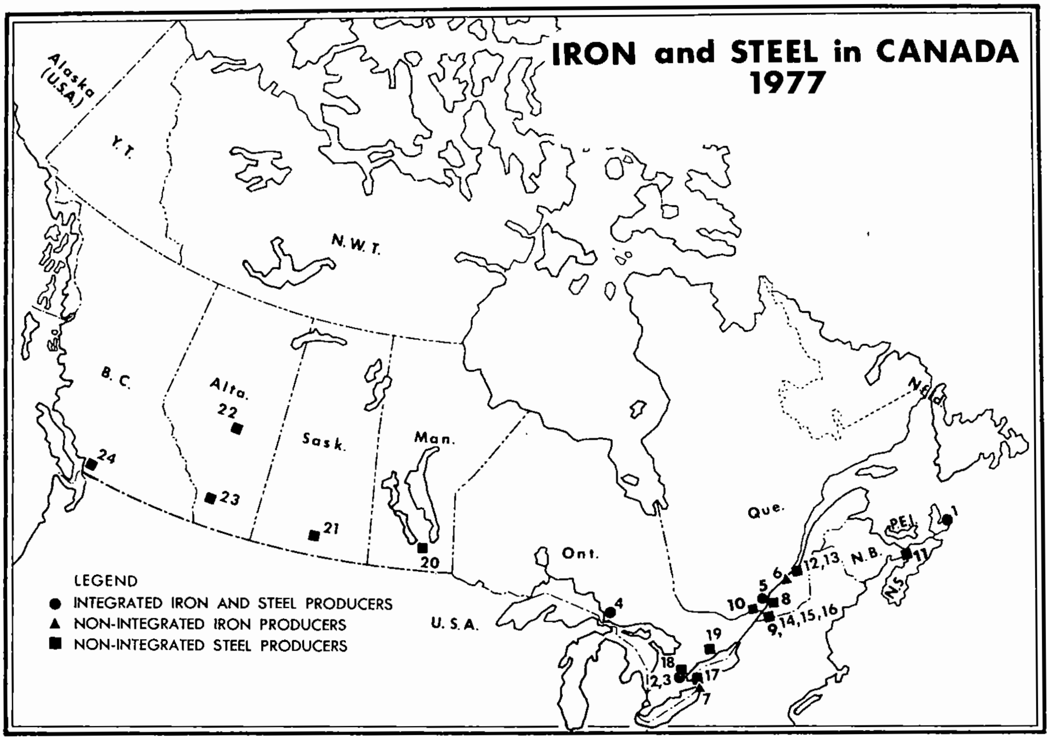
	Estimated for 1977	Planned for 1978	Percentage change
	($ million)		
Manufacturing	3 387	3 698	17.0
Mining	1 188	1 080	- 9.1
Oil and gas companies	3 590	3 219	-10.3
Oil and gas pipelines	584	656	12.3
Transportation and storage	885	872	- 1.5
Communications	1 934	2 053	6.2
Electric utilities	5 267	6 282	19.3
Other companies	878	994	13.2
Total	17 713	18 854	6.4

Source: Department of Industry, Trade and Commerce, Ottawa, Canada.

Table 12. Canada, rolled steel supply and demand, 1974-77 and forecast to 1978

	Producer or mill shipments[1]	Exports[2]	Imports[3]	Apparent rolled steel consumption[4]	Raw steel production[5]
			(million tonnes)		
1974	10 377	1.323	2.774	11.828	13 623
1975	9 482	0.887	1.330	9.925	13 025
1976	9 821	1.441	1.048	9.428	13 290
1977^p	10 327	1.760	1.161	9.728	13 631
% change 1977/1976	+5.2	+22.1	+10.8	+3.2	+2.6
1978^e					
% change 1978/1977	+6.0	+25.0	+5.0	+3.5	+4.0

Sources: Statistics Canada *Primary Iron and Steel* (monthly); and *Trade of Canada*.
[1]Comprises domestic shipments plus producer exports. A portion of domestic shipments to warehouse and steel service centres is also exported. Excludes steel castings amounting to 190 000 tonnes in 1974, 195 000 tonnes in 1975, 157 000 tonnes in 1976 and 134 000 tonnes in 1977. [2]Total exports includes producer exports plus exports from warehouses and steel service centres. Excludes exports of pipe, wire, forgings and steel castings. [3]Excludes imports of pipe, wire forgings and steel castings. [4]Excludes apparent consumption of steel castings. [5]Includes production of steel castings amounting to 201 248 tonnes in 1974, 217 101 tonnes in 1975, 166 526 tonnes in 1976 and 149 098 tonnes in 1977.



Integrated iron and steel producers
(numbers refer to locations on map above)
1. Sydney Steel Corporation (Sydney)
2. Dominion Foundries and Steel, Limited (Hamilton)
3. The Steel Company of Canada, Limited (Hamilton)
4. The Algoma Steel Corporation, Limited (Sault Ste. Marie)
5. Sidbec-Dosco Limited (Contrecoeur)

Nonintegrated iron producers
6. Quebec Iron and Titanium Corporation (Sorel)
7. Canadian Furnace Division of Algoma (Port Colborne)

Principal nonintegrated steel producers
8. The Steel Company of Canada, Limited (Contrecoeur)
9. QSP Ltd. (Montreal)
10. Ivaco Industries Limited (L'Orignal)
11. Enheat Limited (Amherst)
12. Atlas Steels Division of Rio Algom Limited (Tracy)
13. Colt Industries (Canada) Ltd. (Sorel)
14. Canadian Steel Foundries Division of Hawker Siddeley Canada Ltd. (Montreal)
15. Canadian Steel Wheel Limited (Montreal)
16. Sidbec-Dosco Limited (Montreal)
17. Atlas Steels (Welland)
18. Burlington Steel Division of Slater Steel Industries Limited (Hamilton)
19. Lake Ontario Steel Company Limited (Whitby)
20. Manitoba Rolling Mills Division of Dominion Bridge Company, Limited (Selkirk)
21. Interprovincial Steel and Pipe Corporation Ltd. (Regina)
22. Premier Works of Stelco (Edmonton)
23. Western Canada Steel Limited (Calgary)
24. Western Canada Steel Limited (Vancouver)

periodically updated to reflect changing conditions. The plan is designed to lower the percentage of the domestic market now being held by imported products.

The program in the EEC is similar in nature to the one in the United States. Base prices would be established for most steel products and would be determined on market values calculated by the EEC. This system would also apply to domestic producers who would not be permitted to sell at prices lower than the base prices. In addition, for the short term the EEC wants to negotiate bilateral agreements with countries for future steel trade. Without an agreement it appears that exporters may find it difficult to retain or maintain a market share. The EEC scheme came into effect on January 1, 1978.

In an effort to ameliorate the current global situation for steel in the medium to long run, such steps as reorganization, restructuring and amalgamation were being considered by steel producing firms and countries. For example, three steel companies in Sweden are planning to merge their specifically steel operations into a single company. In Belgium the government is studying a restructuring of the entire industry. Jones & Laughlin Steel Corporation and Youngstown Sheet and Tube Company, two large United States producers have announced plans to merge. As a result of losing over $800 million in 1977, the United Kingdom is looking at a rationalization of the government owned British Steel Corporation. In Mexico the three largest steelmaking companies will be merged into a single entity.

Lead

GORDON R. PEELING

Lead production in Canada in 1977 showed a significant increase both in physical output and in value. Mine production recovered from the strike-reduced level of 1976, while a new high was established for refined metal production.

Canada's production of lead, based on lead produced from domestic materials and the recoverable content of ores and concentrates exported, was 284 119 tonnes*, an increase of 10.8 per cent from the 1976 level. The value of production in 1977 showed a more spectacular increase of 52.4 per cent to $195.1 million, the highest level ever and a result of exchange rate adjustments and steadily advancing prices during the year. Mine output of lead, expressed as the lead content of domestic ores and concentrates produced, was 327 593 tonnes, an increase of 34.3 per cent from the 243 956 tonnes produced in 1976.

Primary refined lead output totalled 187 457 tonnes, up 6.7 per cent from the 1976 level of 175 720 tonnes. This was the third consecutive year of increased output. Capacity utilization in the industry was about 83 per cent.

Export of lead contained in concentrates decreased to 135 541 tonnes in 1977 from 140 933 tonnes in 1976. Increased shipments to Japan and West Germany were more than offset by lower shipments to the United States and Belgium and Luxembourg. Metal exports, in response to strong world-wide demand, totalled 130 821 tonnes, up 14 per cent from the 114 402 tonnes exported in 1976. The United States and the United Kingdom continued as Canada's two most important metal export markets, taking about 82 per cent of total exports. Recent changes in import data collection procedures have resulted in greater detail being available on imports. Of particular interest are the figures on imports of lead in ores and concentrates, which totalled 34 558 tonnes in 1977, and on lead and lead alloy scrap, which totalled 41 521 tonnes, more than double the 1976 total of 20 264 tonnes.

Canadian consumption of primary and secondary lead metal in 1977 was 69 643 tonnes and 46 120 tonnes respectively, compared with 62 157 tonnes and 45 497 tonnes respectively in 1976.

* The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Canadian developments

Although mine production in 1977 was substantially higher than in 1976, output was still adversely affected by the weak market conditions prevailing for copper and zinc. As mine producers of copper and zinc kept production at a level commensurate with soft demand and rising inventories, the output of co-product and by-product lead was kept lower than normal. Four copper-zinc-lead mines closed in eastern Canada during 1977.

The number of employees at mine and mill operations of the principal lead producers declined 6 per cent in 1977 to 11 022. The value of Canadian production reached new highs in 1977 as the lead price advanced throughout the year in response to strong demand and tight supply, the latter as a result of production disruptions at major producers in North America, Australia and Europe.

Mine production

Newfoundland. ASARCO Incorporated operates the province's sole lead producer, the Buchans mine located in central Newfoundland. Output of lead in concentrates in 1977 declined as mill throughput was lower than in 1976 and mill recovery** of lead declined from 85 to 83 per cent. Although the company has actively explored the surrounding area, no commercially viable discoveries have been made and present reserves are sufficient to last only until April 1979. Reserves at year-end were 0.4 million tonnes grading 6.12 per cent lead, 10.76 per cent zinc and 116.6 grams of silver a tonne.

New Brunswick. Nigadoo River Mines Limited ceased operations on August 26, 1977 due to depletion of the orebody. Production at Brunswick Mining and

**The term "mill recovery" refers to lead recovered in the lead concentrate only.

Smelting Corporation Limited returned to normal in 1977 after a prolonged strike in 1976. Due to weak zinc markets, Brunswick has deferred the expansion program at the No. 12 mine, reduced employment in both the mining and smelting divisions, started a work-sharing program which will continue until April 1978 and curtailed all capital expenditures not essential to maintaining production levels. The mining operations in the No. 6 open pit ceased in 1977 and stoping was begun underground. The No. 6 underground operations are scheduled to proceed for about four years, at which time reserves will be depleted. With the curtailment of the $53 million expansion program at the No. 12 mine, the new No. 3 shaft, which will increase hoisting capacity from 6 880 to 9 900 tonnes of ore a day, was bottomed at 1 128 metres instead of the planned 1 372 level. Resumption of the program will not take place until increased output is warranted by market circumstances. Mill recovery of lead improved slightly from 57 to 59 per cent in 1977. Reserves at year-end at the No. 12 mine were 97.1 million tonnes grading 9.22 per cent zinc, 3.77 per cent lead, 0.32 per cent copper and 96.3 grams of silver a tonne. Reserves at No. 6 were 0.8 million tonnes grading 7.25 per cent zinc, 2.62 per cent lead, 0.28 per cent copper and 85 grams of silver a tonne. There is also a sizeable copper-rich zone at the No. 12 mine containing 12.8 million tonnes grading 1.27 per cent zinc, 0.45 per cent lead, 1.11 per cent copper and 35.3 grams of silver a tonne.

Output at Heath Steele Mines Limited was down in

Table 1. Canada, lead production trade and consumption, 1976 and 1977

	1976		1977^p	
	(tonnes)	($)	(tonnes)	($)
Production				
All forms[1]				
British Columbia	85 408	42 653 895	79 877	54 858 000
Yukon	32 036	15 999 040	67 698	46 494 000
New Brunswick	65 059	32 491 047	61 142	41 991 000
Northwest Territories	52 942	26 440 157	58 370	40 087 000
Ontario	6 906	3 448 831	8 257	5 671 000
Newfoundland	12 886	6 435 294	8 200	5 632 000
Manitoba	273	136 404	454	312 000
Quebec	814	406 725	121	83 000
Total	256 324	128 011 393	284 119	195 128 000
Mine output[2]	243 956		327 593	
Refined production[3]	175 720		187 457	
Exports				
Lead contained in ores and concentrates				
Japan	75 123	17 952 000	86 429	31 315 000
United States	27 900	6 746 000	17 761	6 877 000
West Germany	9 625	1 442 000	16 974	4 842 000
Belgium and Luxembourg	15 174	2 357 000	6 125	2 272 000
United Kingdom	1 946	364 000	6 658	1 788 000
Other countries	11 165	2 413 000	1 594	940 000
Total	140 933	31 274 000	135 541	48 034 000
Lead pigs, blocks and shot				
United States	38 337	17 688 000	66 243	44 044 000
United Kingdom	36 997	14 549 000	40 949	23 543 000
Netherlands	5 071	1 931 000	6 229	3 246 000
Italy	5 973	2 399 000	6 038	2 899 000
Pakistan	1 425	659 000	2 397	1 110 000
India	4 713	2 148 000	1 721	796 000
Other countries	21 886	8 906 000	7 244	3 883 000
Total	114 402	48 280 000	130 821	79 521 000

Table 1. (cont'd)

	1976		1977p	
	(tonnes)	($)	(tonnes)	($)
Exports (cont'd)				
Lead and alloy scrap (gross weight)				
West Germany	3 788	971 000	5 335	1 282 000
United States	1 234	404 000	2 737	1 228 000
South Africa	6 843	1 446 000	2 260	970 000
Sweden	–	–	1 742	677 000
South Korea	665	124 000	1 926	415 000
Denmark	618	133 000	445	247 000
United Kingdom	157	55 000	179	145 000
Other	1 604	480 000	1 340	351 000
Total	14 909	3 613 000	15 964	5 315 000
Lead fabricated materials not elsewhere specified				
United States	4 436	2 553 000	7 434	5 665 000
Sweden			259	74 000
Japan	–	–	75	37 000
Jamaica	–	–	28	24 000
Other	49	34 000	20	23 000
Total	4 485	2 587 000	7 816	5 823 000
Imports				
Lead pigs, blocks and shot	1 941	928 000	821	575 000
Lead oxide; litharge, red lead, mineral orange	386	311 000	337	349 000
Lead fabricated materials not elsewhere specified	1 337	1 114 000	2 505	3 066 000
Lead in ores and concentrates	32 079	13 831 000	34 558	14 375 000
Lead in dross, skimmings and sludge	747	85 000	373	98 000
Lead and lead-alloy scrap	20 264	3 186 000	41 521	8 257 000

Table 1. (concl'd)

	1976			1977p		
	Primary	Secondary[4]	Total	Primary	Secondary[4]	Total
			(tonnes)			
Consumption						
Lead used for, or in the production of:						
antimonial lead	1 633	15 654	17 287	480	13 618	14 098
battery and battery oxides	25 511	4 821	30 332	35 761	5 742	41 503
cable covering	2 158	x	2 158	2 506	x	2 506
chemical uses; white lead, red lead, litharge, tetraethyl lead, etc.	20 646	x	20 646	18 828	x	18 828
copper alloys; brass, bronze, etc.	348	82	430	259	90	349
lead alloys:						
solders	2 056	5 358	7 414	1 234	10 204	11 438
others (including babbitt, type metals, etc.)	180	3 219	3 399	213	3 209	3 422
semifinished products: pipe, sheet, traps, bends, blocks for caulking, ammunition, etc.	2 682	x	2 682	3 267	x	3 267
Other	6 943	16 363	23 306	2 095	13 257	15 352
Total, all categories	62 157	45 497	107 654	64 643	46 120	110 763

Source: Statistics Canada.
[1]Lead content of base bullion produced from domestic primary materials (concentrates, slags, residues, etc.), plus estimated recoverable lead in domestic ores and concentrates exported. [2]Lead content of domestic ores and concentrates produced. [3]Primary refined lead from all sources. [4]Includes all remelt scrap lead and scrap lead used to make antimonial lead.
p Preliminary; — Nil.
x Confidential, but included in "other".

1977 as increased ore production was offset by lower lead grades and mill recovery (49 per cent versus 55 per cent in 1976). Reserves at year-end 1977 were given as 27.0 million tonnes grading 1.16 per cent copper, 1.53 per cent lead, 4.44 per cent zinc and 60.7 grams of silver a tonne. The new No. 5 shaft came into operation in June, but because of market conditions, ore production in 1978 will remain at 1977 levels.

Quebec. The operations of the Sullivan Mining Group Ltd. at its Cupra Division and its D'Estrie Mining Company Ltd. properties ceased early in 1977, leaving the Manitou-Barvue Division of Louvem Mining Company Inc. as the single lead producer in the province. The Louvem operation treated only 53 756 tonnes of lead-bearing ore (0.46 per cent lead) from the Manitou-Barvue Division in 1977, with the other feed coming from Louvem's zinc operations.

Ontario. All lead production in Ontario is a byproduct of copper-zinc production. Willroy Mines Limited closed its Manitouwadge operations during the first quarter of the year as reserves were exhausted.

Lead production at the Sturgeon Lake Joint Venture operated by Falconbridge Copper Limited almost tripled in 1977 due to increased mill throughput and, more importantly, to an improvement from 10 per cent to 30 per cent in mill recovery of lead. Reserves were 0.82 million tonnes at year-end grading 1.13 per cent lead, 2.59 per cent copper, 9.15 per cent zinc, 182 grams of silver and 0.6 grams of gold a tonne.

Output at both the Geco mine of Noranda Mines Limited and the Kidd Creek mine of Texasgulf Canada Ltd. were lower in 1977 as production was reduced in line with demand. Mill recovery of lead at the Geco operation dropped from 43 to 20 per cent. Reserves at year-end were 23.2 million tonnes grading 1.88 per cent copper, 3.73 per cent zinc, 0.15 per cent lead and 52.5 grams of silver a tonne. Lead recovery at the Kidd Creek mill was slightly improved in 1977, up 3 per cent to 46 per cent. The expansion program which involves addition of a fourth circuit in the mill and a new No. 2 production shaft has been stretched out because of poor market conditions, and new completion dates have not been set. Open-pit production was completed in 1977 and all future production will come from underground operations. Reserves at year-end were 98.3 million tonnes grading 2.84 per cent copper, 5.03 per cent zinc, 0.18 per cent lead and 68.2 grams of silver a tonne.

Operations at Mattabi Mines Limited in the Sturgeon Lake area of northern Ontario were normal during the year but lead concentrate production was substantially higher as higher-grade ore was mined, and the mill recovery of lead improved from 28 per cent in 1976 to 49 per cent in 1977. Reserves at year-end were reported as 4.6 million tonnes grading 0.58 per cent copper, 7.19 per cent zinc, 0.74 per cent lead and 95.0 grams of silver a tonne.

Manitoba and Saskatchewan. A small amount of byproduct lead was produced from the mining operations of Hudson Bay Mining and Smelting Co., Limited. Hudson Bay operated nine ore sources in 1977, only two of which report lead production — Ghost Lake and Chisel Lake. Production in 1977 was 415 tonnes compared with 315 tonnes in 1976. Ore reserves at year-end were 15.9 million tonnes grading 2.75 per cent copper, 2.7 per cent zinc, 1.2 grams of gold and 18.2 grams of silver a tonne.

British Columbia. Operations at the H.B. and Sullivan mines of Cominco Ltd. were normal during 1977. Output of lead decreased slightly at both mines as a result of mining lower-grade ore. Lead recovery in the mills was virtually unchanged from previous years at 65 per cent at H.B. (61 in 1976) and 80 per cent at Sullivan (81 in 1976). Reserves at the H.B. mine are limited and operations are scheduled to cease in the fall of 1978. At the end of 1977 reserves at the two mines totalled 49.9 million tonnes grading 11 per cent combined lead and zinc.

Northair Mines Ltd. enjoyed its first full year of operations in 1977 at its Brandywine mine, where lead output was 1 218 tonnes. The lead content of material treated in the mill increased from 0.86 per cent in 1976 to 1.54 per cent in 1977. Reserves are 0.2 million tonnes grading 2.22 per cent lead, 2.66 per cent zinc, 12.9 grams of gold and 47.3 grams of silver a tonne.

Silvana Mines Inc., which operates the Silmonac mine near Sandon, also reported increased lead output as a result of treating higher-grade material even though mill throughput was down from the previous year. On August 1, 1977 Silvana took over as operator of the Silmonac mine and through a share reorganization became a subsidiary of Kam-Kotia Mines Limited, the previous operator of the property. Plans are under way to increase annual production from the present level of about 18 000 tonnes of ore to about 40 000 tonnes by 1980. Reserves are given as 0.04 million tonnes grading 5.8 per cent lead, 5.9 per cent zinc and 563.3 grams of silver a tonne with a reported potential for perhaps another 0.5 million tonnes.

Lead production by Western Mines Limited at the Lynx and Myra Falls mines on Vancouver Island declined in 1977 as a result of slightly lower-grade ore being milled. Recovery of lead in the mill also declined slightly from 81 per cent in 1976 to 79 per cent in 1977. Reserves at year-end were 1.3 million tonnes grading 1.1 per cent copper, 7.5 per cent zinc, 1.1 per cent lead, 2.7 grams of gold and 126.9 grams of silver a tonne.

Yukon Territory. Mine output of lead in the Yukon increased substantially as operations at the two producers returned to normal after lengthy strikes in 1976.

Output of lead in concentrates at the Faro mine of Cyprus Anvil Mining Corporation was more than twice that of 1976. However, start-up problems in the first half of 1977 kept production low as did lower-than-expected mill head grades. Lead recovery in the mill

Table 2. Canada, lead production, trade and consumption, 1960, 1965, 1970, 1975, 1976 and 1977

	Production		Exports				
	All forms[1]	Refined[2]	In ores and concentrates	Refined	Total	Imports Refined[3]	Consumption[4]
			(tonnes)				
1960	186 563	143 798	46 571	87 497	134 068	562	65 396
1965	264 723	169 175	97 036	117 086	214 122	64	81 799
1970	353 063	185 637	186 219^r	138 637	324 856^r	1 995	84 765
1975	349 133	171 516	211 909	110 758^r	322 667	1 962	89 193
1976	256 324	175 720	140 933	114 402	255 335	1 941	107 654
1977^p	284 119	187 457	135 541	130 821	266 362	821	109 000^e

Source: Statistics Canada.
[1]Lead content of base bullion produced from domestic primary materials (concentrates, slags, residues, etc.) plus the estimated recoverable lead in domestic ores and concentrates exported. [2]Primary refined lead from all sources. [3]Lead in pigs and blocks. [4]Consumption of lead, primary and secondary in origin.
^{p}Preliminary; ^{r}Revised; ^{e}Estimated.

was 76 per cent. Reserves at year-end were 37.5 million tonnes grading 8.6 per cent combined lead and zinc and 34.3 grams of silver a tonne.

Lead production at United Keno Hill Mines Limited increased 41 per cent as production returned to normal after a 42-day strike in 1976. The company operated five underground mines and two small open pits during the year, with the Husky mine supplying 42 per cent of the feed to the mill. Mill recovery of lead declined from 82 per cent in 1976 to 75 per cent in 1977. Ore reserves at year-end were 0.1 million tonnes grading 4.8 per cent lead, 1.1 per cent zinc and 1,244 grams of silver a tonne, sufficient to maintain operations through 1980.

Northwest Territories. Lead-in-concentrate production at Pine Point Mines Limited increased 13 per cent in 1977 as a result of a higher mill head grade of lead. Recovery of lead in the mill remained unchanged at 85 per cent. Increased stripping capacity will be in place in 1979 when a new 30 cubic yard walking dragline will be operative. This will lower stripping costs, which in turn will allow production from lower-grade and deeper orebodies. Ore reserves at year-end were 34.0 million tonnes grading 2.1 per cent lead and 5.3 per cent zinc.

In the high Arctic, Nanisivik Mines Ltd. enjoyed its first full year of production and made its first shipments of concentrate to market during the July to September shipping season. Lead concentrate production was 13 789 tonnes and mill recovery of lead was 85 per cent, much improved from the 10 per cent level during the mill tune-up period in 1976. Ore reserves at year-end were 5.1 million tonnes grading 1.4 per cent lead, 14.0 per cent zinc and about 60 grams of silver a tonne.

Exploration and development

Weak metal markets have resulted in the expansion programs at Mattagami Lake Mines Limited's Lyon Lake Division and Brunswick's No. 12 mine being deferred, with completion dependent upon stronger zinc markets.

Three exploration projects were brought to the decision point upon completion of the feasibility stage in 1977. In Nova Scotia, Imperial Oil Limited became the sole owner of the Gays River lead-zinc property when it purchased the remaining 30 per cent share held by Preuvier Mines Limited for $1.2 million. Early in 1978, Imperial announced that the property would be brought into production by late 1979 at a cost of $27 million. Also in Nova Scotia, Barymin Explorations Limited purchased the Silvermines lead property near Sydney on Cape Breton Island. Drilling done in the 1960s indicated a deposit containing 71 million tonnes grading 2.09 per cent lead in three zones. Further drilling on the west zone in the summer of 1977 established an indicated and potential tonnage of 1.1 million tonnes grading 5.42 per cent lead using a cutoff grade of 4 per cent. Barymin purchased a mill from Kaiser Aluminum & Chemical Corporation and plans to adapt it to treat the Silvermines lead ore. The mill has a capacity of 600 tonnes a day. Metallurgical tests indicate the lead recovery would be greater than 90 per cent in a concentrate grading 70 per cent lead or higher. The total cost to bring the property into production is estimated at $3.5 million. A decision to proceed will be taken if satisfactory financing can be arranged.

In the Yukon Territory, Kerr Addison Mines Limited (60 per cent owner) and Canadian Natural Resources Limited (40 per cent owner) continued their feasibility study on the Grum deposit. However, early in 1978 they announced that the evaluation program was being suspended after concluding that it was not feasible to bring the property into production at this time. Metal prices substantially higher than those presently prevailing will be necessary in order to justify development. The deposit, including ore in the contiguous Vangorda Joint Venture property, contains 26.1 million tonnes grading 6.4 per cent zinc, 4.1 per cent lead and 65.1 grams of silver a tonne.

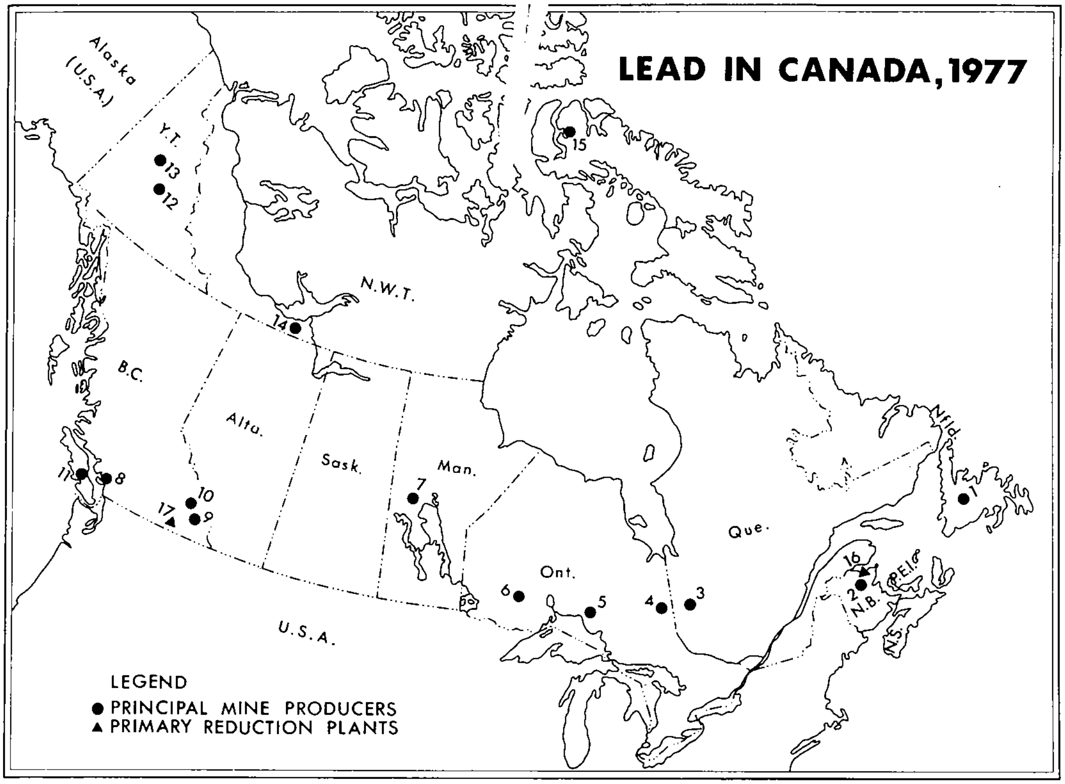
At the Howard's Pass property of Canex Placer Limited, an 80-kilometre (km) access road was completed in late 1977 and equipment was being moved onto the property in preparation for an underground program to commence in early 1978. Part of the work will involve obtaining bulk samples for metallurgical testing. Indications are that the deposit could be one of the largest in North America with an average grade somewhere between 6 per cent and 12 per cent combined lead and zinc.

In the Northwest Territories, negotiations between Cominco Ltd. and the federal government were reopened with regard to bringing the Arvik property into production. The deposit on Little Cornwallis Island contains 22.7 million tonnes grading 14.1 per cent zinc, 4.3 per cent lead and 34 grams of silver a tonne. The property could be in production in the early 1980s, given a favourable outcome to negotiations. Work in 1977 on the X-25 zone in the Pine Point area by Western Mines Limited and Du Pont of Canada Exploration Limited increased drill-indicated reserves from 2.54 to 3.45 million tonnes, grading 12.4 per cent combined lead and zinc, but the boundaries of the zone have yet to be fully defined.

Metal production

Metal production from Canada's two primary producers increased almost 7 per cent in 1977 as plants operated at 83 per cent of capacity and established a new high for Canadian production.

Cominco Ltd.'s plant at Trail, British Columbia operated normally during the year as production increased from 128 000 tonnes in 1976 to 136 000 tonnes in 1977. In April the company announced that it was embarking on a $425 million modernization and expansion program for the Trail facilities and the Sullivan mine. The project will be carried out over eight years.



Principal mine producers
(numbers refer to numbers on map above)

1. ASARCO Incorporated (Buchans Unit)
2. Brunswick Mining and Smelting Corporation Limited (Nos. 12 & 6 mines)
   Heath Steele Mines Limited
   Nigadoo River Mines Limited
3. Louvem Mining Company Inc. (Manitou-Barvue Division)
4. Texasgulf Canada Ltd.
5. Noranda Mines Limited (Geco Division)
   Willroy Mines Limited
6. Mattabi Mines Limited
   Falconbridge Copper Limited
   (Sturgeon Lake Joint Venture)
7. Hudson Bay Mining and Smelting Co., Limited (Chisel Lake, Ghost Lake mines)
8. Northair Mines Ltd.
9. Cominco Ltd. (Sullivan and H.B. mines)
10. Silvana Mines Inc. (Silmonac mine)
11. Western Mines Limited
12. Cyprus Anvil Mining Corporation
13. United Keno Hill Mines Limited
14. Pine Point Mines Limited
15. Nanisivik Mines Ltd.

Primary reduction plants

16. Brunswick Mining and Smelting Corporation Limited, Smelting Division
17. Cominco Ltd.

Part of the work involves construction of a new lead smelter which will expand annual capacity from 154 000 tonnes to about 181 500 tonnes. This work is planned for the latter half of the program and a commencement date for the work has not yet been set. The company has announced, however, that work will start in 1978 on a new $22 million lead concentrate preparation plant at the smelter.

The lead smelter and refinery of Brunswick Mining and Smelting Corporation had its most successful year ever in 1977. Output at the Belledune, New Brunswick plant was 51 200 tonnes in 1977, up 9.9 per cent from the 46 600 tonnes in 1976. Because weak zinc markets resulted in lower mining rates at the No. 6 and No. 12 mines, lead concentrate feed to the smelter had to be augmented with purchased material from custom shippers for part of the year. A new air filtration plant for the smelter was completed and operating by the end of September.

Domestic consumption

Consumption of both primary and secondary lead in Canada in 1977 increased by 2.9 per cent to 110 763 tonnes, compared with the 107 654 tonnes consumed in 1976. The pattern of major components of consumption has changed little in the 1970s, with the following breakdown: battery manufacture, 45 per cent; chemicals, 20 per cent and alloys 10 to 15 per cent, with semi-finished products and miscellaneous uses accounting for the remainder.

Developments in the United States

The United States is the world's largest mine producer, refined metal producer and consumer of lead. Mine production declined 3 per cent in 1977, while primary metal production declined 7 per cent as a result of strikes at several producers. Secondary metal production increased approximately 1 per cent to 664 431 tonnes. Consumption remained almost unchanged from 1976 to 1977 with an increase of less than 1 per cent.

After reviewing the previous administration's materials stock-pile policy, President Carter reaffirmed its major elements. The proposals call for a lead objective of 784 715 tonnes, which is 239 386 tonnes above the present holdings. The moratorium on acquisitions and disposals was lifted in October. Purchases of lead in the near future are unlikely however as producer inventories are very low.

In late December the Environmental Protection Agency (EPA) announced proposed lead standards for ambient air quality. Under the proposed regulations, the lead content of 1.0 cubic metre of air may not exceed 1.5 micrograms on a monthly average basis at the plant boundaries. A final standard will be published in June 1978. One estimate of the impact on the lead industry indicates that such a standard could result in loss of over 80 per cent of the total lead smelting and refining capacity because it will be technologically infeasible to comply to so stringent a standard. The lead industry is also waiting for regulations for in-plant worker exposure to lead to be brought forth by the Occupational Safety and Health Administration (OSHA). The proposed regulations would limit air lead levels to 100 micrograms per cubic metre, a 50 per cent reduction from the present 200 micrograms level. Publication of final regulations, originally scheduled for 1977, was delayed until sometime in 1978 as OSHA decided to extend public hearings on the controversial issue. Even if EPA and OSHA regulations, when finalized, turn out to be less stringent than those presently under discussion, they are still expected to have a severe capital and operating cost impact on the industry, and may result in closure of some producers.

In other regulatory activity, the Food and Drug Administration is moving to eliminate lead solder in cans, while the Consumer Product Safety Commission has promulgated regulations which effectively eliminate the use of lead compounds in interior paints.

World developments

The world lead industry enjoyed a good year in 1977, characterized by increased production, higher revenues and a draw-down of inventories. However, the positive developments in the lead industry must be tempered somewhat by the problems afflicting the other base metals; markets characterized by weak prices, excess capacity and high inventories. The major underlying causes for the bullish conditions for lead were:

- record battery demand resulting from the unusually cold winter of 1976-77;
- production disruptions at major producers in North America, Africa, Australia and Europe;
- depressed market conditions for zinc and copper, forcing many mine producers to cut production rates;
- the switch to calcium-lead alloys in battery manufacturing resulted in an increase in demand for soft lead;
- the delay in implementation of the phase-down regulations for lead in gasoline in the United States helped to sustain demand in this sector.

Mine production recovered slightly in 1977 to just over 2.5 million tonnes, a level that is little changed from the early 1970s, but an increase of 5.5 per cent from the strike-reduced level of 1976. Metal production also increased by a similar amount, as did consumption — 5.0 and 5.4 per cent respectively. Metal production and consumption have both recovered to the 1973-74 peak levels, while mine production continues to lag. This has resulted in a tightening of concentrate supplies and a decline in reported producer and London Metal Exchange (LME) stocks from 361 000 tonnes in 1975 to 245 000 tonnes at year-end 1977. Stock movements in 1977 show that producers' inventories declined 6 per cent while LME holdings were static. This draw-down in stocks was aided by a 54 000-tonne net outflow of lead to socialist countries.

Mine production. Mine production of lead was up on every continent except Africa. Canada showed the largest increase in mine output of any country with a jump of 32.8 per cent above the strike-depressed 1976 level. In Europe, most countries maintained production at 1976 levels, while Greece, Ireland, Sweden and Yugoslavia showed substantial gains because of expansions and new producers coming on stream.

In Africa, a decline in production in the Republic of

Table 3. Principal lead mines in Canada, 1977 and (1976)

Company and Location	Mill Capacity	Grade of Ore Milled: Lead	Zinc	Copper	Silver	Ore Milled	Lead Concentrate Produced	Grade of Lead in Concentrate	Contained[1] Lead Produced	Destination of lead Concentrate
	(tonnes/ day)	(%)	(%)	(%)	(g/tonne)	(tonnes)	(tonnes)	(%)	(tonnes)	
Newfoundland										
ASARCO Incorporated,	1 150	6.12	10.76	0.99	107.0	174 180	15 845	55.84	9 820	1,5,7
Buchans Unit, Buchans	(1 150)	(6.03)	(10.69)	(0.96)	(105.6)	(188 694)	(16 547)	(58.16)	(10 830)	(1,5,7)
New Brunswick										
Brunswick Mining and Smelting	8 950	3.12	7.83	0.37	84.8	3 134 419	182 379	31.78	71 432	1
Corporation Limited,	(8 950)	(2.80)	(7.01)	(0.37)	(84.3)	(2 247 212)	(112 110)	(32.90)	(36 884)	(1)
Bathurst							32 252	15.17	Included	5,7
(Also bulk lead-zinc							(132)	(13.94)	above	(stockpiled)
concentrate)										
Heath Steele Mines Limited,	3 650	1.53	3.90	1.22	68.23	1 150 338	32 018	26.74	11 251	1,3,5,6
Newcastle	(3 650)	(1.85)	(4.53)	(0.99)	(77.8)	(1 052 568)	(34 365)	(31.11)	(13 263)	(3,5,6,8)
Nigadoo River Mines Limited,	1 050	2.39	2.54	0.15	85.7	179 459	. .	. .	. .	2
Bathurst	(1 050)	(2.43)	(2.63)	(0.16)	(93.9)	(198 698)	(8 044)	(52.02)	(4 185)	(2)
Quebec										
Louvem Mining Company Inc.,	900	0.16	5.95	0.12	40.5	277 839	889	17.93	183	3
Val d'Or	(1 450)	(. .)	(5.99)	(. .)	(56.2)	(258 534)	(507)	(29.12)	(148)	(3)
Ontario										
Falconbridge Copper Limited,	1 100	1.26	10.44	3.46	206.4	383 885	4 556	32.27	1 470	1
Sturgeon Lake Joint Venture,	(1 100)	(1.23)	(9.57)	(2.15)	(183.8)	(377 257)	(1 663)	(32.95)	(548)	(1,3)
Sturgeon Lake										
Mattabi Mines Limited,	2 700	0.84	8.40	1.01	121.71	938 427	12 488	31.20	5 447	3
Sturgeon Lake	(2 700)	(0.76)	(8.13)	(1.23)	(121.0)	(966 797)	(3 941)	(51.93)	(2 047)	(2)
Noranda Mines Limited,	4 550	0.11	2.62	1.94	41.8	1 591 682	578	60.57	1 067	3
Geco Division,	(4 550)	(0.12)	(2.55)	(1.69)	(44.2)	(1 529 781)	(1 406)	(56.71)	(1 515)	(3)
Manitouwadge										
Texasgulf Canada Ltd.,	9 050	0.22	7.26	1.84	104.0	3 299 033	28 169	11.76	5 134	3
Kidd Creek mine,	(9 050)	(0.30)	(8.05)	(1.73)	(119.7)	(3 242 279)	(35 017)	(12.13)	(6 459)	(3)
Timmins										
Willroy Mines Limited,	1 450	0.14	4.06	0.95	73.0	57 442	. .	. .	. .	2
Manitouwadge Division,	(1 450)	(0.17)	(3.67)	(0.56)	(54.5)	(311 430)	(749)	(34.46)	(237)	(2)
Manitouwadge										

Table 3. (cont'd)

Company and Location	Mill Capacity	Grade of Ore Milled: Lead	Grade of Ore Milled: Zinc	Grade of Ore Milled: Copper	Grade of Ore Milled: Silver	Ore Milled	Lead Concentrate Produced	Grade of Lead in Concentrate	Contained[1] Lead Produced	Destination of lead Concentrate
	(tonnes/ day)	(%)	(%)	(%)	(g/tonne)	(tonnes)	(tonnes)	(%)	(tonnes)	
Manitoba and Saskatchewan										
Hudson Bay Mining and Smelting	7 700	0.2	2.8	2.2	20.6	1 652 535	676	61.4	415	2
Co., Limited,	(7 700)	(0.2)	(2.7)	(2.3)	(20.6)	(1 417 617)	(457)	(69.0)	(315)	(2)
Flin Flon										
British Columbia										
Cominco Ltd.,	9 050	3.8	3.8	—	47.6	2 198 840	106 691	62.8	75 651	2
Sullivan mine,	(9 050)	(4.0)	(3.95)	(—)	(45.9)	(2 124 892)	(109 675)	(62.6)	(77 302)	(2)
Kimberley										
H.B. mine,	1 100	0.67	3.86	—	. .	357 258	4 811	32.2	1 975	2
Salmo	(1 100)	(0.69)	(3.82)	(—)	(. .)	(374 803)	(5 096)	(31.1)	(2 065)	(2)
Northair Mines Ltd.,	250	1.54	2.03	—	126.5	92 167	2 490	46.5	1 218	3
Squamish	(250)	(0.86)	(1.81)	(—)	(111.8)	(47 554)	(876)	(34.7)	(341)	(3)
Silvana Mines Inc.,	100	7.15	6.04	—	594	15 877	1 892	58.65	1 110	2
Silmonac mine,	(100)	(5.3)	(4.86)	(—)	(457.7)	(16 694)	(1 412)	(59.23)	(836)	(2)
Sandon										
Western Mines Limited,	1 000	1 34	7.58	1.14	147.1	269 071	6 446	44.12	3 365	2
Lynx and Myra Falls mines,	(1 000)	(1.42)	(7.73)	(1.19)	(169.4)	(269 294)	(7 240)	(42.92)	(3 586)	(2)
Buttle Lake, V.I.										
Yukon Territory										
Cyprus Anvil Mining	9 050	2.7	4.9	0.17	22.5	3 116 035	100 390	64.11	75 205	4,5,8
Corporation,	(9 050)	(2.66)	(5.48)	(—)	(0.5)	(1 519 880)	(43 421)	(67.28)	(33 070)	(4,5)
Faro										
(Also bulk lead-zinc							36 855	19.12	Included	Included
concentrate)							(24 622)	(15.65)	above	above
United Keno Hill Mines Limited,	450	4.57	1.12	—	1,109	91 486	6 309	49.7	3 137	3
Elsa, Husky, No Cash, Keno	(450)	(4.02)	(1.17)	(—)	(1,216.8)	(68 506)	(3 805)	(59.0)	(2 227)	(3)
mines										
Elsa										

Table 3. (concl'd)

Northwest Territories										
Nanisivik Mines Ltd.,	1 350	1.98	13.27	—	50	495 326	13 789	60.75	8 346	5,6
Baffin Island	(1 350)	(2.9)	(14.5)	(—)	(. .)	(70 760)	(434)	(47.4)	(943)	(stockpiled)
Pine Point Mines Limited,	9 050	2.14	5.29	—	—	2 833 433	78 349	73.49	62 696	2,3,4,5,6,8
Pine Point	(9 050)	(1.70)	(5.30)	(—)	(—)	(3 422 833)	(66 688)	(74.44)	(55 334)	(2,3,4,5,6,8)

Source: Data supplied by companies to Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
[1]Total lead contained in all concentrates. [2]Destination: (1) Brunswick Mining and Smelting Corp.; (2) Cominco Ltd.; (3) U.S.A.; (4) Japan; (5) Germany; (6) Belgium; (7) United Kingdom; (8) Other or unspecified.

Table 4. Prospective Canadian lead producing mines

Company and Location	Year Production Expected	Mill or Mine Capacity	Indicated Ore Reserves	Grade of Ore: Zinc	Grade of Ore: Lead	Grade of Ore: Copper	Grade of Ore: Silver	Remarks
		(tonnes ore/day)	(tonnes)	(%)	(%)	(%)	(g/tonne)	
Nova Scotia								
Imperial Oil Limited, Gays River	1979	1 350	4 780 000	4.23	2.78	—	. .	Decision to proceed announced. Capital cost estimated at $27 million.
Barymin Explorations Limited, Cape Breton	1979	600	1 120 000	—	5.4	—	—	Purchased mill. Awaiting financing arrangements.
Northwest Territories								
Arvik Mines Ltd., Little Cornwallis Is.	1984/5	2 000	22 700 000	14.1	4.1	. .	34	Cominco Ltd. 75% and Bankeno Mines Limited, 25%. Feasibility study completed. Decision on mining depends on negotiations with federal government.

Sources: Company reports and technical press.
— Nil; . . Not available.

South Africa accounted for the 4 per cent fall in production from the continent. In the Americas, production jumped 5 per cent with Canada and Peru being the major positive factors, while output from Mexico and the United States declined. Peru's increase in output was a result of expansion programs at existing producers. Of the Asian and Oceanic countries, Australia showed the largest gain in output, up 6.4 per cent. There were seven mine closures in 1977 which removed about 11 000 tonnes of output from world capacity. Four took place in Canada, (6 000); one each in Greece, (2 000); Kenya, (2 000) and the United States, (1 000). New mines and expansion of existing producers during the year totalled 109 000 tonnes, although full capacity will not be achieved for some until 1978, or until zinc markets recover. The additions and expansions, as reported by the International Lead and Zinc Study Group (ILZSG), were located in Ireland, 45 000 tonnes; Yugoslavia, 18 000; Spain, 13 000; Morocco, 12 000; Sweden, 11 000; Greece, 7 000; Mexico, 2 000 and Bolivia, 1 000. Although net additions to world capacity totalled 98 000 tonnes, it is likely that this was partially offset by declines in output at existing producers. During the 1970s, world mine production has been about 2.5 million tonnes, with only small changes on a year-to-year basis.

Table 5. United States consumption of lead by end-use 1976 and 1977

	1976	1977^p
	(tonnes)	
Storage batteries	746 077	679 799
Gasoline antiknock additives	217 506	211 294
Solder, type metal, terne metal and bearing metals	84 359	58 909
Pigments	95 791	84 597
Ammunition and collapsible tubes	68 771	63 380
Sheet and pipe	34 679	15 067
Cable covering	14 452	13 027
Weights and ballast	20 290	7 590
Caulking	11 317	5 084
Other uses	58 536	39 515
Total reported[1]	1 351 778	1 178 259
Estimated undistributed consumption	–	174 180
Grand Total	1 351 778	1 352 439

Source: United States Bureau of Mines, Mineral Industry Surveys, Lead Industry in February 1978.
[1]Includes lead content of scrap used directly in fabricated products.
^{p}Preliminary; – Nil.

Table 6. Non-communist world mine production of lead, 1976 and 1977

	1976	1977^p
	(000 tonnes)	
United States	565	547
Australia	388	413
Canada	244	328
Mexico	186	160
Peru	160	182
Yugoslavia	110	118
Sweden	80	87
Morocco	67	65
Spain	67	65
Japan	52	55
Ireland	33	42
Iran	40	42
Republic of South Africa	47	41
West Germany	37	39
Greece	27	35
Argentina	33	33
Italy	30	31
Other countries	215	228
Total	2 381	2 511

Sources: For Canada, Statistics Canada; for all other countries, International Lead and Zinc Study Group, Monthly Bulletin, May, 1978.
^{p}Preliminary.

Metal production. Production of both refined primary and secondary lead increased from 3 499 000 tonnes in 1976 to 3 673 000 tonnes in 1977. Brazil, Denmark, Germany, Mexico, Sweden and Yugoslavia all reported output increases of greater than 10 per cent, while Germany and Mexico showed the largest volume increases in output. While strikes at several major producers affected production adversely in the United States and Australia, small overall increases were still reported by both countries. Production in most other countries was similar to year-ago levels.

During 1977 one new primary lead plant was scheduled to come on stream in India with a capacity of 10 000 tonnes per annum but start-up was delayed until February 1978. New secondary capacity which was scheduled to come on stream in 1977 totalled 361 000 tonnes. However, only 144 000 tonnes was actually in place by year-end with the remainder being delayed until 1978 or later. The new capacity was located in Spain, 9 000 tonnes; United Kingdom, 30 000 and the United States, 105 000. There were no plant closures in 1977, resulting in a net addition to world smelter capacity of 154 000 tonnes.

Consumption. Statistics from ILZSG show that consumption increased for the second year in succession to 3.74 million tonnes and surpassed the previous high of

3.67 million tonnes recorded in 1974. Hot summers and severe winters have resulted in strong demand for replacement batteries for automobiles for two successive years and this, coupled with continued strength in new car sales, has spurred demand for lead. The EEC showed a gain in consumption of 5.4 per cent while the United States and Japan showed increases of 8.1 per cent and 6.1 per cent respectively. Only Africa, as a region, showed a decline in consumption.

Uses

Lead has many useful physical and chemical properties and, because of this versatility, it has a variety of industrial applications. It is soft, ductile, alloys readily with other materials, has good corrosion resistance, a high boiling point, a low melting point and a high specific gravity. Lead is one of the oldest metals known to man and since medieval times has been used in piping, building materials, solders, paint, type metal, ammunition and castings.

Lead is used mainly in lead-acid storage batteries, the bulk of which are used for starting, lighting and ignition (SLI) in automobiles and trucks. Recent improvements in battery manufacture have significantly reduced the weight of lead in a battery unit to about 8 kilograms, and increased the average battery life to about three years. New maintenance-free batteries using a calcium-lead alloy instead of lead-antimony reportedly have a service life of five to six years. Usage of lead in the manufacture of all types of batteries is expected to continue to grow at a rate of about 5.0 per cent per annum, and by 1980 to account for 50 per cent of total lead consumption. This growth will come from increased automobile production and from rapid growth in the use of electric-powered industrial trucks (particularly fork-lift vehicles). Many governments in Europe and North America have experimental transportation programs involving battery systems as the power source, replacing the internal combustion engine. A growing market for batteries involves their use for emergency power supply by such institutions as hospitals and for load levelling and peak power shaving in the electric utility industry.

The next most important use of lead is as an antiknock additive in gasoline. This use is declining as it comes under more strict environmental control regulations throughout the world. Lead consumed for batteries and gasoline additives in 1977 accounted for 66 per cent of total lead consumption in the United States. The metal is also used extensively for cable sheathing, collapsible tubes, caulking materials, ammunition, corrosive-liquid containers, galvanizing spelter and leadbase babbitts.

The commercial and residential construction industry is a growing market for lead in such uses as soundproofing, flashing and construction panels. Because of its unique sound-control characteristics there is an expanding use for lead in sound attenuation both as sheets and lead-composition panelling. Composite

Table 7. Non-communist world production[1] of refined lead, 1976 and 1977

	1976	1977[p]
	(000 tonnes)	
United States	1 107	1 110
West Germany	278	307
United Kingdom	252	264
Japan	219	221
Australia	213	222
Canada	176	187
France	172	185
Mexico	173	206
Yugoslavia	114	133
Italy	118	118
Belgium	106	104
Spain	105	116
Brazil	72	80
Peru	73	79
Republic of South Africa	62	67
Other countries	259	274
Total	3 499	3 673

Sources: For Canada, Statistics Canada; for all other countries International Lead and Zinc Study Group, Monthly Bulletin, May, 1978.
[1]Total production by smelters or refineries, or refined pig lead, plus the lead content of antimonial lead — including production on toll in the reporting country — regardless of the type of source material, i.e. whether ores, concentrates, lead bullion, lead alloys, mattes, residues, slag or scrap. Remelted pig lead and remelted antimonial lead are excluded.
[p]Preliminary.

Table 8. Non-communist world consumption[1] of refined lead, 1976 and 1977

	1976	1977[p]
	(000 tonnes)	
United States	1 269	1 372
West Germany	241	283
Italy	265	274
Japan	230	244
United Kingdom	246	241
France	207	190
Spain	117	120
Belgium	70	91
Mexico	81	88
Brazil	81	85
Yugoslavia	77	85
Other countries	664	668
Total	3 548	3 741

Source: International Lead and Zinc Study Group, Monthly Bulletin, May, 1978.
[1]Consumption of those types of metal as reported under production in Table 7.
[p]Preliminary.

Table 9. Canada, lead production and consumption 1974-1980, 1985

	1974	1975	1976	1977	1978f	1979f	1980f	1985f
				(000 tonnes)				
Mine Production	301	353	244	328	330	335	340	380
Primary Metal Production	126	172	176	187	190	190	195	215
Consumption[1]	105	89	108	111	105	110	115	130

Source: Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
[1] Includes consumption of secondary lead.
f Forecast.

thermal-acoustical panels are now being used to contain the noise from industrial plants. Terne steel, steel sheeting coated with an alloy containing 85 per cent lead, combines lead's corrosion resistance and sound-barrier properties with the strength of steel, and is now available for many building applications. In the allied field of vibration isolation, lead-asbestos or lead-synthetic rubber antivibration pads are now being widely used in foundations for office buildings, and in hotel and apartments exposed to severe vibration from nearby heavy traffic. Because of its sound-control qualities, lead is also used in the mounting of various types of equipment, including airconditioning systems, heavy industrial equipment and commercial laundry machines.

The use of lead chromate paints on highways for pavement marking is growing because it is the most versatile low-cost pigment available for traffic-control paints. Corrosion-resistant lead silico chromate or pre-mixed red lead/iron oxide paint is a standard primer for iron and steel structures.

Miscellaneous uses for lead include glassware, automotive wheel weights, ship ballast, various alloys and as lead-ferrite for permanent magnets in small electric motors. Relatively new and growing areas of use are for radiation shielding in nuclear-powered reactors, nuclear-powered ships and submarines, and shipping casks for transporting radio-active materials. Continuing research has developed new and promising markets for organometallic lead compounds in such applications as anti-fouling paints, wood and cotton preservatives, lubricant-oil additives, polymethane foam catalysts, molluscides, antibacterial agents and rodent repellents.

Refined lead is marketed in several grades that vary mainly according to the content of impurities, including silver, copper, arsenic, antimony, tin, zinc, iron and bismuth. The three principal grades are corroding, chemical and common desilverized lead. The corroding grade (soft lead) has the highest purity and is used chiefly in the manufacture of pigments, battery oxides and tetraethyl lead. Common lead is used mostly in industrial and home construction, while chemical lead possesses superior creep and corrosion resistance and is ideally suited for cable sheathing.

Prices

Prices for lead metal established new highs in 1977, the result of supply shortages and increased physical demand.

The Canadian producer price of virgin lead, delivered in car lots, increased 31 per cent during the year from a monthly average of 26.2 cents a pound in January to 34.2 cents a pound in December. There were seven price increases culminating in a year-end quotation of 35.25 cents a pound.

The United States producer price of virgin lead, delivered, followed the same pattern as in Canada and increased from a price of 25.5 cents a pound at the beginning of the year to 33 cents a pound in December.

The London Metal Exchange (LME) spot price, under the influence of strong east European demand early in the first quarter, established a new high of £438 a tonne (34.1 cents a pound U.S.). Subsequent trading was more subdued and the price in the balance of the year declined gradually to £356 a tonne, equivalent to 30.7 cents (U.S.) a pound at year-end.

Outlook

Information released by the ILZSG shows new lead mine capacity coming on stream in 1978 totalling 47 000 tonnes, less than a 2 per cent increase over 1977 output. The new capacity is located in Australia, 23 000 tonnes; Iran, 18 000 tonnes; Algeria, 4 000 tonnes and Canada, 2 000 tonnes. The largest project in this group is the $90 million (U.S.) Woodlawn property in Australia, being developed by Australian Mining & Smelting Ltd., St. Joe Minerals Corporation and Phelps Dodge Corporation, each with a one-third interest.

In 1979 new capacity scheduled for start-up totals 56 000 tonnes with the following breakdown: Spain, 28 000; Ireland, 12 000; Canada, 10 000; Guatemala, 3 000 and Yugoslavia, 3 000. The largest project is Aznalcollar in Spain with an expected capacity of 23 000 tonnes. This open-pit project is being developed by Andaluza de Piritas Espanola at a cost of $130 million (U.S.).

Development scheduled for 1980 totals 130 000 tonnes, with the Broken Hill project in South Africa of

Table 10. Lead metal prices, 1976, 1977

Month	London Metal Exchange Spot £ per tonne	United States Domestic delivered price ¢ per pound	Canada Delivered carlots ¢ per pound
January	326.2	26.9	26.2
February	378.3	28.7	28.4
March	409.1	31.0	30.5
April	377.3	31.0	31.0
May	384.4	31.0	31.0
June	330.0	31.0	32.3
July	325.8	31.0	32.3
August	316.5	31.0	32.3
September	334.1	31.0	32.3
October	347.3	31.0	32.3
November	348.4	32.0	33.2
December	369.5	32.8	34.2
1977 Average	353.9	30.7	31.3
1976 Average	250.1	23.1	22.6

Source: International Lead Zinc Study Group Bulletin.

90 000 tonnes capacity accounting for most of the increase. This project, being developed jointly by Phelps Dodge Corporation and Gold Fields of South Africa Ltd. at a cost of $191 million (U.S.), will be one of the world's largest producers of lead when it comes on stream. Other developments are located in Mexico, 17 000; India, 15 000; Japan, 4 000 and Spain, 4 000.

Even with the above developments, mine production in 1980 is expected to show only a modest increase from the 1977 level. Most of the additions to capacity during the period will be offset by decreases in production from existing producers because of lower-grade ore and some closures.

The forecast for 1978 (Table 12) indicates a small shortfall on the supply side as concentrates are expected to remain in short supply because of mine cutbacks forced by weak zinc markets. The 1978 to 1980 period will see little change from these conditions, although by the end of the period the system should be close to a balance. Supply problems exist in the secondary industry, where the emphasis on increased output of soft lead, necessitated by the switch to calcium-lead alloys in SLI batteries, may result in this sector not being able to maintain its traditional share of the market. This problem will be largely resolved by 1985 as existing facilities and new capacity are adapted to the production of soft lead.

Consumption is expected to grow modestly in the 1978-85 period at 2 per cent a year, and even at this rate it is expected that supply will have difficulty in meeting demand. The projected tight supply conditions may preclude any substantial purchases for national stockpiles. Primary refined smelting capacity in the western world is currently estimated at about 3.3 million tonnes, and concentrate availability is expected to be at approximately 80 to 85 per cent of this level. The transportation sector is expected to show continued strong growth as increases resulting from battery use will more than offset the expected decline in the use of lead additives in gasoline. Inventories are below normal now and are expected to remain in the low-to-normal range during the 1978 to 1985 period.

Table 11. Location of new or expanded smelter capacity

Expected Start-up Year	Country	Company	Location	Type of Plant	Additional Capacity	Remarks
					(tonnes/ year)	
1978	Brazil	Tonolli	Jacarei	Secondary	40 000	New plant, delayed from 1977.
	Italy	Ammi	San Gavino	Refinery	20 000	Expansion of 30 000-tonne plant.
	United States	Schuylkill Metals	Mound City, Mo.	Secondary	30 000	New plant, delayed from 1977.
1979	Nigeria	Nigerian Smelting & Refining	—	Secondary	5 000	New plant, delayed from 1977.
	Turkey	Cinkur/Etibank	Kayseri	Smelter	6 000	New plant, delayed from 1976.
1980	Brazil	Cobrac	Santo Amaro	Lead plant	13 000	Expansion of existing 32 000-tonne plant.
	United States	NL Industries	Los Angeles, Cal.	Secondary	65 000	Expansion of existing 35 000-tonne plant.

Sources: International Lead and Zinc Study Group; technical press.
— Not available.

Table 12. Apparent Western World lead balance, 1976 to 1980; 1985

	1976	1977	1978	1979	1980	1985
			(000 tonnes)			
Supply						
Mine Production	2 383	2 511	2 510	2 515	2 595	2 850
Losses net of secondary supply	−71	−75	−75	−75	−78	−86
Metal equivalent of mine production	2 312	2 436	2 435	2 440	2 517	2 764
Estimated secondary supply	1 150	1 200	1 250	1 250	1 300	1 550
Total supply	3 462	3 636	3 685	3 690	3 817	4 319
Demand						
Metal consumption	3 548	3 741	3 700	3 765	3 840	4 240
Net exports to socialist countries	+71	+54	+50	+50	+20	–
Total demand	3 619	3 795	3 750	3 815	3 860	4 240
Surplus (deficit)	(157)	(159)	(65)	(125)	(43)	79
Reported Inventories[1]	471	460	420	360	320	450

Sources: Mineral Policy Sector, Department of Energy, Mines and Resources; International Lead and Zinc Study Groups.
[1]Inventories do not enter into the balance calculation as coverage of commercial stocks is incomplete.

Tariffs

Canada

Item No.		G.S.P.[1]	British Preferential	Most Favoured Nation	General
32900-1	Ores of lead	Free	Free	Free	Free
33700-1	Lead, old scrap, pig and block	Free	Free	Free	1¢ per lb
33800-1	Lead, in bars and in sheets	3%	5%	5%	25%
33900-1	Manufactures of lead, n.o.p.	11½%	17½%	17½%	30%

United States

U.S.T.S.	No. Effective Nov. 21, 1975	G.S.P.	Most Favoured Nation (¢/lb on lead content)	
602.10	All lead-bearing ore	Free	0.75	
Unwrought				
624.02	Lead bullion	Free	1.0625	
624.03	Other		1.0625	
624.04	Lead waste and scrap	Free	1.0625	(on 99.6% of lead content)

European Economic Community (EEC)

BTN No.		G.S.P.	Most Favoured Nation
26.01	Lead ore and concentrates	Free	Free
78.01	Unwrought lead: For refining		
	(i.e. argentiferous)	Free	Free
	Other	4.5%	4.5%
	Lead waste and scrap	Free	Free

Japan

BTN No.		G.S.P.	Most Favoured Nation
26.01	Lead ore and concentrates	Free	Free
78.01	Unwrought lead		
	Unalloyed	Free	7.5%[2]
	Alloyed	Free	7% to 12%[2]
	Lead waste and scrap	Free	5%[2]

Sources: For Canada, the Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1978), TC Publication 843. For Japan, Customs Tariff Schedules of Japan, 1976, Japan Tariff Association. For EEC, Official Journal of the European Communities, Vol. 19, No. L314, 1976.

[1]GSP-Generalized System of Preferences extended to all, or most, developing countries; some GSP rates are subject to quotas or withdrawals. [2]Subject to a temporary reduction of 20 per cent.

Lime

D.H. STONEHOUSE

Carbonate rocks are basic to industry. They form about 15 per cent of the earth's crust and fortunately are widely distributed and easily exploitable. The principal carbonate rocks utilized by industry are limestones — sedimentary rocks composed mainly of the mineral calcite ($CaCO_3$) — and dolomites — sedimentary rocks composed mainly of the mineral dolomite ($CaCO_3 \cdot MgCO_3$). Commonly termed limestones, they can be classified according to their content of calcite and dolomite. Their importance to the construction industry is not only as building stone and aggregate, but as the primary material in the manufacture of portland cement and lime. Limestones are also used as flux material, in glass manufacture, as refractories, fillers, abrasives, soil conditioners and in the manufacture of a host of chemicals.

Quicklime (CaO or $CaO \cdot MgO$) is formed by the process of calcination, in which limestones are heated to the dissociation temperature of the carbonates (as low as 402°C for $MgCO_3$ and as high as 898°C for $CaCO_3$) and held at that temperature over sufficient time to release carbon dioxide. Although the word "lime" is used generally, and wrongly, to refer to pulverized limestone as well as to forms of burned lime, it should refer only to calcined limestone (quicklime) and its secondary products, slaked lime and hydrated lime. Slaked lime is the product of mixing quicklime and water, hydrated lime is slaked lime dried and, possibly, reground.

Calcining is done in kilns of various types, but essentially those of vertical or rotary design are used, having had many adaptations to the standard designs incorporated into them over the years. Of comparatively recent design are the rotary hearth, travelling grate, fluo-solid and inclined vibratory types. The high cost of energy has made it imperative to include preheating facilities in any new plant design, and environmental regulations have necessitated the incorporation of dust-collection equipment.

Canadian industry and developments

Lime plants have been established near urban and industrial centres in Canada where large reserves of suitable limestone are available and where most of the major consumers of lime are situated. Lime is a high-bulk, low-cost commodity and it is uncommon to ship it long distances when the raw material for its manufacture is available in so many localities. The more heavily populated and industrialized provinces of Ontario and Quebec together produced over 80 per cent of Canada's total lime output in 1977, with Ontario contributing about one-half of Canada's total. Commercial lime (lime that is normally produced for shipment and use off the producing plant site) was not produced in 1977 in Nova Scotia, Prince Edward Island, Newfoundland or Saskatchewan; the needs in each of these provinces being supplied from plants in neighbouring provinces or states.

During 1977, 18 companies operated a total of 24 lime plants in Canada: one in New Brunswick, four in Quebec, ten in Ontario, three in Manitoba, four in Alberta and two in British Columbia. A total of 84 kilns was available: 31 rotary, 49 vertical, one vibratory grate and three rotary grate. Preliminary returns indicate that lime production in 1977 was maintained close to the 1976 level despite poor performances by both the steel and pulp and paper industries, each of which are major consumers of lime. Production figures do not include some captive production such as that from pulp and paper plants that burn sludge to recover lime for re-use in the causticization process.

With the addition of some new and larger capacity over the last two or three years, most of which has come on stream by now, the industry could produce between 10 000 and 12 000 tonnes* a day or about 3.5 million tonnes a year.

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*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

During 1977 Domtar Chemicals Limited, Lime Division, continued the installation of a third rotary kiln at its Joliette, Que. plant. The new kiln, when operative early in 1978, will increase plant capacity by 400 tonnes a day. BeachviLime Limited began to run in its new second rotary kiln at the company's Beachville plant in late 1977.

Early in February 1977, Gulf Oil Canada Limited announced it would close its 75-year-old calcium carbide and acetylene black plant at Shawinigan, Que., with shut-down scheduled for early 1978. Competition from new, high-volume operations in other parts of the world which are coming on stream with the latest available technology was cited as the reason for the company decision. The company has marketed calcium hydroxide, produced as a byproduct of the Shawinigan operation. Federal aid from the Departments of Regional Economic Expansion (DREE) and Industry, Trade and Commerce (ITC), along with provincial government aid to modernize the company's chemical plant, was accepted, and continued operation of the plant now seems assured.

As part of the Industrial Minerals Sector Task Force on energy conservation, the lime industry has itself made significant improvements, recording a decrease of some 11 per cent in energy consumption per unit of output 1974 to 1976.

Atlantic provinces. In 1968 at Aguathuna, near Stephenville on the west coast of Newfoundland, Sea Mining Corporation Limited constructed a new plant designed to produce magnesium hydroxide from seawater. Although the plant never operated commercially, a rotary kiln, which was installed to produce lime

Table 1. Canada, lime production and trade, 1976-77

	1976		1977p	
	(tonnes)	($)	(tonnes)	($)
Production[1]				
By type				
Quicklime	1 703 371		1 685 000	
Hydrated Lime	227 017		194 000	
Total	1 930 388	61 670 000	1 879 000	60 866 000
By province				
Ontario	1 202 118	37 021 000	1 244 000	38 401 000
Quebec	405 387	13 155 000	326 000	11 129 000
Alberta	137 526	4 684 000	130 000	4 663 000
Manitoba	. .	3 033 000	. .	2 647 000
New Brunswick	. .	1 907 000	. .	2 137 000
British Columbia	59 137	1 870 000	59 000	1 889 000
Total	1 930 388	61 670 000	1 879 000	60 866 000
Imports				
Quick and hydrated				
United States	36 842	1 431 000	21 950	1 298 000
Belgium-Luxembourg	—	—	2 497	124 000
France	40	13 000	34	30 000
Total	36 882	1 444 000	24 481	1 452 000
Exports				
Quick and hydrated				
United States	309 332	10 167 000	359 366	13 656 000
Bermuda	—	—	51	6 000
Other countries	—	—	129	12 000
Total	309 332	10 167 000	359 546	13 674 000

Source: Statistics Canada.
[1]Producers' shipments and quantities used by producers.
pPreliminary; — Nil; . . Not available.

Table 2. Canada, lime production, trade and apparent consumption, 1960, 1965, 1970, 1975-77

	Production[1]					Apparent
	Quick	Hydrated	Total	Imports	Exports	Consumption[2]
	(tonnes)					
1960	1 100 956	286 644	1 387 600	30 681	19 657	1 398 624
1965	1 215 978	254 028	1 470 006	22 983	217 120	1 275 869
1970	1 296 590	224 026	1 520 616	30 649	181 994	1 369 271
1975	1 533 944	199 195	1 733 139^r	30 099	234 034	1 529 204^r
1976	1 703 371	227 017	1 930 388	36 882	309 332	1 657 938
1977^p	1 685 000	194 000	1 879 000	24 481	359 546	1 543 935

Source: Statistics Canada.
[1]Producers' shipments and quantities used by producers. [2]Production plus imports less exports.
^{r} Revised; ^{p}Preliminary.

for captive use in the extraction process, was put into service during 1969 and 1970 to supply some quicklime for waste-neutralization application on the island's east coast. This market is now supplied by Quebec-based lime producers. The plant has not been dismantled.

Havelock Processing Ltd. began production of a high-calcium quicklime early in 1971 utilizing a newly installed, 90-tonne-a-day rotary kiln at the company's quarry site at Havelock, New Brunswick. Markets currently include mineral processing operations, pulp and paper industries, mainly within the province, and a growing export trade. Havelock Lime Works Ltd. operates the company's crushed limestone plant which has been expanded to offer a range of products from coarse aggregate, through washed and screened sizes for asphalt and concrete to finely pulverized filler material.

Periodically during the last few years the possibility of establishing a lime producer in the northeast region of New Brunswick has been investigated. Limestone in sufficient quantity and of acceptable quality has been proved in the Elm Tree area, but, although market projections indicate an increasing demand for lime in the mining and pulp and paper industries in this area, the amount, in total, does not yet appear to warrant a second plant within the province.

Studies have been made to determine the viability of a lime-manufacturing plant in Nova Scotia associated with existing and planned steel-producing facilities. Limestone and dolomite for the Sydney steel plant currently come from Irish Cove and Frenchvale, N.S. respectively.

Quebec. At Joliette, Domtar Chemicals Limited, Lime Division, produces quicklime and hydrated lime from a high-calcium Trenton limestone for the steel and pulp and paper industries. Plans to increase the output capacity of the Joliette plant have been completed and a new kiln which will double the plant capacity should be operative during 1978. Shipments are made to Atlantic consumers as well as to Quebec and Ontario.

Domlin Inc. produces high-calcium quicklime and hydrated lime from Silurian limestone at Lime Ridge, near Sherbrooke. Additional production capacity resulted from activation of a new rotary kiln during 1973. Markets include steel, pulp and paper, construction, and agricultural industries.

A high-calcium Ordovician limestone of the Beekmantown Formation has been mined for many years by Shawinigan Chemicals Division of Gulf Oil Canada Limited, near Bedford, for use in the company's carbide plant at Shawinigan. The quality of the limestone makes it a highly acceptable material for the production of calcium carbide. Hydrated lime made during calcium carbide-acetylene manufacture is sold for commercial use. Plans to close the Shawinigan plant during 1978 have been curtailed following provincial and federal offers of financial aid to modernize the operation.

Ontario. Domtar Chemicals Limited, Lime Division, operates a limestone quarry and a lime plant at Beachville. The high-calcium limestone is mined, crushed, screened and used primarily as feed to the lime plant, which has both vertical and rotary kilns. At Hespeler, Domtar produces lime, crushed stone and agricultural limestone. The lime plant has vertical kilns and produces high-quality, white quicklime. Both plants also produce hydrated lime.

BeachviLime Limited, a wholly-owned subsidiary of Dominion Foundries and Steel, Limited (Dofasco) of Hamilton, purchased the Beachville, Ontario plant of Cyanamid of Canada, Limited in 1973. The plant at that time included one rotary kiln and one calcimatic kiln.

Major renovations undertaken immediately following take-over increased the plant's lime-producing capability in order to supply increased demands for lime by Dofasco's basic oxygen furnaces and to supply

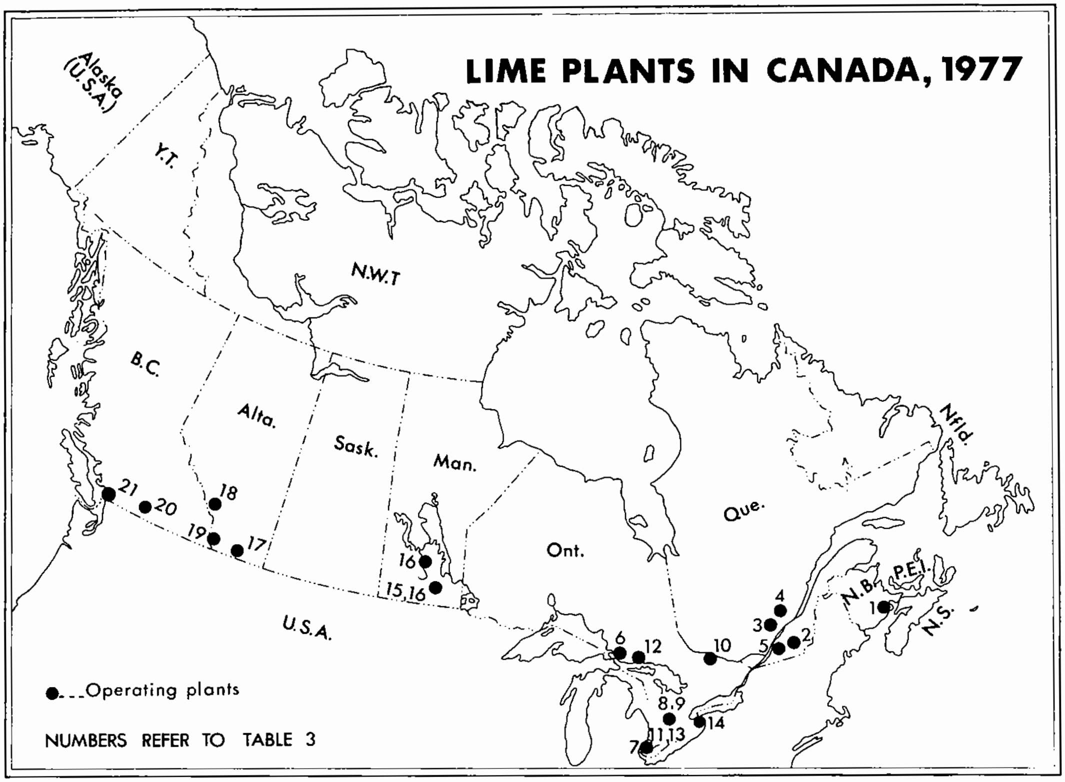

Table 3. Canadian lime industry, 1977

Company	Plant Location	Type of Quicklime
(Numbers refer to numbers on map above)		
New Brunswick		
1. Havelock Processing Ltd.	Havelock	High-calcium
Quebec		
2. Domlin Inc.	Lime Ridge	High-calcium[2]
3. Domtar Chemicals Limited	Joliette	High-calcium[2]
4. Gulf Oil Canada Limited Shawinigan Chemical Division	Shawinigan	High-calcium[2]
5. Quebec Sugar Refinery[1]	St-Hilaire	High-calcium
Ontario		
6. The Algoma Steel Corporation, Limited[1]	Sault Ste. Marie	High-calcium
7. Allied Chemical Canada, Ltd.[1]	Amherstburg	High-calcium
8. BeachviLime Limited	Beachville	High-calcium
9. Canadian Gypsum Company, Limited[3]	Guelph	Dolomitic[2]
10. Chromasco Limited[1]	Haley	Dolomitic
11. Domtar Chemicals Limited	Beachville	High-calcium[2]
	Hespeler	Dolomitic[2]
12. Reiss Lime Company of Canada, Limited	Spragge	High-calcium
13. The Steel Company of Canada, Limited (Stelco)	Ingersoll	High-calcium[2]
14. Steetley of Canada (Holdings) Limited	Dundas	Dolomitic

Table 3. (concl'd)

Company	Plant Location	Type of Quicklime
Manitoba		
15. The Manitoba Sugar Company, Limited[1]	Fort Garry	High-calcium
16. Steel Brothers Canada Ltd.	Faulkner	High-calcium
	Fort Whyte	High-calcium
Alberta		
17. Canadian Sugar Factories Limited[1]	Taber	High-calcium
	Picture Butte	High-calcium
18. Steel Brothers Canada Ltd.	Kananaskis	High-calcium
19. Summit Lime Works Limited	Hazell	High-calcium and Dolomitic
British Columbia		
20. Steel Brothers Canada Ltd.	Kamloops	High-calcium
21. Columbia Lime Products Limited	Fort Langley	High-calcium

Source: Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
[1]Production for captive use. [2]Hydrated lime produced also. [3]Purchased by Guelph DoLime Limited, February 1978.

other, non-captive, markets. A second rotary kiln was brought on stream late in 1977. On February 28, 1978 Dofasco purchased, through Guelph DoLime Limited, a subsidiary of BeachviLime, the dolomite quarry and lime plant of Canadian Gypsum Company, Limited at Guelph. This acquisition will provide Dofasco with a controlled source of dolomitic limestone and lime.

Limestone for use as open-hearth and blast-furnace flux, for portland cement manufacture and as a pulverized stone is also produced at Beachville.

Through a subsidiary, Chemical Lime Limited, The Steel Company of Canada, Limited, Hamilton, is supplied with flux stone and high-calcium lime from a quarry and lime plant near Ingersoll. Vertical kilns were installed at the lime plant in 1959. A new rotary kiln of 300-tonne-a-day capacity was installed in 1971 to supply projected requirements of the company's steel-manufacturing facilities at the Hilton Works.

Near Amherstburg, Allied Chemical Canada, Ltd. mines a high-calcium limestone for the production of lime which is used, along with salt from a nearby brine field, in the manufacture of soda ash. Canadian Gypsum Company, Limited produces a dolomitic lime near Guelph.

Early in 1969, Reiss Lime Company of Canada, Limited began construction of docking facilities on Lake Huron, just west of Spragge, to import limestone from the Rogers City area in Michigan for the manufacture of lime to be used in uranium processing. Production of high-calcium lime began in mid-1970 at an initial capacity of 60 000 tonnes a year. The company is owned by Denison Mines Limited and C. Reiss Coal Co., Wisconsin, U.S.A.

At Dundas, Steetley of Canada (Holdings) Limited produces metallurgical-grade dolomitic lime and dead-burned dolomite from three rotary kilns, mainly for steel industry uses. The company also produces flux stone, crushed stone products and agricultural "lime".

Western provinces.

In 1977, Steel Brothers Canada Ltd. operated limestone quarries at Spearhill and Faulkner in Manitoba, at Kananaskis, Alberta and at Pavilion Lake in British Columbia. The Spearhill lime plant, from which a white, high-calcium lime was produced, was phased out during 1976 following start-up of a new preheater kiln at Faulkner in June. The new plant, a duplicate of the Pavilion Lake plant which went on stream in early 1975, is capable of producing over 300 mtpd, is coal-fired with oil back-up and has been run in at full capacity with comparatively few start-up problems. Stone from the Faulkner quarry is trucked to the company's Fort Whyte plant where a vibratory grate calciner is used in lime manufacture. Quicklime is supplied to chemical, metallurgical and construction industries as well as to a growing market in the waste treatment field. Limestone is supplied to The Manitoba Sugar Company, Limited from the Manitoba quarries.

The limestone quarry at Kananaskis is about 10 kilometres (km) west of the lime plant and provides kiln feed for the production of quicklime and hydrated lime. A second rotary kiln went on stream early in 1972, doubling the production capacity of the plant. The subsequent installation of a preheater system has substantially reduced the unit energy consumption of the plant.

Table 4. Canada, consumption of lime, quick and hydrated, 1975-76 (producers' shipments and quantities used by producers, by use)

	1975		1976^p	
	(tonnes)	($000)	(tonnes)	($000)
Chemical and metallurgical				
Iron and steel plants	582 748	15 152	650 774	19 290
Pulp mills	198 238	6 145	208 483	7 320
Uranium plants	56 168	1 437	84 673	2 732
Water and sewage treatment	77 638	2 201	76 570	2 551
Nonferrous smelters	79 051	2 516	73 660	2 473
Cyanide and flotation mills	72 758	1 884	50 548	1 454
Sugar refineries	30 928	883	38 362	1 212
Other industrial[1]	542 466	14 020	648 953	20 712
Construction				
Finishing lime	24 067	1 406	22 193	1 373
Mason's lime	29 368	1 040	24 948	1 067
Sand-lime brick	11 874	284	16 950	461
Agricultural	11 248	438	11 166	469
Road stabilization	8 463	272	6 841	241
Other uses	8 124	237	16 267	315
Total	1 733 139	47 915	1 930 388	61 670

Source: Statistics Canada.
[1]Includes glass works, fertilizer plants, tanneries and other miscellaneous industrial uses.
^{p} Preliminary.

The new rotary kiln plant at Pavilion Lake, about 24 km west of Cache Creek went on stream in early 1975. It is equipped with the latest preheater design and is capable of producing approximately 300 tonnes a day of high-calcium lime for the mining and forestry industries in the British Columbia interior.

Summit Lime Works Limited, near Crowsnest, produces high-calcium limestone for use at sugar refineries; dolomitic and high-calcium stone for metallurgical use and high-calcium quicklime and hydrated lime for the chemical, metallurgical and construction industries.

During 1971, Texada Lime Ltd. constructed a calcimatic-kiln lime plant at Fort Langley, British Columbia capable of producing up to 200 tonnes a day. Limestone is barged from Texada Island, and the product — a high-calcium quicklime — is marketed throughout the mining and pulp and paper-producing regions of British Columbia. The plant went on stream in February 1972. MacDonald Consultants Ltd. of Vancouver, in partnership with M C Q Industries of Columbus, Ohio, were responsible for the design and development of the project. In late 1973 Texada Lime Ltd. was sold to Columbia Lime Products Limited.

Markets, outlook and trade

The metallurgical industry provides the largest single market for lime. With increased application of the basic oxygen furnace (BOF) in the steel industry, lime consumption increased greatly in certain areas of the United States and Canada. An expected increase in the demand for steel will result in the need for more fluxing lime and will encourage the development of captive sources by steel producers. The pulp and paper industry is the second-largest consumer of lime, most of which is used in the preparation of digesting liquor and in pulp bleaching. Any reduction of activity in either of these two industry segments, brought on by strikes or lack of product demand, can have immediate and serious effect on the lime industry, at least regionally.

The uranium industry uses lime to control hydrogen-ion concentration during uranium extraction, to recover sodium carbonate and to neutralize waste sludge. In the production of beet sugar, lime is used to precipitate impurities from the sucrate. It is used also in the manufacture of many materials such as calcium carbide, calcium cyanamide, calcium chloride, fertilizers, insecticides, fungicides, pigments, glue, acetylene, precipitated calcium carbonate, calcium hydroxide, calcium sulphate, magnesia and magnesium metal.

The rapidly-growing concern for the safeguarding and treatment of water supplies and the appeal for enforced antipollution measures should result in greater use of lime for water and sewage treatment.

Table 5. World production of quicklime and hydrated lime, including dead-burned dolomite sold and used, 1976-77

Country	1976[p]	1977[e]
	(thousand tonnes)	
U.S.S.R.	23 000[e]	. .
United States	18 351	17 962
West Germany	9 623	9 707
Japan	9 176	9 525
Poland	8 110	. .
France	4 776	4 899
Romania	3 000[e]	. .
East Germany	3 000[e]	. .
Czechoslovakia	3 000	. .
Belgium	2 304	2 449
Brazil	2 000[e]	2 268
Italy	1 925	1 996
Canada	1 930	1 879
Yugoslavia	1 900[e]	. .
Other countries	13 816	56 155
Total	105 911	106 840

Sources: U.S. Bureau of Mines, Mineral Commodity Summaries, January 1978. U.S. Bureau of Mines, Mineral Trade Notes, Vol. 75, No. 2. Statistics Canada.
[p]Preliminary; [e]Estimated; . . Included in other countries.

The removal of SO_2 from hydrocarbon fuels, either during the burning procedure, or from stack gases by either wet or dry scrubbing, could necessitate the use of lime and develop a major market for this commodity as SO_2 emission regulations are developed. Lime is effective, inexpensive, and can be regenerated in systems where the economics would so dictate. The creation of large amounts of gypsum waste sludge during SO_2 removal will present a disposal problem. Paradoxically, the lime industry is itself caught up in the clean-up campaigns sponsored by various levels of government, particularly those efforts directed at dust removal.

Soil stabilization, especially for highways, offers a potential market for lime. However, not all soils have the physical and chemical characteristics to react properly with lime to provide a dry, impervious, cemented and stable roadbed. Hydrated lime added to asphalt hot-mix prevents the asphalt from stripping from the aggregate. This could become more important as new technologies relating to asphalt maintenance and repair are adopted and as the sources of good clean aggregate become scarce.

The use of lime-silica bricks, blocks, and slabs has not been popular in Canada as in European countries, although lighweight, cellular, insulating masonry forms have many features attractive to the building construction industry.

Although quicklime and hydrated lime are not of relatively high monetary value, they are transported considerable distances in bulk or in packages if a market exists. Freight costs can represent a large part of the consumer's cost. Production costs have increased significantly as a result of higher energy costs. The industry, on average, uses about 1 530 kilocalories per kilogram of production. New plans have incorporated preheater systems, and the need to replace some of the older, less-efficient production capacity with fuel-conserving equipment is well recognized. The industry is aiming at a 14 per cent improvement in fuel utilization by 1980 over the base year 1973.

Limestones are well distributed in Canada, but it does not necessarily follow that a lime-consuming industry will produce lime for captive use — lime producers will usually offer competitive prices. Nevertheless, some major users do produce lime for their own use and, especially in the United States in recent years, iron and steel producers have integrated backwards into lime manufacture. The complexities and inconsistencies of lime production and marketing are illustrated by the fact that Domtar, a Canadian company, operates a lime plant in Tacoma, Washington and in 1975 purchased a lime plant at Bellefonte, Pennsylvania from National Gypsum Company.

Canada is a net exporter of lime.

Prices

Quoted prices for both quicklime and hydrate vary greatly throughout the country, reflecting the costs of production and the influence of nearest competition. In Ontario, prices for quicklime and hydrated lime were quoted as $27.60 and $28.10 respectively, bulk, fob works, carload lots, per short ton, during the first quarter of 1976 and had risen to $29.35 and $29.85 by the fourth quarter. *Canadian Chemical Processing* quoted $32.14 and $31.23 in 1977.

Canadian lime prices quoted in "Canadian Chemical Processing" of December 1977

Lime, carloads, fob works, bulk, per short ton

Ontario, quicklime — $32.14
Ontario, hydrated — $31.23

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
29010-1	Lime	free	free	25%	free

United States

Item No.		
512.11	Lime, hydrated	free
512.14	Lime, other	free

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa; Tariff Schedules of the United States Annotated (1978), TC Publication 843.

Magnesium

D. PEARSON

Magnesium is found in naturally occurring minerals such as dolomite, magnesite, brucite and olivine; in seawater, brines and evaporite deposits as magnesium chloride. It is consumed mostly in the form of non-metallic compounds, principally magnesium refractories. About 10 per cent of consumption, on a magnesium-content basis, is used as metal.

Primary magnesium is produced by two basic processes. The first is by electrolysis of magnesium chloride derived from seawater and brines. The second is by reduction of magnesium ore, such as dolomite or magnesite, by ferrosilicon (Pidgeon process). Canadian production is by the latter method, which is more suitable for smaller plants. The electrolytic method has risen to prominence because of large-scale plants utilizing low-cost electric power. Power requirements to produce magnesium electrolytically are 8 to 9 kWh a pound, considerably higher than for the silicothermic process, even including production of the ferrosilicon.

Canada

Chromasco Limited is the only Canadian producer of primary magnesium. This company has operated a mine and smelter at Haley, Ontario, 80 kilometres west of Ottawa since 1942.

A high-quality (98% pure) dolomite, low in impurities such as silica and the alkali metals, is mined from an open pit and calcined. The calcined material, "dolime" is mixed with ferrosilicon and charged in batches into retorts, which are heated by natural gas. Under vacuum and at high temperature, the magnesium content is reduced and accumulated as crystalline rings known as "crowns" in the water-cooled head sections of the retorts. The plant has an annual capacity of 10 800 tonnes* of magnesium metal. It operated well below this capacity in 1977. Part of the furnace capacity of the plant is used to produce calcium and strontium.

The company produces ingots of magnesium metal in the following grades and purities: commercial 99.90 per cent; high purity, 99.95 per cent; and refined, 99.98 per cent. Magnesium alloys are produced to all specifications. Other magnesium products include master alloys, rods, bars, wire and structural shapes. The Pidgeon process is particularly suited for production of the purer forms.

To produce commercial-grade magnesium, the crowns are simply remelted and cast into ingots. This grade is suitable for general fabrication purposes and for alloying with aluminum, and represents the major proportion of production. The high-purity grade is mostly used for the formation of Grignard reagents (alkyl-magnesium-halides, which react to form a variety of organic and inorganic compounds). The refined grade is in demand for chemical laboratory use and as a reducing agent for titanium, zirconium, uranium and beryllium.

Production of magnesium in 1977 was 7 580 tonnes valued at $17 644 000 compared with 6 092 tonnes in 1976 with a value of $12 825 000. Domestic consumption of magnesium increased to 6 222 tonnes whilst in 1976, 4 230 tonnes were consumed. Alloying with aluminium was the principal use.

Canada's trade of magnesium metal and alloys increased in 1977. Imports were 2 199 tonnes in 1977 compared with 1 812 tonnes in 1976. These came mainly from the United States. Exports increased 33 per cent over that of 1976. Of the 4 320 tonnes exported in 1977, 75 per cent went to European countries including the United Kingdom. Exports of magnesium metal to the United States in 1977 remained at about the same level as the preceding year. Canada continued to operate at a disadvantage in that, the import tariff into the United States is 20% whereas the comparable Canadian tariff is only 5%. Certain highly pure items are the only Canadian products to find a market in the United States except under the Defense Production Sharing Program. This program has been on a small scale in recent years.

Two projects that could increase Canada's magnesium capacity were being evaluated in 1977. Chromasco Limited, has agreed in principal to use Pechiney Ugine Kuhlmann Development, Inc's "Magnetherm" process to expand the existing capacity in two stages to

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Canada, magnesium production and trade, 1976 and 1977

	1976		1977p	
	(tonnes)	($000)	(tonnes)	($000)
Production[1] (metal)	6 092	12 825	7 580	17 644
Imports				
Magnesium metal				
United States	1 052	2 123	1 405	3 427
Brazil	56	93	—	—
Norway	20	45	73	140
United Kingdom	—	—	. . .	. . .
Total	1 128	2 261	1 478	3 567
Magnesium alloy				
United States	581	1 442	620	2 128
United Kingdom	85	333	101	647
Australia	18	71	—	—
Switzerland	. . .	1	—	—
Total	684	1 847	721	2 775
Exports				
United Kingdom	1 098	2 376	1 710	4 321
United States	625	1 849	620	1 654
West Germany	348	604	658	1 352
Switzerland	89	186	443	1 008
France	218	473	376	920
Argentina	143	247	128	270
Brazil	11	21	135	254
Israel	25	76	48	179
Belgium and Luxembourg	—	—	72	150
Australia	43	125	21	95
Colombia	2	8	24	85
India	51	115	33	77
South Korea	26	45	23	48
Spain	80	139	18	37
Uruguay	3	14	6	32
Other countries	5	12	5	15
Netherlands	432	749	—	—
Japan	26	69	—	—
Turkey	22	44	—	—
Total	3 247	7 152	4 320	10 497

Source: Statistics Canada.
[1]Magnesium metal in all forms and in magnesium alloys produced for shipment, less remelt.
pPreliminary; — Nil; . . . Figure too small to be expressed.

35 400 tonnes by 1985. Société Genèrale de Sucreries et Raffineries en Roumanie S.A., a Belgian company, was seeking government support to build a 12 700 tonne a year magnesium plant, near Trois Rivières, Quebec. The project was shelved for lack of government support.

World Review

World production of primary magnesium in 1977 is estimated at 257 200 tonnes compared with 244 000 tonnes in 1976. As in previous years, the United States produced almost half of the world's output. The

U.S.S.R. and Norway continued to be producers of substantial quantities of magnesium.

In the United States there were four magnesium companies that operated during 1977. The Dow Chemical Company produces magnesium metal from seawater at Freeport, Texas. It is the world's largest producer of magnesium. The company has announced that they are expanding their capacity from 110 000 tonnes to 127 000 tonnes, with completion scheduled by 1980.

Northwest Alloys, Inc., a subsidiary of the Aluminum Company of America (Alcoa), near Addy, Washington gradually started eight of its nine magnesium furnaces during 1977. This plant will have an annual capacity of 21 800 tonnes a year. The company plans to increase the capacity to 30 000 tonnes by 1980. The plant also produces ferrosilicon.

In 1972, NL Industries, Inc. constructed a magnesium plant based on the use of well brines at Rowley, Utah. Since that time, the unit has been plagued with problems. The technical problems were mainly overcome, and by the end of 1977 production had reached an annual level of approximately 22 680 tonnes.

The electrolytic plant of American Magnesium Company at Snyder, Texas has an annual capacity of 9 000 tonnes. The company has announced plans to expand production to 27 000 tonnes by 1980. Production in 1977 averaged only about 50 per cent of current capacity.

Norsk Hydro-Elektrisk Kvaelstofaktieselskab of Norway brought into production a 13 600 tonnes a year magnesium plant using a new process by making an anhydrous magnesium chloride from brine as a first step. This process is reported to be more economical than the traditional process used in that country. The Norwegian company reported last year their intention to construct a 100 000 tonnes a year plant at Mongstad Norway, using the improved process. This plant is to be completed by 1981. In Yugoslavia, the Magnohrom Company, with technical assistance of Socièté Française d'Electrometallurgie (SOFREM), is expected to be progressively brought into use in the second half of 1978 with an annual capacity of 5 000 tonnes at Bola Stena.

It has been reported that Brazil will have a 4 500-tonne-capacity magnesium plant by 1985.

Table 2. Canada, magnesium production, trade and consumption, 1960, 1965, 1970 and 1975-77

	Production[1] Metal	Imports Alloys	Imports Metal	Exports Metal	Exports Metal	Consumption[2] Metal
	(tonnes)	(tonnes)	(tonnes)	(tonnes)	($)	(tonnes)
1960	6 612	. .	. .	. .	3 232 805	1 995
1965	9 169	150	1 488	. .	4 456 255	4 081
1970	9 392	232	1 847	6 957	5 562 000	4 477[r]
1975	3 826	886	7 500	3 803	9 199 000	5 404
1976	6 092	684	1 128	3 247	7 152 000	4 230
1977[p]	7 580	721	1 478	4 320	10 497 000	6 222

Source: Statistics Canada.
[1]Magnesium metal in all forms and in magnesium alloys produced for shipments, less remelt. [2]Consumption as reported by consumers.
[p]Preliminary; . . Not available: [r]Revised.

Table 3. Canada, consumption of magnesium, 1960, 1965, 1970 and 1975-77

	1960	1965	1970	1975	1976	1977[p]
	(tonnes)					
Castings[1]	143	464	771	960	610	311
Extrusions[2]	209	507	429	341	477	568
Aluminum alloys	1 215	2 684	2 833	2 918	2 073	4 490
Other uses[3]	428	424	444	1 185	1 070	853
Total	1 995	4 079	4 477	5 404	4 230	6 222

Source: Statistics Canada.
[1]Die, permanent mould and sand. [2] Structural shapes, tubing, forgings, sheet and plate. [3]Cathodic protection, reducing agents, deoxidizers and other alloys.
[p]Preliminary.

Technology

Emphasis is on minimizing the energy requirements to reduce magnesium from its compounds as well as upgrading facilities and equipment. The Dow Chemical Company has announced a new production unit to go into operation by 1980 using a new technology that will save 30 per cent of the energy now being used. Larger die casting equipment is being developed so that the industry may be in a better position to produce parts for the automobile industry when magnesium price becomes more competitive.

Uses

The major use of magnesium is in aluminum alloys where it provides hardness and strength. Because of its high strength-to-weight ratio, it is often used in structural applications, i.e., those which involve load-carrying components. The higher price of magnesium has always placed it at a disadvantage to aluminum for structural applications even though it weighs only two thirds as much as aluminum.

Typical structural uses of magnesium are in aircraft, particularly helicopters, missiles and space exploration vehicles, luggage frames, and materials-handling equipment such as gravity conveyors and hand trucks. Magnesium castings are used extensively in power lawnmowers, chain saws, typewriters and electronic equipment.

Nonstructural applications, which have grown more quickly than structural uses, account for about 75 per cent of the consumption of magnesium. A rapidly-growing sector of this market is for aluminum alloy beverage cans, which contain about 2.5 per cent magnesium. Other important nonstructural uses of magnesium are as an alloying element for ductile iron, as a reducing agent in the production of titanium, for cathodic protection, in the chemical industry for Grignard reagents and as an anti-knock fuel additive.

While the present use of magnesium as a desulphurizer in the manufacturing of steel is low, it is expected to grow and may become second only to the use in aluminum alloying.

Table 4. World primary magnesium production, 1967, 1976 and 1977

	1967	1976	1977
	(000 tonnes)		
United States	88.4	109.3^e	119.7^e
U.S.S.R.^{e}	39.9	62.6	65.3
Norway	28.5	38.8	38.2
Japan	6.7	11.2	9.4
France	4.2	8.0	8.7
Canada	8.1	6.1	7.6
Other non-communist countries	10.1	7.0	7.3
Other communist countries^e	1.0	1.0	1.0
Total	186.9	244.0	257.2

Sources: Statistics Canada; American Bureau of Metal Statistics Inc.
^{e} Estimated.

Prices

The Canadian price of commercial grade magnesium, carload lots, fob Haley, Ontario was 96 cents a pound at the beginning of the year and was increased in July to $1.01 where it remained for the balance of the year.

In the United States, the price in 10 000 pound lots of 99.8 per cent metal, fob Freeport, Texas on January 1, 1977 was U.S. 96 cents a pound. It was raised to U.S. 99 cents on July 1. The price of diecasting alloy AZ 91B was quoted in the United States at U.S. 96 cents at the beginning of the year and was raised to U.S. 99 cents on July 1.

United States magnesium prices, in United States currency, as quoted in "Metals Week"

	(¢/lb)
Magnesium metal, in 10 000-lb lots:	
Pig 99.8%[1]	. .
Primary ingot, 99.8%	
January 1, 1977 to June 30, 1977	96.00
July 1, 1977 to December 31, 1977	99.00
Die casting alloy AZ91B ingot	
January 1, 1977 to June 30, 1977	96.00
July 1, 1977 to December 31, 1977	99.00

[1]Last quote March 8, 1974, 42.00 cents.
. . Not available.

Outlook

Alloying with aluminum will continue to be the major use for magnesium particularly in the manufacture of canning sheet for the beverage can industry. In the ferrous industry, magnesium is finding increasing favour as a desulphurizer. There is little magnesium metal used in automobiles, and it is not expected that this area will grow until the price of magnesium becomes more competitive with aluminum. The traditional suppliers are optimistic for a modest increase in demand and are expanding their capacities accordingly.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
		(%)	(%)	(%)	(%)
35105-1	Magnesium metal, not including alloys, in lumps, powders, ingots or blocks	5	5	25	3
34910-1	Alloys of magnesium, ingots, pigs, sheets, plates, strips, bars, rods and tubes	5	5	25	3
34915-1	Magnesium scrap	free	free	free	free
34920-1	Sheet or plate, of magnesium or alloys of magnesium, plain, corrugated, pebbled, or with a raised surface pattern, for use in Canadian manufactures (expires 30 June, 1980)	free	free	25	free
34925-1	Extruded tubing, of magnesium or alloys of magnesium, having an outside diameter of five inches or more, for use in Canadian manufactures (expires 30 June, 1979)	free	free	25	free

United States

Item No.		On and after January 1, 1972
628.55	Magnesium, unwrought, other than alloys; and waste and scrap (duty on waste and scrap suspended to June 30, 1978)	20%
628.57	Magnesium, unwrought alloys, per lb on magnesium content	8¢ + 4%
628.59	Magnesium metal, wrought, per lb on magnesium content	6.5¢ + 3.5%

Sources: For Canada, the Customs Tariff and Amendments, Revenue Canada, Customs and Excise Division, Ottawa; for United States, Tariff Schedules of the United States Annotated (1978), TC Publication 843.

Manganese

D.G. LAW-WEST

Since more than 90 per cent of all manganese produced finds its way into iron and steel products, the demand for manganese ores is determined by the world level of production in the iron and steel industry. During 1977 steel production recovered only slightly, but ferromanganese producers continued their normal production levels, and a large oversupply of ferromanganese resulted. This oversupply created bargain prices for ferromanganese consumers, while manganese ore prices remained stable with a slight increase of 3 to 4 per cent during the year.

Canada

Canada has no economic deposits of manganese, given the present state of technology and market conditions. There are several low-grade deposits that have been identified in Nova Scotia, New Brunswick and British Columbia. The largest of these deposits is located near Woodstock, New Brunswick with resources estimated at 45 million tonnes* grading 11 per cent manganese and 14 per cent iron. Although research has developed techniques to utilize such low grade deposits, production costs cannot be recovered at today's manganese prices.

There are two ferroalloy producers in Canada, who import metallurgical-grade manganese ore to make ferromanganese — Union Carbide Canada Limited (UCC) and Chromasco Limited. Both have plants at Beauharnois, Quebec and produce principally for the domestic market. Canada also imports manganese metal, an important additive in specialty steels as well as in aluminum alloys. The main consumers include Atlas Steel — a division of Rio Algom Limited; Aluminum Company of Canada, Limited and Reynolds Aluminum Company of Canada Ltd. High-purity manganese dioxide and battery grade manganese ores are imported into Canada by various companies including, Mallory Battery Company of Canada Limited, Cerlite Burgess, Ray-O-Vac Division of ESB Canada Limited, Cominco Ltd. and Canadian Electrolytic Zinc Limited.

World developments

In 1977 estimated world production of manganese ores and concentrates was about 24 million tonnes down slightly from 24.7 million tonnes produced in 1976.

Although the manganese industry was generally uneventful throughout the year, there were several noteworthy developments. In Brazil, several ferromanganese producers are carrying out ambitious expansion programmes. A newly formed company, Convap (Fermat) plans to install one 20 megavolt amp (mVA) furnace each year from 1978 to 1982, each furnace will be rated at 44 000 tonnes per year of high-carbon ferromanganese (H-C FeMn). Cia Paulista de Ferro-Ligas, another Brazilian company will be adding four furnaces of a total capacity of 25 000 tonnes a year at 15 mVA by 1981. The largest single company increase is by Prometal with a planned installation of 33 mVA, 65 000 tonnes a year standard ferromanganese by 1979. Expansion of medium- and low-carbon ferromanganese is limited to Prometal's 3 mVA 20 000 tonne-a-year furnace, which is expected to be operating by 1980.

Expansion of silicomanganese production is also being planned by three companies; Prometal, planning for an additional 80 000 tonnes a year by 1981; Paulista, with 13 000 tonnes a year from three small furnaces by 1979 and Alcan, with 32 000 tonnes a year, also in 1979.

Elsewhere in Brazil, Industria e Comercio de Minerios S.A. (ICOMI) halted production of manganese pellets as a result of declining export sales. Also Cia Auxiliar de Empresas de Mineracao (CAEMI), a large manganese producer, reduced ore exports by 30 per cent to 700 000 tonnes from 1 million tonnes in 1976.

In Zambia, the Zambian Industrial Development Corporation holds 70 per cent in a joint venture with the Swedish company Oy Airam (30 per cent). The two companies are reopening a manganese mine, which

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Canada, manganese trade and consumption, 1976 and 1977

	1976		1977[p]	
	(tonnes)	($)	(tonnes)	($)
Imports				
Manganese in ores and concentrates[1]				
Gabon	53 424	7 768 000	18 042	2 886 000
French Africa nes	–	–	10 000	1 675 000
France	–	–	9 535	1 566 000
United States	5 182	905 000	5 955	1 252 000
South Africa	19 463	1 832 000	8 749	935 000
Mexico	3	1 000	4 313	556 000
Brazil	33 054	4 501 000	1 013	147 000
Angola	7 846	981 000	–	–
Total	118 972	15 988 000	57 607	9 017 000
Manganese metal				
South Africa	6 295	5 264 000	6 505	6 008 000
United States	104	110 000	206	258 000
Japan	152	132 000	135	123 000
West Germany	2	1 000	4	2 000
Total	6 553	5 507 000	6 850	6 391 000
Ferromanganese including spiegeleisen[2]				
Norway	6 006	3 194 000	5 309	4 013 000
United States	6 064	2 719 000	8 033	3 843 000
South Africa	7 881	3 099 000	8 312	2 958 000
Portugal	600	192 000	3 324	1 119 000
Other countries	4 503	2 466 000	4 386	1 891 000
Total	25 054	11 670 000	29 364	13 824 000
Silicomanganese including silicospiegeleisen[2]				
United States	4 950	2 583 000	2 691	1 569 000
Norway	3 588	2 013 000	1 139	431 000
Yugoslavia	–	–	1 000	348 000
Chile	41	18 000	3	9 000
Other countries	3 443	1 636 000	–	–
Total	12 022	6 250 000	4 833	2 357 000
Exports				
Ferromanganese[2]				
United States	9 799	4 003 000	19 550	6 902 000
Venezuela	–	–	3 493	1 079 000
Jamaica	62	36 000	62	38 000
Total	9 861	4 039 000	23 105	8 019 000
Consumption				
Manganese ore				
Metallurgical grade	236 411	. .	179 727	. .
Battery and chemical grade	2 218	. .	2 430	. .
Total	238 629	. .	182 157	. .

Source: Statistics Canada.
[1]Mn content. [2]Gross weight.
[p]Preliminary; – Nil; . . Not available; nes Not elsewhere specified.

has been closed for 10 years, near Mansa in the Laupula province in Zambia. Production is expected to be 770 tonnes a year of ore for the 10-year life of the project.

In Upper Volta, work is continuing on the Tumbao high-grade manganese deposit, which is expected to come on stream in 1980. The Societe Miniere de Tumbao (Somitam) is owned 51 per cent by the government of Upper Volta, 30 per cent by Japanese interests, 9 per cent by West Germany, 7 per cent by United States and 3 per cent by the French.

Uses

The excellence of manganese as a desulphurizer makes it irreplaceable in the steel industry. Steels containing excess sulphur are not homogeneous and tend to crack and tear during rolling and forming. Added manganese combines with the sulphur and produces a manganese sulphide slag that is readily separated from the steel. Manganese also acts as a deoxidizer during the manufacture of steel.

The form in which manganese is usually added during the making of steel is as a ferroalloy. The principle manganese ferroalloys are shown in Table 4. Steel manufacturers in Canada add about 5.8 kilograms of manganese a tonne of crude steel produced.

Manganese is often added to specialty steels to increase strength and hardness. Manganese metal, instead of ferromanganese, is used in making these specialty steels because it provides better control of the manganese content and the level of impurities.

The Hadfield steels, a type of specialty steel, contain between 10 and 14 per cent manganese. These steels are extremely hard and tough and are suited to use in applications where severe mechanical conditions are encountered, such as rock crusher parts or teeth of earth moving machinery.

Iron castings often contain an appreciable amount of manganese, which has been added to remove excess sulphur. Sulphur causes surface imperfections as well as making precise casting very difficult.

Manganese is also alloyed with nonferrous metals. Aluminum-manganese alloys are noted for their strength, hardness and stiffness; manganese-magnesium alloys are hard, stiff and corrosion-resistant; and manganese-bronzes are used in the production of ship's propellers.

Manganese also has a wide variety of nonmetallurgical uses. The most important one is as manganese dioxide in dry cell batteries. In batteries, manganese dioxide is used for its readily available oxygen rather than for its manganese. Hydrogen is produced during the cell activity and slows the action. The oxygen from the manganese dioxide combines with the hydrogen to allow the battery to operate at its maximum efficiencies. Manganese ores that are used in batteries must grade above 85 per cent manganese dioxide and have a low iron content. Since very few natural manganese dioxide ores are satisfactory for battery purposes, most batteries contain a blend of natural ore and synthetic manganese dioxide.

The normal classification of manganese ore is as follows: *Manganese ores* contain more than 35 per cent manganese and are used in the manufacture of both low- and high-grade ferromanganese. *Battery grade ores* are included in this class; however, battery grade ores must contain no less than 85 per cent manganese dioxide. *Ferrogenous manganese ores* contain 10 to 35 per cent manganese and are used for the manufacture of spiegeleisen. *Manganiferous iron ores* contain 5 to 10 per cent manganese and are used to produce manganiferous pig iron.

All types of manganese ores, including manganese dioxide ores, are used in the production of manganese

Table 2. Canada, manganese imports, exports and consumption, 1960, 1965, 1970, 1975, 1976 and 1977

	Imports			Exports	Consumption	
	Manganese Ore[1]	Ferro-manganese	Silico-manganese	Ferro-manganese	Ore	Ferromanganese and Silicomanganese
	(gross weight, tonnes)					
1960	51 120	14 057	2 146	661	66 242	36 448
1965	81 175	31 354	714	3 463	108 217	70 186
1970	115 052	17 891	975	510	153 846	97 952
1975	69 773	35 701	5 732	1 168	160 976	95 869
1976	118 972	25 054	12 022	9 861	238 629	83 687
1977[p]	57 607	29 364	4 833	23 105	182 157	. .

Source: Statistics Canada.
[1]Mn content.
[p]Preliminary; . . Not available.

Table 3. World production of manganese ores

	Mn[e]	1974	1975	1976[p]
	(per cent)	(thousands of tonnes)		
U.S.S.R.	35	8 155[r]	8 459	8 500
Republic of South Africa	30+	4 745	5 769	5 452
Brazil	38-50	1 789	2 156	2 177[e]
Australia	37-53	1 522	1 555	2 154
Gabon	50-53	2 064	2 217	2 152
India	10-54	1 502[r]	1 531	1 689
People's Republic of China	30+	998[e]	998[e]	998[e]
Mexico	35+	403	428	423
Ghana	30-50	250	409	312
Hungary	30–	134	182	175
Zaire	35-55	288	309	157[e]
Japan	27-45	167	158	142
Morocco	53	175	131	117
New Hebrides	42-44	47	47	46[e]
Thailand	46-50	29	25	44
Iran	33+	30	36	40
Bulgaria	30–	34	35	40
Other countries[1]		122	118	141
Total		22 454	24 563	24 759

Source: U.S. Bureau of Mines, Mineral Industry Surveys, September 1977.
[1] Includes 12 countries, each producing less than 35 000 tonnes a year.
[p] Preliminary; [e] Estimated; [r] Revised.

chemicals such as: potassium permanganate, a powerful oxidant used in the purification of public water supplies; manganous oxide, an important addition to welding rods and fluxes; and an organometallic form of manganese, which inhibits smoke formation and improves combustion of fuel oil.

Various manganese chemicals are employed to produce various colour effects in face bricks and, to a lesser extent, to colour or decolour glass and ceramics. They also have use as paint and varnish driers, and in the production of dyes, fungicides and pharmaceuticals.

Prices

Most manganese ore is sold under contracts that are usually negotiated towards the end of the year for the next year's deliveries. However, contract talks for manganese prices continued well into April 1977, as producers wanted an average 3.5 per cent increase in prices to $1.47-$1.52 a dry tonne. The consumers had wanted prices to remain at 1976 levels.

Ferromanganese was in oversupply, and many producers were discounting prices in order to move some of their stocks. Standard ferromanganese (78 per cent Mn) prices started the year at $425 a long ton unit and ended at $399.50. There were reports during the year of prices as low as $300-$350 a long-ton unit. The market for ferromanganese will not strengthen until there is some improvement in the steel industry.

Manganese nodules

Manganese nodules have been found in both marine and freshwater environments. Although they are widely distributed, potentially exploitable manganese nodules are found only in a few areas and at depths of more than 3 000 metres. Nodules are formed by the accretion of manganese and iron oxides along with smaller amounts of minerals such as nickel, copper and cobalt, around a nucleus. Over a long period of time they form into spheres or lenses from 2 to 10 centimetres (cm) in diameter having a wet density of 2 gram/cm^3 and being very porous contain up to 30 per cent water by weight.

Table 4. Principal manganese ferroalloys

	Manganese	Silicon	Carbon
	(per cent)		
Ferromanganese			
High-carbon	74-82	1.25 max	7.5 max
Medium-carbon	74-85	1.50 max	1.5 max
Low-carbon	80-85	7.00 max	0.75 max
Silicomanganese	65-68	18-20 max	0.6-2.0
Spiegeleisen	16-28	1.0-4.5	0.65 max

Source: Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.

Table 5. The three major consortia involved in seabed mining

	Consortium	Companies
1.	Ocean Mining Associates	United States Steel Corporation, U.S.A. Union Minière S.A., Belgium Deepsea Ventures Inc. (contracted)
2.	Kennecott Joint Venture	Kennecott Copper Corporation (50%) U.S.A. Noranda Mines Limited (10%) Canada Mitsubishi Corporation (10%) Japan Rio Tinto Zinc Corp. Group (10%) U.K. British Petroleum Company Limited (10%) U.K.
3.	Ocean Management Inc.	Inco Limited (25%) Canada Arbeitsgemeinschaft Meerestechnische gewinnbare Rohstoff (25%) W. Germany SEDCO, Inc. (25%) U.S.A. Deep Ocean Mining Company (25%) Japan

Manganese nodules are by no means a homogeneous deposit, they vary both in density (weight per unit area) and chemical composition, especially with respect to nickel, copper and cobalt.

The presence of manganese nodules on the deep sea bed has been known since the 1872-76 oceanographic expedition of the British *HMS Challenger*, however, it was not until 1958 that nodules were considered potentially economic. By 1974-75 there were three major consortia seriously involved in the development of mining deep seabed nodules (Table 5). The high capital cost of demonstrating an effective mining and processing system is the main reason why the consortia have evolved. It has been estimated that each consortium will spend between $40-$80 million for the completion of feasibility studies scheduled for 1978-79. The studies will include; delineation of an area with sufficient nodule reserves to support an economic venture, development and testing of an ocean mining system and a nodule processing system.

All consortia are progressing reasonably well and should be testing pilot scale mining techniques within the very near future. Commercial scale seabed mining is still many years away.

Outlook

As the steel industry slowly recovers so will the manganese industry; however, with large consumer stockpiles there will be a slight lag in demand for manganese. The short-term outlook for manganese ore prices is for increases of about 4 per cent.

However, there has been a marked increase in ferromanganese production capacity from ore-producing countries. This could result in ferromanganese prices continuing to remain depressed.

The long term will see a slight decrease in manganese consumption in steel making as external

United States prices in U.S. currency, published by Metals Week of December 1976 and December 1977

	December 1976	December 1977
	(¢)	(¢)
Manganese ore, per long-ton unit (22.4 lb.) cif U.S. ports, Mn content		
Min. 48% Mn (low impurities)	147.0–153.0	148.0–153.0
Ferromanganese, fob shipping point, freight equalized to nearest main producer, carload lots, lump, bulk	($)	($)
Standard 78% Mn, per long ton unit	425.0	399.5
	(¢)	(¢)
Medium-carbon, per lb. Mn	40.75–41.50	40.75–41.50

United States prices in U.S. currency, published by Metals Week of December 1976 and December 1977 (concl'd)

	December 1976	December 1977
	(¢)	(¢)
Silicomanganese, per lb. of alloy, fob shipping point, freight equalized to nearest main producer, carload lots, lump, bulk		
16-16½% Si, 2%C	22.5–24.0	18.75
Manganese metal, electrolytic metal, 99.9%, per lb. Mn, boxed fob shipping point		
Regular	58.0	58.0
6% N	61.0	61.0

desulphurization and continuous casting procedures become more prevalent. The annual growth rate for world manganese demand is expected to be about 3 per cent to the year 2000.

Tariffs

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
Canada					
32900-1	Manganese ore	free	free	free	free
33504-1	Manganese oxide	free	free	free	free
35104-1	Electrolytic manganese metal	free	free	20%	free
37501-1	Ferromanganese, spiegeleisen and other alloys of manganese and iron, not more than 1% Si in the Mn content, per lb.	free	0.5¢	1.25¢	free
37502-1	Silicomanganese, silico spiegel and other alloys of manganese and iron more than 1%, Si on the Mn content per lb.	free	0.75¢	1.75¢	free
United States			(¢ per lb. on Mn content)		
601.27	Manganese ore including ferruginous manganese ore and manganiferous iron ore, all the foregoing containing over 10 per cent by weight of manganese		0.12¢		
607.35	Ferromanganese, not containing over 1% C		0.3 + 2% ad. val.		
607.36	Ferromanganese, containing over 1% but not over 4% C		0.46		
607.37	Ferromanganese containing over 4% C		0.3		
632.32	Manganese metal, unwrought, waste and scrap (duty temporarily suspended on waste and scrap to end of June 1978)		1.5¢ per lb. + 10% ad. val.		

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. Tariff Schedules of the United States, Annotated (1978), TC Publication 843.

Mercury

J.G. GEORGE

There has been no mine output of mercury in Canada since July 1975 when the Pinchi Lake mine of Cominco Ltd., 48 kilometres (km) north of Fort St. James, British Columbia, suspended operations indefinitely. The mine's closure resulted from a significant decline in mercury prices caused by a drop in demand for the metal. From January 1, 1975 to the time of closure of the property, the Pinchi Lake mill processed 113 400 tonnes* of cinnabar ore. Beneficiation of the ore involved concentrating it by flotation, then roasting the concentrate to produce mercury vapour which, in turn, was cooled and condensed to produce liquid metallic mercury. In 1975 the roaster produced 12 000 flasks** of refined mercury.

Cominco Ltd. also produced high-purity mercury metal with metallic impurities totalling ten parts per billion, or less, at its electronic materials plants at Trail, British Columbia. This specialty metal product was manufactured mainly for special applications in the electronics industry, such as advanced radiation detector materials.

Canadian imports of mercury metal in 1977, at 21 909 kilograms (kg) (636 flasks), were considerably lower than the 62 638 kg (1 817 flasks) imported in 1976. Partial consumption of mercury metal in Canada, as reported by Statistics Canada, was 30 447 kg (883 flasks) in 1977***; in 1976 it was 26 039 kg (755 flasks).

World review

Estimated world mine production of mercury in 1977 was 230 000 flasks, or somewhat less than the 240 000 flasks estimated for 1976 output. The U.S.S.R. retained its status as the world's largest mine producer of mercury and Spain continued to be the world's second-largest producer. The Almaden mine of Minas de Almaden y Arrayanes in Spain was once again the largest mercury producer in the world. Early in 1977 the Yugoslavian government ordered the state-owned Idrija mercury mine to suspend operations. The mine, which was the third-largest mercury producer in the world, contains about 10 per cent of the world's known mercury reserves but was unable to produce profitably because of depressed mercury prices and excessive world stocks. About mid-1977, Minas de Almaden announced that it was withdrawing from the market because of the continuing decline in mercury prices. The company, however, continued to produce mercury, but stockpiled its excess output. It also stated that it would honour its long-term sales commitments.

United States mine output of mercury increased significantly again in 1977 as a result of increased production from the McDermitt mercury property in northern Humboldt County, Nevada. The McDermitt mine began operations in mid-1975 but its 1977 output was considerably greater than its original rated capacity of 20 000 flasks of refined mercury a year. The property is being mined by open-pit methods and the ore is processed in a concentrator with a rated capacity of 635 tonnes of ore a day. The flotation concentrate is furnaced in a system containing a multiple-hearth roaster equipped with emission control devices.

The United States is believed to be the world's largest consumer of mercury but has always produced less than its requirements. Total consumption in 1977 in the United States of primary, redistilled and secondary mercury was estimated at 60 760 flasks, a decrease of more than 6 per cent from the 64 870 flasks consumed in 1976. A large portion of the U.S. requirements was again derived from imports, which totalled 28 603 flasks in 1977 compared with 43 964 flasks in 1976.

World consumption of mercury in 1977 is believed to have been about 240 000 flasks, or about 2 per cent less than the 245 000 flasks estimated for 1976 output.

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*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.
**The flask containing 76 net pounds avoirdupois (34.473 kilograms) is used throughout.
***Preliminary figure.

The reduction is largely attributed to the sluggish economies of the main consuming countries. Environmental factors also continued to dampen the metal's use in paints, agriculture, pharmaceuticals, and the chlor-alkali industry.

For the past few years delegates from several of the major producing countries have held meetings in different countries at least once a year. The meetings have been producer-oriented and one of the main items on each agenda has always been an attempt to bring about more stability to the mercury market, mainly by agreeing on concerted measures to control supplies and regulate prices. In October 1977 this group of world producers, known as the International Association of Mercury Producers (ASSIMER), met again in Geneva, Switzerland and reportedly decided to take measures to curb speculators and adapt their exports to the needs of traditional consumers. The member countries of the organization, established in 1975 with headquarters in Geneva, are Spain, Italy, Turkey, Yugoslavia, Algeria and Peru, which together account for about 90 per cent of exports from Yugoslavia and the non-Communist countries. Among the objectives of the association are stabilization of prices by curtailing production or withholding supplies from the market, the development of new uses for mercury and improvement of its environmental image.

At the end of 1977 the United States strategic and critical materials stockpile contained a total of 191 304 flasks of mercury, little changed from the 191 407 flasks on hand at the end of 1976. The stockpile goal is 54 004 flasks, leaving a surplus of 137 300 flasks, none of which may be released, however, without authorization of the United States Congress. Such stocks are exclusive of excess mercury held by the United States Atomic Energy Commission (USAEC). At December 31, 1976 these surplus USAEC stocks, which do not require Congressional authorization prior to being released, amounted to 1 255 flasks. General Services Administration (GSA) continued its offerings of such stocks in 1977 at the rate of 500 flasks (maximum) a month. GSA sold 1 200 flasks in 1977, leaving a surplus of 55 flasks of USAEC mercury at December 31, 1977.

In March 1974 the United States Environmental Protection Agency (EPA) promulgated its final effluent limitation guidelines for existing and new sources in the inorganic chemicals manufacturing category. The daily effluent limitation is 0.00028 pound of mercury per 1 000 pounds of product for mercury-cell plants in existence since March 1974. The limitation is 0.00014 pound of mercury per 1 000 pounds of product for new producing plants. One of the stated goals of the Federal Water Pollution Control Act of 1972 is the elimination of all pollutant discharges by 1985.

On April 6, 1973 EPA published the final air emission standard for mercury at 5.1 pounds a day, per plant, released to the atmosphere. In 1974, EPA proposed an amendment to the emission standard for hazardous air pollutants in which mercury emissions from the incineration and drying of wastewater treatment plant sludges would be limited to a maximum of

Table 1. Canadian mercury production, trade and consumption 1976 and 1977

	1976		1977p	
	(kilograms)	($)	(kilograms)	($)
Mine production	—	—	—	—
Imports (metal)				
United States	20 774	102 000	16 284	108 000
Spain	5 307	21 000	5 489	26 000
United Kingdom	45	1 000	136	1 000
Netherlands	21 318	90 000	—	—
People's Republic of China	14 378	38 000	—	—
Sweden	816	9 000	—	—
Total	62 638	261 000	21 909	135 000
Consumption[1] (metal)				
Heavy chemicals	12 455	. .	16 245	. .
Electrical apparatus	12 271	. .	12 275	. .
Gold recovery	230	. .	233	. .
Miscellaneous	1 083	. .	1 694	. .
Total	26 039	. .	30 447	. .

Source: Statistics Canada.
[1] Partial consumption only.
p Preliminary; . . Not available; — Nil.

3 200 grams (7.05 pounds) per day. Further, the National Institute for Occupational Safety and Health submitted criteria for a recommended standard on the occupational exposure to inorganic mercury. On March 14, 1975 EPA proposed National Interim Primary Drinking Water Regulations and held hearings thereafter on the proposed regulations. In addition, comments and information were received from representatives of state agencies, public interest groups and others. The regulations proposed maximum contaminant levels in public drinking water and set the mercury level at 0.002 milligram per litre.

In 1975, EPA concluded its hearings on the cancellation of biocidal uses of mercury, including mildewcides in paint. Early in 1976 the agency ordered an immediate halt to the use of mercury compounds in pesticides. Later in the same year EPA rescinded its ban on the use of mercury compounds in some agricultural products and postponed the ban for other uses. The use of mercury in winter disease control products for golf courses was reinstated permanently. For other agricultural uses — summer disease control and seed protection — the manufacturers of the control products can continue to use mercury until August 1978. EPA also reinstated the use of mercury compounds in latex (water-based) paints but continued the ban on their use in nonwater-based paints. The agency also requested a review of the uses of mercury in other pesticides.

In Canada, legislation, known as the "Chlor-Alkali Mercury Regulations" (P.C. 1972-576), was passed by the federal government March 28, 1972 and became effective 60 days after that date. This legislation restricted the quantity of mercury that may be discharged in the effluent from any chlor-alkali plant in Canada using the mercury-cell process. It stipulates that mercury in the liquid effluent, from any such chlor-alkali plant, deposited in any one day in waters frequented by fish, shall not exceed 0.005 pound per ton of chlorine produced by the plant in that day.

Also in Canada, the Food and Drugs Act, a federal statute (Chapter F-27 R.S.C., 1970, as amended) is designed, among other things, to protect Canadians against health hazards related to foods. The act is administered by the Health Protection Branch of the Department of National Health and Welfare. Section 4 (a) of the act provides legal authority for the branch to determine those levels in foods of substances such as mercury, which are considered to represent a hazard to human health, and to prohibit the sale of foods containing unsafe levels of the substances in question. After a study of the available data on the toxic effects to humans of mercury-contaminated fish, the consumption of fish by Canadians, and action taken by other countries on this matter, the Health Protection Branch decided in 1969 that, as a temporary measure,

Table 2. Canadian mercury production, trade and consumption 1968-77

	Production, Metal	Imports, Metal	Exports, Metal	Consumption, Metal
	(kilograms)			
1968	195 117	89 766	. .	148 751
1969	727 380	60 600	. .	140 076
1970	841 141	69 536	. .	154 474
1971	637 750	55 338	. .	87 982
1972	504 581	79 243	. .	51 998
1973	430 913	48 171	. .	32 959
1974	482 622	108 817	. .	37 786
1975	413 676	73 527	. .	32 869[1]
1976	—	62 638	. .	26 039[1]
1977[p]	—	21 909	. .	30 447[1]

Sources: Statistics Canada for all figures, except for metal production statistics, obtained directly from Cominco Ltd. and representing output from its Pinchi Lake mine in B.C.
[1]Partial consumption only.
[p]Preliminary; — Nil; . . Not available.

Table 3. World production of mercury, 1973, 1976 and 1977

	1973	1976[e]	1977[e]
		(flasks)	
U.S.S.R.[e]	52 000	55 000	52 000
Spain	62 069	44 000	40 000
United States	2 227	23 133	31 375
People's Republic of China[e]	26 000	26 000	24 000
Italy	33 504	22 278	20 000
Algeria	13 300	16 000	19 000
Mexico	21 646[1]	15 026	10 000
Turkey	7 861	8 000	9 500
Yugoslavia	15 606	14 000	8 000
West Germany	4 700	6 000	6 000
Czechoslovakia	6 498	6 000	6 000
Peru	3 581	3 000	3 000
Philippines	2 169	. .	. .
Ireland	1 345	. .	. .
Japan	3 742	. .	. .
Canada	12 500[2]	—	—
Other countries	1 266	1 563	1 125
Total	270 014	240 000	230 000

Sources: Preprint from the 1975 U.S. Bureau of Mines *Minerals Yearbook* for 1973 statistics. U.S. Bureau of Mines Commodity Data Summaries 1978 for some of the 1976 and 1977 statistics.
[1]Exports. [2]Output of Cominco Ltd. as reported by that company.
[e]Estimated; — Nil; . . Data not available, but estimate included in figure for "Other countries".

it would take no exception to the sale of fish containing not more than 0.5 part per million (ppm) of mercury determined on a wet basis. In effect, this 0.5 ppm mercury level represents an administrative guideline applicable to fish only, and legally binding only at the point of sale. Apparently this same 0.5 ppm mercury level in fish was subsequently adopted by the United States government authorities.

Outlook

Mercury prices remained depressed throughout most of 1977 because of poor demand caused by sluggish world economic conditions and excessive stocks. Also, substitution resulted from mercury and its compounds being declared hazardous substances, for certain uses, by environmental agencies.

In 1978, mercury prices could strengthen somewhat, partly due to higher costs of production, but mainly because of improved economic conditions in the United States, Europe and Japan. Excessive worldwide stocks will, however, continue to keep a damper on any price increases. Much will depend on the outcome of the efforts of the major producers to control production and offerings to the market and, hence, prices. There is also the risk that rising prices, if sustained for any period, could lead to the reopening of mercury mines that cannot be operated economically under present conditions.

Because of environmental factors, a negative influence on the mercury market in the medium-term is the trend to greater use of the diaphragm cell (which requires no mercury) in the electrolysis of brine to produce chlorine and caustic soda. The mercury cell process for the electrolytic preparation of chlorine and caustic soda is one of the two major uses for mercury (the other being for electrical apparatus). However, there is one bright spot in the outlook for the metal. Its consumption in the electrical apparatus industry is growing significantly and is likely to continue to do so for an indefinite period. In the United States alone 28 127 flasks of mercury were used for electrical apparatus in 1977 compared with 26 423 flasks in 1976. Also, an increase in demand could eventually result from the concerted efforts being made by the mercury producers' association to find new uses and markets for the metal and its compounds. The development of improved antipollution technology could help the metal to achieve a better image.

Table 4. United States mercury consumption, by uses; primary, redistilled and secondary in origin

	1973	1976	1977p
	(flasks)		
Agriculture[1]	1 830	607	513
Catalysts	673	1 264	497
Dental preparations	2 679	1 990	1 025
Electrical apparatus	18 000	27 498	28 127
Electrolytic preparation of chlorine and caustic soda	13 070	16 054	10 483
General laboratory use	658	595	330
Industrial and control instruments	7 155	5 067	4 674
Paint:			
Antifouling	32	–	–
Mildew-proofing	7 571	7 845	8 380
Pharmaceuticals	606	60	171
Other[2]	1 913	2 920	2 472
Total known uses	54 187	63 900	60 760[3]
Total unknown uses	96	970	. .
Grand Total	54 283	64 870	60 760

Sources: Preprint from the 1975 U.S. Bureau of Mines *Minerals Yearbook*, for 1973 statistics. U.S. Bureau of Mines, Mineral Industry Surveys, *Mercury in the First Quarter 1977*, for 1976 statistics. U.S. Bureau of Mines, Mineral Industry Surveys, *Mercury in the Fourth Quarter 1977*, for 1977 Statistics.
[1]Includes fungicides and bactericides for industrial purposes. [2]Includes mercury used for installation and expansion of chlorine and caustic soda plants. [3]The individual items do not add to the total, which has been increased to cover approximate total consumption.
pPreliminary; – Nil; . . Not available.

Uses

Mercury's two major uses in recent years have been for electrical apparatus and for the electrolytic production of chlorine and caustic soda. Together, these two applications accounted for almost 65 per cent of mercury consumed in the United States in 1977. Electrical uses include mercury lamps, batteries, rectifier bulbs, oscillators, and various kinds of switches including "silent" switches for use in housing. Because mercury lamps are more adaptable to higher voltage supply lines than are incandescent lamps, they are used as fluorescent lamps and for industrial and street lighting purposes. The mercury battery invented in 1944 is basically a dry-cell type battery. It has a relatively long shelf life and can withstand high temperature and high humidity. It is used in Geiger-Muller counters, portable radios and two-way communications equipment, digital computers, electronic measuring devices, hearing aids, guided missiles, and spacecraft.

Other applications are in mildew-proofing paints, industrial and control instruments, pharmaceuticals, insecticides, fungicides, bactericides and dental preparations, although in some countries some of these uses have already been restricted or banned by governmental regulations. Several mercury compounds, especially chloride, oxide and sulphate, are good catalysts for many chemical reactions, including those involved in the making of plastics. Because of its

Table 5. Average monthly prices of mercury in 1977 at New York and cif main European port

	New York[1]	Cif main European port[2] Low	High
		($U.S./flask)	
January	140.238	141.143	150.429
February	159.842	161.250	177.500
March	169.044	176.111	192.778
April	154.143	152.750	165.875
May	132.286	133.000	143.555
June	116.773	118.143	127.429
July	110.263	115.555	125.889
August	115.000	117.500	127.500
September	132.524	123.889	134.444
October	138.600	127.375	136.125
November	131.526	122.444	130.333
December	128.285	125.500	130.500

Sources: *Metals Week* for New York prices; *Metal Bulletin* (London) for cif main European port prices.
[1]Consensus of fixed-price prompt sales of 20 or more flasks of prime virgin metal in the United States. Price includes delivery, United States import duty, plus any applicable surcharges. [2]Prices are cif main European port, min. 99.99 per cent.

capacity to absorb neutrons, the metal has been used as a shield against atomic radiation. New technologies could open up new areas of use in the nuclear, metal-chloride vapour, plastic, chemical, amalgam and ion exchange fields. Substitutes for mercury include nickel-cadmium or other battery systems for electrical apparatus, disphragm cells for mercury cells in the chlor-alkali industry, organotin compounds in paints and solid-state devices for industrial and control instruments.

Prices

Mercury prices rose sharply in the first quarter of 1977 and reached a peak of $180 a flask (New York price) early in March, the high point for the year. In the second quarter the New York price declined abruptly and early in July reached a low for the year of $103 a flask. In the second half of the year the New York price fluctuated in a narrower range and ended the year at about the same level as it began. The price of mercury per flask, in New York, as quoted in *Metals Week,* averaged $135.71 in 1977 compared with an average of $121.30 for 1976. In 1977, the cif main European port price, as quoted in *Metal Bulletin* (London), ranged between a high of $U.S.220 a flask in March and a low of $U.S.95 in July.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
92805-2	Mercury metal	free	free	free	free
92828-4	Mercury oxide for manufacture of dry-cell batteries (expires February 28, 1981)	free	free	25%	free

United States

Item No.		Non-communist countries	Communist countries except Yugoslavia
601.30	Mercury Ore	free	free
632.34[1]	Mercury metal, unwrought and waste and scrap	12.5 cents per pound	25 cents per pound

European Economic Community

Item No.		Autonomous	Conventional
28.05	Mercury, in flasks of a net capacity of 34.5 kg, of a f.o.b. value, per flask, not exceeding 224 u.a.[2]	8.40 u.a. per flask	6.72 u.a. per flask
28.28	Mercury oxides	7%	5.6%

Sources: For Canada, the Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1978), TC Publication 843. For European Economic Community, Official Journal of the European Communities, volume 20, No. L289, November 1977.
[1]The suspension of duty on waste and scrap was extended until June 30, 1978. [2]u.a. — Unit of account equivalent to 0.88867088 gram of fine gold.

Molybdenum

MICHEL A. BOUCHER

Unlike many ferrous and nonferrous metals such as copper, zinc and nickel that were in a depressed state in 1977, demand for molybdenum remained firm, largely as a result of increased use of molybdenum-bearing steel in oil and gas transmission pipelines, deep oil and gas well drilling, and by the automotive industry in order to reduce weight and save energy.

In 1977 non-communist world consumption exceeded production for the third consecutive year, and as a result molybdenum prices increased by 12 to 16 per cent.

Canada, production, trade and consumption

Canadian shipments of molybdenum (Mo) contained in concentrate, ferromolybdenum and oxide in 1977 were 16.4 million kilograms (kg) valued at $146.7 million, up from 14.6 million kg valued at $98.6 million in 1976. Mine production in Canada rose about 1.6 million kg in 1977 to 15.6 million kg. The balance of Canadian shipments came from producer stocks. Molybdenum is recovered as a primary product in two mines in Canada, as a coproduct with copper in one mine and as a byproduct of copper at four mines. All but Gaspé Copper Mines, Limited, which is located in Quebec, are in British Columbia. Endako Mines Division of Canex Placer Limited, a primary producer, accounts for about 45 per cent of Canada's mine production and Brenda Mines Ltd., a coproduct producer, accounts for about 25 per cent. Most of the remainder is regarded as byproduct production.

Gibraltar Mines Ltd. began recovering molybdenum in early 1977 for the first time since 1974 when recovery was deemed uneconomic, and the molybdenum circuits were shut down. Gibraltar is expected to produce at an annual rate of about 0.15 million kg of Mo in concentrate.

Prior to 1976, AMAX Inc. was an important supplier for the Canadian market. However, in 1976 AMAX withdrew from the Canadian market as a result of tight markets in the U.S. and in its major export markets. The slack in the Canadian market was taken up by Endako, which in 1977 supplied some 80 per cent of the Canadian demand, compared with a market share of 45 to 50 per cent in 1975.

The best prospect for a fast increase in molybdenum production is the Iona mine, owned by Bethlehem Copper Corporation. Production of molybdenite concentrates at this mine is expected to start in late 1978 at an annual rate of 450 to 500 tonnes* of Mo contained in concentrates. In 1979 the Iona mine will be phased out and replaced by the Jersey mine, which is expected to produce some 200 tonnes Mo a year.

Another prospect is the AMAX property at Kitsault, British Columbia and formerly known as British Columbia Molybdenum Limited. The operation was shut down in 1972 due to poor markets for molybdenum and then was sold to AMAX. Its 2.3 million kg Mo a year installed capacity is expected to be increased to 3.6 million kg in the early 1980s.

Exports of molybdenum products increased by 5 per cent to 15.3 million kg in 1977. In terms of value however, exports increased by some 44 per cent to $125.6 million, reflecting the strong demand for molybdenum in the world.

Total imports of molybdic oxide, concentrate and ferromolybdenum increased 23 per cent to close to 504 000 kg. Consumption in 1977 was 927 847 kg Mo, down from 1 260 329 kg in 1976.

Canadian consumption could more than double once construction of the Alcan-Foothills Pipeline begins. Depending on the final pipe specifications, the Canadian section of the pipeline could require between 5 and 7 million kg of molybdenum. This demand could materialize by late 1978 and is expected to be spread over approximately three years.

World production, consumption and developments

In 1977 production in the non-communist world increased by about 6.5 per cent over 1976 to 83 million kg

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Mo. Non-communist world consumption, plus export to the communist countries, also increased about 6.5 per cent to 86 million kg. The increase in production came largely from the Henderson mine of AMAX Inc. in Colorado, where output rose from 1.4 million kg in 1976 to 10.7 million kg in 1977. The Henderson mine is scheduled to reach full production of 23 million kg a year in 1980. This increase in United States production was, however, partially offset by a decrease in production at one primary producer, Molycorp Inc. and a decrease in the amount of molybdenum recovered as a byproduct of copper mining in the United States due to the depressed state of the world copper market. Production at Molycorp's Questa, New Mexico mine was first reduced in June as a result of storm damage and then suspended in July as a result of a rockslide in the main pit. Molycorp has continued milling from stocks, but its annual output will decline from the normal level of 5 million kg a year to about 3 million kg in 1977. There is some doubt as to whether the mine will ever by fully reopened. However, Molycorp and Kennecott Copper Corporation are studying plans to open a new mine in the Questa area.

As a result of the continuing poor market for copper, several important byproduct producers in the U.S. ceased or curtailed production in 1977. Among them were: Kennecott Copper; Cyprus Mines Corporation, which suspended production at its Cyprus Pima

Table 1. Canada, molybdenum production, trade and consumption, 1976 and 1977

	1976		1977p	
	(kilograms)	($)	(kilograms)	($)
Production (shipments)[1]				
British Columbia	14 088 760	93 848 499	15 382 000	137 638 000
Quebec	529 847	4 723 761	1 049 000	9 053 000
Total	14 618 607	98 572 260	16 431 000	146 691 000
Exports				
Molybdenum in ores and concentrates and scrap[2]				
Japan	4 865 504	31 035 000	3 920 000	41 739 000
Belgium and Luxembourg	4 028 218	24 255 000	5 798 000	40 844 000
United Kingdom	2 274 856	13 493 000	2 268 000	16 049 000
United States	1 104 361	5 226 000	1 223 000	9 781 000
West Germany	522 493	2 748 000	1 156 000	8 866 000
Netherlands	961 979	5 671 000	402 000	3 181 000
France	422 612	2 679 000	356 000	3 111 000
Australia	74 616	375 000	147 000	1 645 000
Other countries	299 326	1 699 000	40 000	378 000
Total	14 553 965	87 181 000	15 310 000	125 594 000
Imports				
Molybdic oxide (containing less than 1 per cent impurities)	110 631	566 000	192 000	1 221 000
Molybdenum in ores and concentrates[3] (Mo content)	169 077	855 648	237 668	1 702 635
Ferromolybdenum[3] (gross weight)	128 845	673 603	74 330	498 485
Consumption (Mo content)				
Ferrous and nonferrous alloys	1 190 945	. .	875 686	. .
Electrical and electronics	3 431	. .	2 719	. .
Other uses[4]	65 953	. .	49 442	. .
Total	1 260 329	. .	927 847	. .

Source: Statistics Canada, except where noted.
[1]Producers' shipments (Mo content) of molybdenum concentrates, molybdic oxide and ferromolybdenum. [2]Includes molybdenite, molybdic oxide in ores and concentrates. [3]United States exports of molybdenum to Canada, reported by the U.S. Bureau of Commerce, Exports of Domestic and Foreign Merchandise (Report 410), value in U.S. currency. These imports are not available separately in official Canadian trade statistics. [4]Chiefly pigment uses.
pPreliminary; . . Not available.

Table 2. Canada, molybdenum production, trade and consumption, 1960, 1965, 1970, 1975-77

	Production[1]	Exports[2]	Imports		Consumption[5]
			Molybdic oxide[3]	Ferro-molybdenum[4]	
			(kilograms)		
1960	348 187	. .	297 585	104 598	472 678
1965	4 335 069	. .	344 503	180 738	772 281
1970	15 318 593	13 763 807	33 520	29 619	1 036 940
1975	13 026 696	15 680 099	56 382	269 281	1 436 883
1976	14 618 607	14 553 965	110 631	128 845	1 260 329
1977^p	16 431 000	15 310 000	192 000	74 330	927 847

Source: Statistics Canada, except where noted.
[1]Producers' shipments (Mo content) molybdenum concentrates, oxide and ferromolybdenum. [2]Mo content, ores and concentrates. [3]Gross weight. [4]U.S. exports to Canada, reported by the U.S. Bureau of Commerce, Exports of Domestic and Foreign Merchandise (Report 410), gross weight. [5]Mo content of molybdenum products reported by consumers.
^{p}Preliminary; . . Not available.

mine indefinitely; and Duval Corporation, the second largest molybdenum producer in the United States, which closed its Esperanza mine and announced that the Sierrita and Mineral Park mines would operate at a reduced rate. Production in Chile, the world's only other major producer, remained steady at 11 to 12 million kg in 1977.

Numerous companies were actively engaged in exploration for molybdenum as a result of the recent price increases and the current tight supply situation. This exploration activity was primarily centred in the three major producing countries — the United States, Canada and Chile. The most important discovery of the year was the Mt. Emmons orebody in Colorado, which is owned by AMAX Exploration, Inc. Preliminary drilling on the deposit has indicated a zone of mineralization of more than 130 million tonnes grading from 0.2 per cent to 1.0 per cent MoS_2 with an average grade of 0.4%. Amax Exploration will continue work on the deposit in 1978.

Most potential future molybdenum producers will be operations where molybdenum is recovered as a byproduct of copper mining. Some of these operations include: Cuajone in southern Peru; Tyrone in New Mexico and owned by Phelps Dodge Corporation; La Caridad, Mexico and Sar Cheshmeh in Iran.

Depending on the size of the operation average investment costs per kilogram of molybdenum for byproduct producers are estimated at $4 to $10. This compares with $15 to $25 for primary producers. The higher investment costs for primary producers are due to the facts that molybdenum ores are two to five times leaner than the equivalent copper ores and that molybdenum mining operations are much smaller than copper mining operations. For these reasons, and also because of the prevailing higher prices paid for molybdenum, byproduct producers will likely try to increase mill revenues by maximizing molybdenite recovery and by building new molybdenite recovery circuits.

As indicated in Table 5, molybdenum is expected to remain in short supply in the short- to medium-term.

Supply will depend in part on production rates at Climax Molybdenum Company's new Henderson mine, which as of the end of 1977 had produced more than originally scheduled. Copper mining production will also affect the supply of molybdenum, as 40 per cent of world production is a byproduct or coproduct of copper mining, especially in Chile, but also in Canada and to a lesser extent in the U.S.

Some of the shortfalls between production and consumption in recent years have been met by stockpile and inventory reductions. The General Services Administration (GSA) of the United States released the last of the molybdenum held in the strategic stockpile during 1976 and there are no plans for stockpiling molybdenum as it is not regarded as a strategic metal due to the level of self-sufficiency. Producer inventories have also been reduced considerably in the past three years.

The major growth area for molybdenum consumption will continue to be in high-strength low alloy (HSLA) steel applications where production is estimated to grow at about 10% a year until the mid-1980s. HSLA steels are widely used in transmission pipelines for oil and natural gas, for which the demand will remain strong for several years. It's application in the production of stainless steels, which are used to resist corrosion due to such conditions as sea water environments and to sour natural gas in deep well drilling, are expected to grow at 7 to 8 per cent a year. In chemical applications growth in catalysts and pigments will be in the order of 6 to 7 per cent. A growth rate of about 3 per cent is expected in tool and high temperature steels.

Table 3. Canada, mine production in 1977 and prospective mine producers

Company and Mine Name	Location	Type of Producer	Mill Capacity (tpd) [2]	Ore Milled		Concentrates Produced			Year-end Stocks (tonnes Mo contained in concentrates)
				Tonnes	Grade (% Mo)	Tonnes	Grade (% Mo)	Contained Mo, tonnes	
Current producers									
Canex Placer Limited, Endako Mine	Endako, B.C.	Primary	26 300	9 082 700	0.097	. .	. .	6 927	1 272[1]
Noranda Mines Limited, Boss Mountain Division	Williams Lake B.C.	Primary	1 540	523 490	0.216	1 846	53.8	1 095	11
Brenda Mines Ltd.	Peachland, B.C.	Coproduct	21 800	9 632 340	0.047	6 690	56.8	3 800	1 182
Lornex Mining Corporation Ltd., Lornex mine	Highland Valley, B.C.	Byproduct	43 500	15 477 950	0.015	3 187	54.0	1 721	212
Utah Mines Ltd., Island Copper mine	Port Hardy B.C.	Byproduct	34 500	13 110 000	0.017	2 100	43.0	903	16
Gibraltar Mines Ltd.	McLeese Lake B.C.	Byproduct	36 300	12 765 210	0.013	264	53.3	141	4
Gaspé Copper Mines, Limited, Needle Mountain and Copper Mountain	Holland Twp. Gaspé, Que.	Byproduct	34 000	12 180 000	0.023	2 018	51.5	1 040	—
Total								15 627	2 697

Prospective producers

			Ore Reserves (million tonnes)	Grade (% Mo)	Expected Production	
					Tonnes/Year Of Ore	Year
Bethlehem Copper Corp., Iona mine	Highland Valley, B.C.	Byproduct	..	0.018	6 000 000	1978
AMAX Inc., Kitsault	Alice Arm, B.C.	Primary	120	0.12	4 200 000	1982

Sources: Company annual reports; *Canadian Mines Handbook*, 1977-78; Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
[1]Mo contained in molybdic oxide; [2] Tonnes of ore a day.
. . Not available; — Nil.

Table 4. Molybdenum production in ores and concentrates, 1975-77

Country[1]	1975	1976	1977[p]
	(tonnes Mo content)		
Australia[e]	11	11	11
Bulgaria	140	140	150
Canada (shipments)	14 415	14 619	16 431
Chile	9 091	10 899	11 000[e]
People's Republic of China	1 500	1 500	1 500
Japan	140	150[e]	150[e]
South Korea	76	119	101
Mexico	17	16	18[e]
Peru	651	450	463
U.S.S.R.[e]	9 060	9 350	9 700
United States	48 072	51 362	55 523
Total	83 173	88 616	95 047

Sources: U.S. Bureau of Mines, Mineral Trade Notes, Vol. 75, No. 5, May 1978; for Canada, Statistics Canada.
[1]In addition to the countries listed, North Korea, Nigeria, and Romania are believed to produce molybdenum, but output is not reported quantitatively, and available general information is inadequate to make reliable estimates of output levels.
[e]Estimated; [p]Preliminary.

Table 6. United States consumption of molybdenum by end use, 1976

	(tonnes Mo content)
Steel	
Carbon	844
Stainless and heating resisting	2 875
Full alloys[1]	9 180
High-strength, low-alloy	1 058
Electric	54
Tool	1 378
Cast irons	1 942
Superalloys	1 239
Alloys[2]	
Welding and alloy hard-facing rods and materials	186
Other alloys[3]	346
Mill products made from metal powder	1 490
Chemical and ceramic uses	
Pigments	574
Catalysts	836
Other	501
Miscellaneous and unspecified	380
Total	22 883

Source: United States Bureau of Mines, Minerals Yearbook, 1976 Preprint.
[1]A steel in which the maximum of the range given for the content of alloying elements exceeds one or more of the following limits: Mn, 1.65 per cent; Si, 0.60 per cent; Cu, 0.60 per cent. [2]Excludes steels and superalloys. [3]Includes magnetic and nonferrous alloys.

Table 5. World forecast of molybdenum supply and demand, 1978-85

	1978	1979	1980	1985
	(million kilograms Mo)			
Supply				
United States	66.70	71.20	77.10	99.80-113.40
Canada[1]	15.10	14.25	14.50	18.80- 22.70
Chile	10.90	11.80	11.80	17.20- 19.10
Others	1.80	1.35	1.35	1.40- 11.30
Total	94.50	98.60	104.75	137.20-166.50
Demand				
United States	34.00	36.30	39.50	54.50
Western Europe	34.00	36.75	39.90	54.50
Japan	12.00	12.70	13.60	17.70
Canada	1.60	2.00[3]	3.50[3]	2.50
Others	6.35	6.35	6.80	7.25
Eastern Europe[2]	5.90	5.90	6.80	8.20
Total	93.85	100.00	110.10	144.65

Source: Placer Development Limited.
[1]EMR's estimate. [2]Exports to Eastern Europe. [3]Assuming that the Canadian Arctic Pipeline will be built.

Prices

While new markets were being developed by molybdenum producers in the early 1970s, the prices of molybdenum products remained almost constant in nominal terms and even declined in real terms from 1970 to 1973. However, from 1973 to date prices have increased considerably; for example molybdic oxide increased from $1.90 a pound in 1973 to $4.31 at the end of 1977. The prices were increased at a time when markets were strong in order to render economic new production developments such as the Henderson mine.

Outlook

In view of the enormous expenditures in energy-related applications, particularly oil and natural gas well drilling and pipelines, demand for molybdenum is expected to remain strong in the foreseeable future. Although production from present and new sources will increase considerably, supply will be tight, and price increases can be anticipated for 1978. In general, molybdenum producers should enjoy a healthy business climate for several years.

Prices in U.S. currency, per pound of contained molybdenum, f.o.b. shipping point, as reported in "Metals Week"

	1976[1]	1977[1]
	($/lb)	
Molybdenum concentrates		
95% MoS_2	3.45	4.01
Molybdic oxide (MoO_3)		
in cans	3.82	4.31
Ferromolybdenum, 60% Mo		
5 000-lb lots		
Climax lump	4.43	4.99
Powder[2]	4.49	. .
Dealer export (fas port)	4.60-4.75	5.65-6.40

[1]As at December 31. [2]Discontinued March 18, 1977.
. . Not available; fas Free alongside ship; fob Free on board.

Tariff profile (most favoured nation under GATT)

Item	European Economic Community	United States	Japan	Canada
Molybdenum ores and concentrates	Free	12c per lb on Mo centent	—	Free
A. Quota	—	—	Free	—
B. Other	—	—	7.5%	—
Molybdenum oxides and hydroxides	8%	10c per lb on Mo content+ 3%	—	15%
A. Molybdenum trioxide	—	—	5%[1]	—
B. Other	—	—	12.5[1]	—
Ferromolybdenum	7%	10c per lb on Mo content+ 3%	7.5%[1]	5%
Molybdates	11.2%	10c per lb on Mo content+ 3%	7.5%[1]	15%
Molybdenum carbides	9.6%	10c per lb on Mo content+ 3%	5%[1]	5%
Molybdenum metal				
A. Unwrought: powder	6%	10c per lb on Mo content+ 3%	5%[1]	Free
other	5%	10c per lb on Mo content+ 3%	5%[1]	Free
Waste and scrap	5%	10.5%[2]	5%[1]	Free
B. Wrought				
bars, angles, plates, sheets	8%	12.5%	7.5%[1]	Free
Wire	8%	12.5%	7.5%[1]	Free
C. Other	10%	12.5%	7.5%[1]	Free

Sources: Official Journal of the European Communities, Common Customs Tariff; Tariff Schedules of the United States Annotated (1978) TC Publication 843; Customs Tariff Schedules of Japan, 1977; The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa.
[1]Temporarily reduced by 20%. [2]Temporarily suspended.
GATT — General Agreement on Tariffs and Trade.

Natural Gas

W.G. LUGG

The Canadian natural gas industry experienced another successful year in 1977, particularly in terms of additions to reserves and production revenue. Production increased by 3 per cent and revenues from the sale of natural gas were at an all-time high of \$4 331 million, reflecting substantial increases in both export and domestic natural gas prices. Expenditures for exploration and development of both oil and gas, including royalty payments, escalated by \$1 595 million to \$6 812 million; most of the expenditures were made in Alberta.

Exploration reached record proportions and drilling exceeded the record level established in 1976 in both number of wells and metres drilled. Both exploratory and development drilling increased. Most drilling activity and exploratory success occurred in Alberta and accounted for 85 per cent of well completions and total metres drilled in Canada. In British Columbia and Saskatchewan, the number of wells and metres drilled also increased substantially, while drilling activity in the frontier regions and Manitoba continued to decline.

Net reservoir withdrawals increased by 3.8 per cent to 91 000 million cubic metres (m^3). Domestic markets accounted for the bulk of the increase, although volume of exports increased slightly over 1976. Export volume was up 3.8 million cubic metres per day (m^3/d) to 77.6 million m^3/d, while demand in the domestic market rose by 5.0 million m^3/d to 111.0 million m^3. Imports from the United States were negligible in 1977.

Gross additions to marketable reserves amounted to 102 965 million m^3, primarily because of extensions and revisions to existing fields in Alberta. By the end of 1977 natural gas reserves had risen to 1 684 712 million m^3, 33 737 million m^3 more than in 1976.

Pipeline construction declined slightly in 1977 despite a late upsurge in gas-gathering pipeline construction projects. The hearings conducted by the National Energy Board (NEB) relating to proposed northern pipeline construction were completed in 1977. Subsequently, the federal government, acting on most of the recommendations of the NEB, approved the application of Foothills Pipe Lines Ltd. to construct a major pipeline system connecting the Alaskan North Slope gas to southern markets. In September of 1977, the United States and Canadian federal governments signed an agreement to construct this pipeline. A record number of new gas plants were constructed in 1977, the majority of which were small capacity projects.

Outlook

Additions to gas reserves from established producing areas which fell below annual production in 1972 and 1973 are now currently well above annual consumption rates. Nevertheless, exploratory drilling will likely be maintained at a high level in the short term and probably longer, as the backlog of new discoveries recorded during the past two years is more fully evaluated and new discoveries are made.

Development drilling, which increased in 1977, will likely decline in 1978 as the demand for natural gas has not developed as quickly as forecast. The substantial surplus of heavy fuel that currently exists in many North American markets, along with the fact that natural gas prices are controlled while fuel oil prices are not, has created a situation in which this oil is curtailing market growth of natural gas in eastern Canadian markets.

In summary, there appears to be little chance in the short term that new markets will be found to absorb the surplus gas that has been accumulating in western Canadian producing centres. Therefore it is likely that annual production of natural gas in 1978 will remain stationary at 103 673 million m^3 or increase marginally.

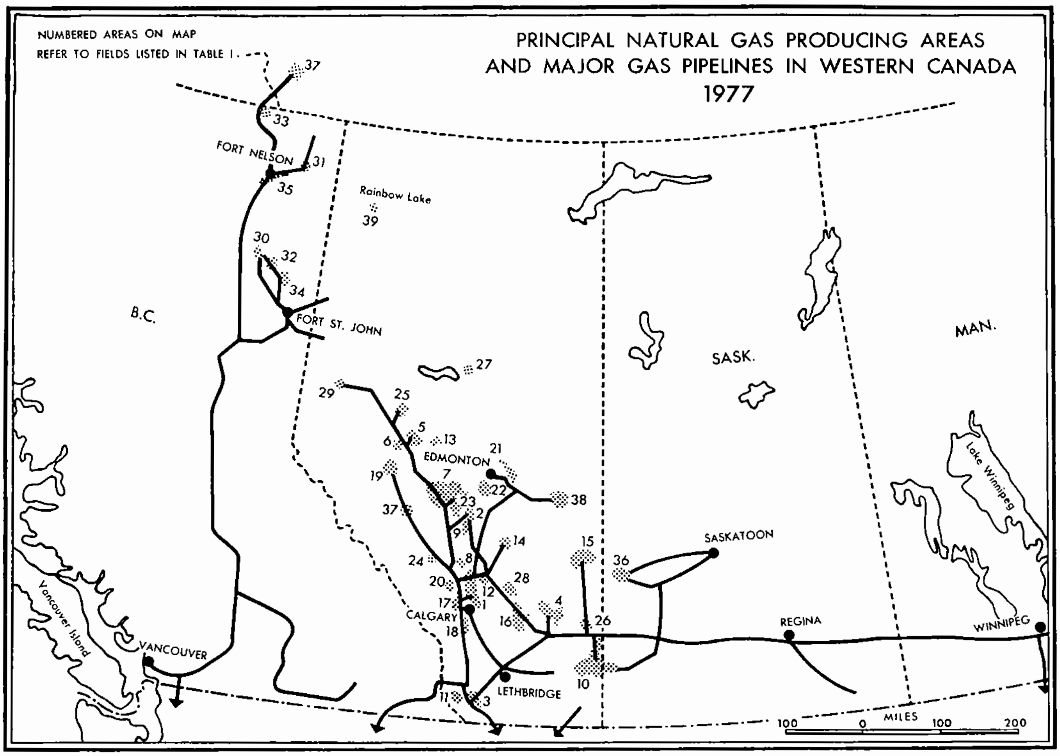
Production

In 1977 net withdrawals of natural gas amounted to 91 147 million m^3 or 250 million m^3/d for an increase of 3.8 per cent over 1976 withdrawals. Alberta continued to be the main-producing province, accounting for 86 per cent of Canada's marketable gas production. British Columbia accounted for more than 11 per cent of the total, with the balance coming from four other provinces and the Northwest Territories. The Kaybob

Table 1.Canadian natural gas fields producing 281 740 cubic metres[1] or more 1976 and 1977

(numbers in brackets refer to map locations)	1976	1977
	(000 cubic metres)[2]	
Alberta		
Kaybob South (25)	6 002 235	6 747 379
Waterton (11)	4 080 651	4 040 133
Crossfield (1)	3 663 681	3 547 425
Edson (19)	2 795 709	2 811 317
Medicine Hat (10)	3 252 704	3 479 709
Strachan (24)	2 486 844	2 347 417
Ricinus West (24)	2 709 110	2 799 802
Westerose South (2)	1 909 777	1 871 450
Brazeau River (37)	1 903 012	1 759 720
Harmattan Elkton (8)	2 011 203	2 192 334
Harmattan East (8)	1 941 003	2 034 568
Dunvegan	1 409 778	1 028 277
Homeglen-Rimbey (9)	1 274 703	1 173 224
Carstairs (12)	1 259 169	1 157 167
Gilby (9)	1 394 529	1 261 072
Crossfield East (1)	1 179 876	1 052 690
Nevis (14)	1 097 728	943 188
Jumping Pound West (17)	1 322 348	1 452 918
Marten Hills (27)	1 254 739	1 134 225
Provost (15)	1 080 917	1 183 487
Windfall (5)	996 085	1 109 681
Cessford (4)	882 374	784 202
Minnehik-Buck Lake (23)	858 756	841 542
Wildcat Hills (20)	880 202	820 372
Pembina (7)	976 632	947 259
Ferrier (8)	876 449	672 062
Sylvan Lake (2)	860 388	721 703
Bonnie Glen (22)	1 460 839	1 640 198
Alderson (10)	930 322	1 040 291
Lone Pine Creek (1)	642 731	582 151
Pine Creek (6)	723 676	624 332
Viking Kinsella (38)	538 671	1 056 492
Swan Hills (13)	644 049	538 250
Judy Creek (13)	637 554	692 975
Kaybob (25)	570 877	538 250
Rainbow (39)	661 839	653 902
Swan Hills South (13)	676 323	644 123
Ricinus	777 753	799 989
Westlock (21)	611 499	619 455
Ghost Pine (28)	438 272	361 344
Quirk Creek	543 506	579 225
Carson Creek	592 895	542 911
Burnt Timber (20)	486 090	784 918
Lookout Butte (3)	386 362	261 951
Bantry	505 024	132 281
Jumping Pound (17)	356 386	454 843
Suffield	61 436	557 297
Paddle River	264 924	440 227
Tweedie	228 786	405 961
Hotchkiss	135 512	364 739
Plain	262 598	344 183
Garrington	254 895	341 022
Verger	193 716	328 841
Cache	129 547	314 475
Twinning	228 456	305 758
Wimborne (12)	393 964	306 581
Warwick	407 505	328 522
Hussar (16)	354 630	252 976
Fort Saskatchewan (21)	299 604	175 803
Leduc-Woodbend (22)	361 250	366 790
Bindloss (26)	308 864	262 372
Bruce	257 963	396 225
Olds (12)	299 407	259 091
Medicine River	277 789	292 187
Countess (16)	312 469	370 075
Carson Creek North (13)	281 534	272 582
Wayne-Rosedale (3)	282 622	231 144
Whitecourt	292 238	218 730
Bigstone (25)	310 142	257 254
Craigend (27)	253 658	340 902
Willesden Green	284 501	285 992
Princess	504 767	1 003 246
Hairy Hill	384 783	342 530
Coleman	301 308	227 070
British Columbia		
Clarke Lake (35)	2 260 294	1 665 935
Yoyo (31)	2 018 403	1 904 121
Sierra (31)	889 791	1 015 509
Laprise Creek (30)	579 906	742 599
Rigel (34)	418 288	425 497
Buick Creek (32)	310 641	327 774
Jedney (30)	301 791	335 732
Stoddart (34)	288 779	268 557
Northwest Territories		
Pointed Mountain (37)	947 543	768 797

Sources: Provincial government reports.
[1]$m^3 \times 10^3$ = thousand cubic metres. [2]14.65 pounds per square inch absolute(psia), or 101.325 kilopascals (kPa).



South field remained the largest producer in Alberta and the Yoyo field in northeast British Columbia was that province's most productive field. New reserves in the Burnt Timber and Limestone Mountain fields in Alberta's southwestern Foothills were brought into production in 1977 and added substantially to provincial productive capabilities. In addition, a record number of smaller fields were placed on production in 1977 and it is anticipated that the large reserves of the Sukunka-Grizzly Valley trend of northeastern British Columbia will likely be placed on production in 1978.

Table 2 shows the amount of gas injected into reservoirs, either as a conservation measure to increase the ultimate recovery of liquid hydrocarbons, or as part of distributors' storage operations. The Kaybob South field is an example of a conservation scheme to maximize ultimate recovery of the liquid constituents of field gas. Here, gas is produced and processed to remove the liquid hydrocarbons and sulphur, after which most of the residual gas is reinjected to maintain pressure in the original producing reservoir. This operation is to ensure the maximum possible recovery of natural gas liquids before the reservoir is depleted by the sale of the gas. Similarly, natural gas may temporarily be reinjected into producing oil reservoirs, thereby maintaining reservoir pressure to maximize production of crude oil where this is possible. The volumes shown as distributors' storage represent gas that is stored by gas utilities during low-demand periods, usually in summer, and later withdrawn as required to meet peak demands in winter. This helps to level out the utilities' demand on the trunk carriers over the year. In Alberta and Ontario, most of the gas is stored in former-producing fields that have been depleted. However, in Saskatchewan much of the storage is in large man-made subsurface caverns that have been leached from salt beds specifically to provide storage facilities near major-consuming areas.

Exploration and development

Alberta. Both the number of wells and metres drilled increased substantially in Alberta in 1977. Drilling statistics show exploratory drilling increased 18 per cent to 2.31 million metres (m) and development drilling by 2 per cent to 2.89 million m. Successful gas completion amounted to 2 953 wells, compared to 3 193 in 1976.

The foothills of the Rocky Mountains and the deep basin areas of western Alberta continued to be the principle areas of interest for industry exploration in the established producing regions of western Canada. At least 14 significant deeper zone gas discoveries were drilled in Alberta during 1977. Amongst the most

Table 2. Pressure maintenance projects and storage of natural gas in Canada 1976 and 1977

	1976 Input	1977[p] Input		1976 Input	1977[p] Input
	(000 cubic metres)			(000 cubic metres)	
Alberta					
Aerial	8 174	11 253	Pembina	27 799	33 251
Ante Creek	42 826	45 979	Rainbow	350 677	382 141
Bellshill Lake	12 556	18 773	Rainbow South	77 694	83 421
Bigstone	1 257	476	Ricinus	398 122	444 624
Bonnie Glen	1 055 787	1 266 544	Swan Hills South	337 323	242 990
Bow Island	88 319	36 586	Turner Valley	9 347	37 614
Carson Creek	84 964	113 601	Viking Kinsella	112 880	191 750
Carbon	664 334	397 543	Waterton	421 009	311 175
Carstairs	59 666	70 211	Willesden Green	310 972	344 651
Cessford	—	1 763	Windfall	977 553	955 139
Crossfield East	26 522	66 022	Wizard Lake	390 465	517 003
Duhamel	14 635	16 321	Zama	—	170
Golden Spike	149 052	210 862	Total	11 168 573	12 673 994
Hartmattan East	1 005 437	1 224 931			
Hartmattan Elkton	1 230 932	1 556 332			
Joarcam	51 388	57 082	**Ontario**	2 989 300	462 223
Kaybob South	3 081 038	3 866 971			
Leduc-Woodbend	146 696	141 353	**Saskatchewan**	372 683	308 862
Lloydminster	8 227	4 988			
Mitsue	22 922	17 373	Total Canada		
Marten Hills	—	141	(14.73 psia)	14 530 556	13 455 079

Sources: Provincial government reports.
[p] Preliminary; — Nil.

important of these was the Pinto test, located approximately 133 km west of the Berland River field. The well has been confirmed as a Devonian Leduc reef gas discovery with more than 30 m of pay section.

In the Pass Creek area of west-central Alberta, several significant gas discoveries have been recorded during the past two years, and this is considered to be one of the most promising exploration areas in Alberta. The Viking and Gething formations are believed to be the exploration targets, but again, further evaluation must be undertaken to assess the economic significance of the discoveries. Another noteworthy discovery in the same general area was drilled in the Hanlon region late in 1976. The discovery well is reported to have encountered hydrocarbon shows in several separate zones.

In the south, PanCanadian Petroleum Limited has been carrying out an extensive exploration program in the Strathmore-Carsland area. To year-end this company had drilled 70 wells, with 52 of these being successful gas completions in multiple gas-bearing zones in Cretaceous horizons.

In the Winnefred Lake area of eastern Alberta, more than a dozen separate gas discoveries were recorded during the year. Many of these are multiple zone discoveries, production being obtained from erosional highs on subcropping Devonian formations and overlaying Cretaceous sandstones. The Primrose Lake Weapons Range encompasses an area of several hundred square miles and lies immediately to the south of Winnefred Lake. Geological data suggests that the Winnefred Lake producing trends extend into this region, and in this connection, the Alberta government has granted the Alberta Energy Company Ltd. permission to explore for and develop oil and gas within the boundaries of the Range. The execution of the agreement is subject to granting of surface access by the federal government. This area could eventually prove to be a major new gas-producing region in Alberta.

In west-central Alberta, the Elmworth-Wapiti Cretaceous gas play continued to expand in 1977. The original discovery was made by Canadian Hunter Exploration Ltd. in 1976 and since that time more than 50 successful exploratory wells have been drilled. The principal producing horizon is the Fahler conglomerate of Cretaceous age. In addition, at least six more zones in the Cretaceous have tested commercial rates of flow. By the end of 1977, the boundaries of the potentially productive area encompassed an area of 80 by 25 m and was still expanding. Although much of the

Table 3. Canada, production of natural gas, 1976 and 1977[1]

	1976		1977p	
	million cubic metres	$ 000	million cubic metres	$ 000
Gross new production				
New Brunswick	3		2	
Quebec	. . .		. . .	
Ontario	140		239	
Saskatchewan	1 903		1 678	
Alberta	85 580		89 910	
British Columbia	11 878		11 795	
Northwest Territories and Yukon	54		49	
Total, Canada	99 558		103 673	
Waste and flared				
Saskatchewan	192		196	
Alberta	934		863	
British Columbia	124		104	
Northwest Territories and Yukon	45		40	
Total, Canada	1 293		1 203	
Reinjected				
Alberta	10 441		11 276	
British Columbia	140		47	
Northwest Territories and Yukon	—		—	
Total, Canada	10 581		11 323	
Net withdrawals				
New Brunswick	3	60	2	43
Quebec	. . .	2	. . .	. . .
Ontario	140	4 860	239	10 267
Saskatchewan	1 710	12 034	1 482	13 534
Alberta	74 207	2 282 404	77 771	3 110 319
British Columbia[2]	11 614	349 657	11 644	287 620
Northwest Territories and Yukon	9	201	9	287
Total, Canada	87 683	2 649 218	91 147	3 422 070
Processing shrinkage				
Saskatchewan	39		35	
Alberta	10 819		10 924	
British Columbia	1 146		1 120	
Total, Canada	12 004		12 079	
Net new supply, Canada	75 679		79 068	

Sources: Statistics Canada and provincial government reports.
[1]14.73 psia (101.878 kPa); [2]British Columbia total includes Pointed Mountain gas produced in Northwest Territories and Beaver River gas produced in the Yukon but processed in British Columbia.
pPreliminary; — Nil; . . . Insignificant.

Table 4. Canada, production, trade and total sales of natural gas, 1966-77

		Net Withdrawals	Imports	Exports	Sales in Canada
1966	000 cubic metres	38 011 236	1 233 701	12 074 000	18 002 757
	$	179 183 990	17 592 370	108 749 931	416 212 202
1967	000 cubic metres	41 690 777	1 497 740	14 310 223	19 779 162
	$	197 983 450	19 914 301	123 663 828	454 722 005
1968	000 cubic metres	47 939 226	2 499 304	16 944 121	21 693 086
	$	225 263 658	35 392 758	153 751 558	490 767 434
1969	000 cubic metres	56 027 884	1 068 886	18 974 434	23 885 042
	$	262 332 030	16 025 449	176 187 766	537 186 938
1970	000 cubic metres	64 505 573	336 473	21 758 969	25 989 118
	$	315 099 792	5 123 896	205 988 180	582 316 948
1971	000 cubic metres	70 791 941	453 535	25 581 486	28 365 477
	$	342 548 891	7 021 000	250 719 000	641 898 026
1972	000 cubic metres	82 520 334	446 434	28 527 660	32 457 958
	$	388 500 342	7 629 000	306 843 000	740 382 930
1973	000 cubic metres	88 367 585	416 410	29 203 534	34 826 520
	$	451 853 205	7 793 000	350 745 000	797 855 930
1974	000 cubic metres	86 272 607	261 405	27 214 927	37 231 875
	$	723 766 000	5 777 000	493 640 000	980 395 000
1975	000 cubic metres	87 519 740	295 940	26 896 300	37 526 031
	$	1 520 661 000	7 830 000	1 092 168 000	1 307 287 000
1976	000 cubic metres	87 683 816	253 674	27 026 195	38 834 918
	$	2 649 218 000	8 818 000	1 616 490 000	1 895 543 000
1977^p	000 cubic metres	91 147 120	772	28 144 546	40 547 054
	$	3 422 070 000	43 000	2 028 053 000	2 303 220 000

Source: Statistics Canada.
Figures in Tables 4 and 12 differ for imports and exports because of different reporting procedures and timing.
^{p} Preliminary.

exploration data is confidential, unofficial estimates place proven reserves at 56 633 million m^3, with an ultimate reserve potential of 424 752 million m^3.

In addition to the large potential gas accumulations in the aforementioned discoveries, there exists another large gas resource that has been virtually ignored by explorationists until recently. This resource occurs in low permeability gas reservoirs such as the Milk River formation of southern Alberta and the Bluesky and Gething formations of northwest Alberta. Low permeability gas resources are generally defined as gas that has been trapped in rocks having low permeabilities, relative to more conventional gas reservoirs, and having flow capabilities ranging from nil to 8 495 m^3/day. The Milk River and Bluesky trends exemplify this type of reservoir, and although known to exist for several years, were largely passed over by explorationists until about 1973. Increased gas prices and improving well completion technology provided the incentive to industry to develop these resources to the extent that they now contribute about 283 168 million m^3 to Alberta's proven gas reserves. There is growing evidence of the probable existence of an enormous low productivity gas accumulation in the Deep Basin area of western Alberta. This area is immediately in front of the Foothills belt of Alberta and British Columbia and covers some 67 340 square kilometres (km^2). If recoverable, this gas would ultimately prove to be a major addition to Canada's energy supply.

British Columbia. Total metres drilled and the number of wells completed almost doubled in 1977. Both exploratory and development work increased, as aggregate metres drilled was up by 75 per cent to 490 324 m.

There were several significant gas discoveries made in northeast British Columbia in 1977, as drilling incentives and a modified royalty structure coupled with escalated tax write-offs for exploration costs have sparked a major return to exploratory drilling. One of

Table 5. Canada, liquids and sulphur recovered from natural gas 1966-77

	Propane	Butane	Condensate Pentanes Plus	Sulphur
	(cubic metres)	(cubic metres)	(cubic metres)	(tonnes)[1]
1966	1 983 151	1 300 062	4 668 713	1 757 209
1967	2 249 166	1 482 987	4 887 492	2 203 448
1968	2 520 818	1 656 959	5 278 723	3 090 925
1969	2 831 090	1 778 223	6 126 421	3 773 919
1970	3 382 352	2 099 228	7 019 513	4 309 041
1971	3 851 547	2 455 929	7 456 208	4 628 393
1972	4 696 619	3 093 703	9 671 111	6 723 409
1973	5 315 544	3 567 161	9 867 029	7 115 881
1974	5 268 092	3 519 638	9 413 046	6 950 327
1975	5 531 963	3 642 717	8 816 323	6 487 466
1976	5 410 000	3 583 000	7 872 000	6 442 000
1977[p]	5 512 000	3 650 000	7 712 000	6 500 040

Source: Statistics Canada and provincial government reports.
[1]The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.
[p]Preliminary.

the most important discoveries was at Dahl, north of the Beatton River area, where several significant gas discoveries were made in the Bluesky sandstone of Cretaceous age. By the end of the year the discovery area spanned several townships and was still expanding.

The Grizzly Valley area, where major gas reserves have been found, continued to command industry attention. Another discovery was made in the Monkman Pass region when the well, BP Murray *et al* D-48, tested commercial flows of gas from a zone in a Triassic formation. Further evaluation drilling will be required before the true significance of the find is known.

Elsewhere in British Columbia, Mobil Oil Canada, Ltd. discovered three new gas pools and extended the limits of the Sierra pool. The new discoveries are located immediately south of the Sierra gas field.

Yukon Territory, Northwest Territories and Arctic Islands. Exploration in the territorial regions continued at a subdued pace in 1977, as only 26 wells were drilled for a total of 80 766 m. Probably the most significant development in the mainland territories this year was the establishment of commercial production in the southern Yukon. Columbia Gas Development of Canada Ltd. drilled a successful step-out to a previous discovery, 29 km southwest of the Pointed Mountain field in the Northwest Territories. The well, Columbia *et al* Kotaneelee YT H-38, tested substantial flows of gas from Mississippian and Devonian horizons. Since the discovery is located on a large structural feature, it is anticipated that the reserve potential of the field may be quite large, although further evaluation will be required to substantiate this.Farther north in the Mackenzie Delta, Gulf Oil Canada Limited drilled a successful step-out well to the Parsons Lake field. To date 14 successful gas wells and one oil well have been drilled in the Parsons Lake field.

In the deeper water areas of the Beaufort Sea, Dome Petroleum Limited completed drilling the final well of its 1977 three-well exploratory drilling program, offshore from the Mackenzie Delta. All three wells were suspended before reaching total depth and will be completed during the 1978 summer drilling season. Preliminary evaluation indicates that all of these wells are significant discoveries, although one well, Kopanoar M-13, has not been tested. The Nektoralik K-59 well yielded substantial flows of oil and condensate from three separate zones on test, and the other confirmed discovery, Ukalerk C-50, tested a 24-m thick gas reservoir with flow rates in excess of 5 million m^3/day. Since all three of these wells are located on large structural features and may encounter other productive horizons when deepened, they could prove to be major field class discoveries. Coupled with these three finds and last years's discovery by the Tingmiark K-91 well in the same general area, Dome has identified 40 additional large structural features, within the 305-m water-depth lines, that are considered to have excellent potential for oil and gas accumulations. The three drillships used in the drilling operations will be wintered at Booth and Herchel islands before resuming Dome's drilling program in the summer of 1978.

Saskatchewan. The number of wells drilled in Saskatchewan more than doubled in 1977, and this is chiefly attributable to the improving fiscal regime for exploration companies in that province. The number of wells drilled increased from 251 to 530, and metres drilled increased from 226 297 to 434 686.Most of the

Table 6. Wells drilled by province, 1976 and 1977

	Oil		Gas		Dry[1]		Total	
	1976	1977^p	1976	1977^p	1976	1977^p	1976	1977^p
Western Canada								
Alberta	550	705	3 193	2 953	1 216	1 420	4 959	5 078
Saskatchewan	154	359	16	83	81	88	251	530
British Columbia	13	38	86	148	74	119	173	305
Manitoba	3	9	—	—	11	2	14	11
Yukon and Northwest Territories and Arctic Islands	4	—	9	8	14	18	27	26
Westcoast offshore	—	—	—	—	—	—	—	—
Subtotal	724	1 111	3 304	3 192	1 396	1 647	5 424	5 950
Eastern Canada								
Ontario	3	9	67	93	74	63	144	165
Quebec	—	—	2	—	2	6	4	6
Atlantic Provinces	—	—	—	—	2	—	2	—
Eastcoast offshore	—	—	—	—	10	2	10	2
Hudson Bay offshore	—	—	—	—	—	—	—	—
Subtotal	3	9	69	93	88	71	160	173
Total Canada	727	1 120	3 373	3 285	1 484	1 718	5 584	6 123

Source: Canadian Petroleum Association.
[1] Includes suspended and abandoned wells, but excludes service wells and miscellaneous wells.
^{p} Preliminary; — Nil.

Table 7. Metres drilled in Canada for oil and gas by province, 1976 and 1977

	Exploratory[1]		Development		All Wells[2]	
	1976	1977^p	1976	1977^p	1976	1977^p
Alberta	1 964 336	2 315 420	2 832 655	2 889 527	4 796 991	5 204 947
Saskatchewan	130 526	200 504	95 771	234 182	226 297	434 686
British Columbia	147 967	227 422	131 527	262 902	279 494	490 324
Manitoba	10 411	8 749	750	610	11 161	9 359
Territories and Arctic Islands	58 107	57 312	25 700	23 454	83 807	80 766
Westcoast offshore	—	—	—	—	—	—
Total Western Canada	2 311 347	2 809 407	3 086 403	3 410 675	5 397 750	6 220 082
Ontario	35 321	34 040	37 951	55 408	73 272	89 448
Quebec	8 543	13 233	—	—	8 543	13 233
Atlantic Provinces	3 271	—	—	—	3 271	—
Eastcoast offshore	22 793	7 742	—	—	22 793	7 742
Total Eastern Canada	69 928	55 015	37 951	55 408	10 787	110 423
Total Canada	2 864 422	2 864 422	3 124 355	3 466 083	5 505 631	6 330 505

Source: Canadian Petroleum Association.
[1] Exploratory total includes new field wildcats, new pool wildcats, exploratory part of deeper pool tests, shallower pool tests, outposts, and stratigraphic tests. [2] All wells total excludes service wells, potash wells and miscellaneous wells.
^{p} Preliminary; — Nil.

exploratory and development drilling was confined to the southwest corner of the province where the productive shallow gas trends of Alberta and Saskatchewan are located. Although these trends continue to be enlarged, there were no noteworthy discoveries of new reserves in this area.

Eastern Canada. In 1976 and 1977, exploration on the Scotian Shelf and Grand Banks was revitalized to some degree by Petro-Canada when it embarked on a multiwell drilling program, which commenced early in 1976. The program involved three separate exploration agreements with major oil companies active in the east offshore area for several years. Whether exploration activity is maintained in these areas in the future will largely depend on the success of Petro-Canada's current programs.

In Quebec, the Quebec crown corporation, Quebec Petroleum Operations Company (SOQUIP) continued its exploration program in the St. Flavien area of the St. Lawrence Lowlands. Their efforts were rewarded when their well, Soquip *et al* Lyster No. 1, recovered commercial quantities of gas from a structure located immediately south of the noncommercial St. Flavien gas field. Further drilling will be required to determine if this area will warrant further development.

In Ontario during the past year, 165 exploratory and development wells were drilled, compared to 144 in 1976. Of these, 93 were classed as gas completions. As in previous years, much of the exploratory success was confined to the Silurian pinnacle reef trend along the east flank of the Michigan Basin in Lambton County. However, in 1977 a relatively new gas-producing trend began to emerge in the Ontario portion of Lake Erie from Silurian porosity traps.

Reserves

At the end of 1977, the Canadian Petroleum Association (CPA) estimated Canada's proven reserves of marketable gas at 1 684 712 million m^3, compared to 1 650 975 million m^3 in 1976. Using the 1977 level of production of 79 000 million m^3, the life index (reserves to production ratio) declined slightly to 21.6 years. Gross additions to reserves amounted to 102 965 million m^3, including 52 452 million m^3 attributed to extensions to existing fields, 40 574 million m^3 to an upward revision to field reserves and 9 939 million m^3 to new discoveries. Much of the gain was attributable to reserve increases in Alberta, although the Territories again contributed substantially as did British Columbia. Gross additions of marketable gas in Alberta amounted to 77 296 million m^3 and most of this was due to extensions and revisions of existing fields. Gas reserves in the Territories, which included the Arctic Islands for the first time in 1975, increased by 15 523 million m^3, primarily by revisions of previous estimates. Alberta with 1 310 559 million m^3 of marketable gas reserves, accounted for 78 per cent of Canadian reserves at the end of 1977, British Columbia 11 per cent and the Territories 9 per cent.

In a recent report "The Supply and Demand for Alberta Gas" prepared by the Alberta Energy Resources Conservation Board (AERCB), Alberta's remaining recoverable reserves of natural gas to the end of 1977 were estimated to be 1 639 542 m^3. Accepting this estimate and CPA's reserve estimates for the remainder of Canada, then Canada's remaining natural gas reserves at the end of 1977 approximate 2 013 466 million m^3 for a life index of 25.5 years at 1977 production rates.

Natural gas processing

Gas-processing capacity increased in 1977 because of the addition of a record number of new plants and some expansion to existing facilities. Almost all of the new facilities constructed were in the small plant category. As natural gas prices have increased, there have been a multiplicity of new field discoveries, and older fields previously considered to be uneconomic are now being produced.

The largest single project of the year was completed by Shell Canada Resources Limited at their Burnt Timber gas field. The addition of a second plant doubled raw gas intake to 3.80 million m^3/d to produce 3.20 million m^3/d of residue gas, 52 m^3/d of pentanes plus and 425 tonnes/d of sulphur.

In new plant construction, four medium-sized plants were placed on stream this year. The largest of these was Imperial Oil Limited's plant in the Edson area, which now serves the Niton oil and gas fields. The plant is a refrigeration type which produces residue gas and a mixed liquid product. Its raw gas capacity is 0.84 million m^3/d to produce 0.80 million m^3/d of residue gas plus 95.4 m^3/d of propane mix. The second intermediate-sized plant constructed in 1977 was General Crude Oil Company's Teepee Creek plant. It was completed in late 1977 and is now processing 0.49 million m^3/d of intake gas to produce 0.45 million m^3/d of residue gas and 15 m^3/d of stabilized condensate. Petro-Canada Exploration Inc.'s Connorsville plant was the third intermediate project completed and

Table 8. Canada, estimated year-end marketable reserves of natural gas, 1976 and 1977

	1976	1977
	(million cubic metres)	
Alberta	1 292 429	1 310 559
British Columbia	189 598	186 624
Saskatchewan	23 994	23 285
Eastern Canada	8 272	12 039
Northwest Territories	136 682	152 205
Total	1 650 975	1 684 712

Source: Canadian Petroleum Association.

is now producing 0.79 million m³/d of residue gas and 14.3 m³/d of pentanes plus. CanDel Oil Ltd.'s Big Bend plant was the final medium-sized plant completed in 1977 and is now processing 0.99 million m³/d of sales gas to produce 0.97 million m³/d of residue gas.

Construction of new plants in 1977 was again primarily confined to small gas-processing units and there were several of these. Amongst the most important was Chevron Standard Limited's Joffre field plant which has a raw gas intake of 0.25 million m³/d to produce 0.23 million m³/d of residue gas and 32.4 m³/d of propane and butane mix. In the Edson field, Sabine Canada, Ltd.'s 0.23 million m³/d absorption refrigeration plant came on stream this year. This plant produces 0.20 million m³/d of residue gas and 15.7 m³/d of pentanes plus. Gulf Oil Canada Limited completed construction of three small plants in the Bashaw, Buffalo Lake and Hanna fields. The Bashaw plant recovers 0.08 million m³/d of residue gas and 6.4 m³/d of natural gas liquids mix from a raw gas intake of 0.11 million m³/d; the Buffalo Lake operation recovers 0.2 million m³/d of residue gas and 2.3 m³/d of pentanes plus from a raw gas stream of 0.2 million m³/d and the Hanna plant processes 0.08 million m³/d to recover 0.08 million m³/d of residue gas and 1.0 m³/d of pentanes plus.

Construction under way includes the expansion of Alberta Natural Gas Company Ltd.'s Cochrane straddle plant, expected to be completed by mid-1978. When completed, the plant will recover 4 134 m³/d of ethane and an additional volume of 826 m³/d of propane. At the same time, Pacific Petroleums, Ltd. is

Table 9. Canada, natural gas-processing plant capacities by field, 1977

Main Gas Field Served	Raw Gas Capacity	Residue Gas Produced	Main Gas Field Served	Raw Gas Capacity	Residue Gas Produced
	(million cubic metre/day)			(million cubic metre/day)	
Alberta					
Acheson	0.211	0.176	Countess (2 plants)	1.588	1.500
Atmore	0.370	0.370	Crossfield (2 plants)	22.910	16.414
Bantry (2 plants)	0.494	0.423	Davey	0.282	0.282
Bashaw (3 plants)	0.811	0.653	Dunvegan	8.472	8.313
Bassano	0.282	0.278			
Big Bend	1.200	1.200	East Crossfield (2 plants)	5.401	4.271
Bigoray	0.105	0.070	East Rainbow Lake	0.635	0.388
Bigstone	1.694	1.023	Edson (3 plants)	13.661	12.284
Blacke Butte	0.353	0.353	Elmora	0.423	0.423
Black Diamond	0.423	0.388	Enchant	1.059	0.988
Bonnie Glenn (2 plants)	6.707	5.718	Equity, Ghost Pine	1.059	1.023
Boundary Lake South	0.600	0.458			
Braeburn	0.211	0.176	Ferintosh	0.176	0.176
Brazeau River	6.918	6.036	Ferrier (2 plants)	3.883	3.177
Brazeau South	2.329	2.118	Ferrier South	0.706	0.670
Bruce	1.059	—	Ferrybank (3 plants)	1.235	1.164
Burnt Timber	4.800	4.024			
			Garrington (3 plants)	1.059	0.953
Cadomin	0.088	0.086	Ghost Pine	3.883	3.812
Calling Lake	0.653	0.653	Gilby (11 plants)	5.930	4.942
Carbon (2 plants)	5.683	5.506	Gilby North	0.776	0.741
Caroline (3 plants)	1.870	1.588	Gold Creek	1.976	0.529
Carson Creek	3.530	2.188	Golden Spike	3.177	reinj
Carstairs	11.790	8.825	Greencourt	1.059	0.988
Cessford (6 plants)	7.589	7.342			
Cessford North	0.247	0.211	Hanna (3 plants)	0.670	0.529
Choice	0.370	0.353	Harmattan-Elkton		
Chip Lake	0.176	0.141	(2 plants)	18.886	11.119
Chigwell (3 plants)	0.413	0.370	Harmattan-Elkton South	0.176	0.070
Connorsville	1.059	0.988	Hercules	0.105	0.105
Corbett Creek	0.317	0.317	Holmberg	0.423	0.423

Table 9. (cont'd)

Main Gas Field Served	Raw Gas Capacity	Residue Gas Produced	Main Gas Field Served	Raw Gas Capacity	Residue Gas Produced
	(million cubic metre/day)			(million cubic metre/day)	
Alberta (cont'd)					
Homeglen-Rimbey	14.932	12.602	Plain	1.412	1.412
Hotchkiss	0.635	0.617	Portage	0.706	0.688
Hussar (3 plants)	4.059	3.353	Prevo	0.176	0.141
Huxley	0.458	0.353	Princess (2 plants)	0.811	0.776
			Provost (7 plants)	5.189	4.889
Innisfail	0.706	0.458			
			Quirk Creek	3.177	2.400
Joffre (2 plants)	0.600	0.476			
Judy Creek, Swan Hills			Rainbow Lake (2 plants)	3.018	reinj[4]
(3 plants)	9.672	7.024	Redwater	0.776	0.494
Jumping Pound	8.825	7.060	Retlaw	0.247	0.247
			Ricinus	2.647	1.659
Kaybob (3 plants)	1.129	0.953	Rockyford	0.176	0.172
Kaybob South (3 plants)	29.723	5.259	Rosevear	1.094	0.917
Kessler	0.211	0.176			
Keystone (2 plants)	0.882	0.811	Savanna Creek	2.647	2.223
Killam (3 plants)	1.412	1.412	Sedalia (2 plants)	0.458	0.458
			Sibbald	0.211	0.176
Lacombe	0.176	0.176	Simonette	1.306	0.953
Lac La Biche	0.653	0.653	Sounding	0.353	0.317
Leduc Woodbend			South Lone Pine Creek	1.235	0.917
(2 plants)	1.341	1.157	Stanmore (2 plants)	0.882	0.688
Leedale	0.141	0.141	Stettler	0.141	0.141
Lone Pine Creek	2.365	1.906	Strachan D-3	9.707	7.554
			Strachan, Ricinus West	14.897	9.072
Marten Hills	4.695	3.071	Sturgeon Lake South	0.811	0.670
Marten Hills South	0.847	0.847	Swalwell (3 plants)	1.129	1.094
McLeod River	0.264	0.211	Swan Hills	0.317	0.141
Medicine River (3 plants)	3.247	2.576	Sylvan Lake (5 plants)	2.718	2.471
Mikwan North	0.529	0.458			
Minnehik-Buck Lake	3.812	3.530	Teepee Creek	0.282	0.247
Mitsue	0.741	0.529	Three Hills	0.105	0.105
Morinville (2 plants)	1.553	1.412	Three Hills Creek	0.353	0.247
			Turner Valley	1.412	1.200
Nevis, Stettler (2 plants)	7.942	6.212	Twinning, Swalwell		
Nipisi	0.882	0.494	(2 plants)	0.458	0.423
Niton	1.059	1.023			
North Twining	0.292	0.268	Virginia Hills	0.423	0.353
			Vulcan	1.941	1.553
Okotoks	1.059	0.458			
Olds (2 plants)	3.600	2.753	Waskahigan	0.564	0.458
Oyen (2 plants)	0.194	0.194	Waterton	16.520	10.978
			Wayne-Rosedale		
Paddle River	3.035	2.576	(4 plants)	3.106	2.859
Parflesh	0.070	0.070	West Paddle River	0.635	0.600
Peco (2 plants)	0.494	0.458	Whitecourt	2.294	2.153
Penhold	0.211	0.211	Wildcat Hills	3.953	3.353
Phoenix	0.105	0.105	Willesden Green		
Pembina (14 plants)	7.813	3.666	(2 plants)	0.600	0.529
Pincher Creek	3.177	2.435	Wilson Creek	0.635	0.529

Table 9. (concl'd)

Main Gas Field Served	Raw Gas Capacity	Residue Gas Produced	Main Gas Field Served	Raw Gas Capacity	Residue Gas Produced
	(million cubic metre/day)			(million cubic metre/day)	
Alberta (concl'd)					
Wimborne (2 plants)	2.259	1.765	Smiley	0.070	0.052
Windfall, Pine Creek	7.589	4.236	Steelman	1.341	1.059
Wintering Hills	0.494	0.458	Totnes	0.247	0.247
Wood River	0.176	0.176	West Gull Lake	0.529	0.494
Worsley	0.882	0.741			
			British Columbia		
Zama	0.882	0.670	Beaver River	8.472	1.059
Pipeline at Edmonton[1]	2.471	2.329	Boundary Lake (2 plants)	1.023	0.953
Pipeline at Empress[2] (2 plants)	116.493	112.327	Clarke Lake	38.831	32.123
			Fort St. John	17.650	16.061
Pipeline at Cochrane[3]	31.770	30.888			
			Ontario		
Saskatchewan			Becher	0.035	0.035
Cantuar	0.882	0.847	Corunna (2 plants)	0.176	0.176
Coleville, Smiley	1.341	1.306	Port Alma	0.564	0.564
Hatton	0.282	0.247			
Dollard	0.070	0.070	**Northwest Territories**		
Milton	0.141	0.141	Pointed Mountain	6.671	3.530

Source: *Natural Gas Processing Plants in Canada* (Operators List 7) January 1978. Department of Energy, Mines and Resources, Ottawa.
[1]Plant reprocesses gas owned by Northwestern Utilities Limited. [2]Plant reprocesses gas owned by TransCanada PipeLines Limited. [3]Plant reprocesses gas owned by exporting companies. [4]Reinjected.

adding a 3 975 m^3/d ethane recovery unit to its Empress straddle plant. Dome Petroleum Limited is expanding its Edmonton extraction plant from an intake volume of 1.98 million m^3/d to 8.9 million m^3/d. Production of residue gas will be increased to 7.4 million m^3/d and propane to 1 613 m^3/d. In addition, a 3 668 m^3/d ethane recovery plant has been added.

Future major projects in the planning stage include Shell Canada Resources Limited's gas plant in the Rosevear field. Current plans call for a raw inlet capacity of 1.16 million m^3/d to produce 0.96 million m^3/d of residue gas, 55.6 m^3/d condensate and 155 tonnes/d of sulphur; start-up date is anticipated in 1979. PanCanadian has filed an application with AERCB to construct a 1.0 million m^3/d plant on the Stoney Indian Reserve. Construction is scheduled to commence in 1978 and be completed in 1979.

In the Mackenzie Delta, Imperial Oil Limited has suspended an engineering study on a planned major gas-processing plant. The rejection of the Mackenzie Valley pipeline proposal by the federal government was given as the reason for the decision. Gulf Oil and Shell Canada gave similar reasons for decisions to suspend preliminary engineering and design work on another Delta gas plant facility.

Transportation

Pipeline construction in 1977 was down slightly from 1976, primarily because of a slowdown in the building of gas-gathering lines resulting from a lack of markets for newly discovered reserves in Alberta.

In large-diameter transmission pipeline construction, The Alberta Gas Trunk Line Company Limited was the principal contributor with 188 km of 1.06-m and 0.91-m mainline construction. Remaining large diameter construction included the addition of 91 km of 1.06-m loop (parallel) line to TransCanada's mainline in Saskatchewan; 38 km of 0.91-m loop to Westcoast Transmission Company Limited's mainline in the Fort St. John area; and 31 km of 1.05-m line by British Columbia Hydro and Power Authority in the Huntingdon area of southern British Columbia.

In the smaller diameter category, Dome Petroleum's ethane-ethylene pipeline complex was the largest pipeline project of the year. This project (Cochin Pipeline) consists of 2 896 km of 0.30-m line from Fort Saskatchewan, Alberta to Elmore, Saskatchewan; 227 km of 0.20-m ethane line from the Cochrane gas plant to Joffre; and 195 km of a combination line from the South Edmonton gas separation and ethane recovery plant to the Joffre plant and the underground storage at Fort Saskatchewan. As part of the major oil and fuel gas transmission lines required to service the Syncrude project, 260 km of 0.40-m gas transmission line from the Atmore field to the Syncrude plant was completed early in 1977. The gas will be used in upgrading raw bitumen to synthetic crude oil.

Construction of gathering line was down considerably, but construction of distribution line remained at a high level although slightly down from the previous year. Amongst the most important projects completed in the gathering-line category were those of the Alberta Energy Company Ltd. and Alberta Eastern Gas Limited in the southeastern corner of Alberta.

The series of hearings that the National Energy Board (NEB) commenced in October 1975 to determine the feasibility of building a natural gas pipeline from the mainland Arctic regions, ended in 1977. Three major proposals were examined by the NEB prior to handing down their decision. Canadian Arctic Gas Study Limited (CAGSL) proposed a 1.22-m pipeline to carry natural gas from the Alaska North Slope and the Mackenzie Delta to markets in Canada and the United States. Cost of the 3 861-km pipeline was estimated at $8-$10 billion. Foothills Pipe Lines Ltd., formed by The Alberta Gas Trunk Line Company Limited and Westcoast Transmission Company Limited, also submitted an application to the NEB to construct a pipeline from the Mackenzie Delta to the South. Their proposed 1 319-km, 1.06-m line was designed to join up with the existing distribution systems in Alberta and British Columbia and bring only Canadian gas to Canadian markets. Cost of this line was estimated between $3-$5 billion, with a addi-

Table 10. Kilometres of gas pipelines in Canada, 1972-77ᵖ

	1972	1973	1974	1975	1976	1977ᵖ
Gathering						
New Brunswick	9.7	9.7	9.7	9.7	20.8	20.8
Quebec	1.6	1.6	1.6	1.6	2.1	—
Ontario	1 828.2	2 026.1	1 825.0	1 839.5	1 992.0	1 939.1
Saskatchewan	1 483.8	1 549.8	1 208.6	1 643.1	2 290.1	2 757.2
Alberta	6 762.5	7 740.9	9 025.2	10 050.4	12 848.4	13 822.3
British Columbia	1 591.6	1 649.6	1 736.5	1 907.1	2 069.8	2 120.3
Northwest Territories and Yukon	—	—	54.7	54.7	55.0	55.0
Total	11 677.4	12 977.7	13 861.3	15 506.1	19 278.2	20 715.2
Transmission						
New Brunswick	20.9	20.9	20.9	20.9	21.6	21.6
Quebec	238.2	238.2	238.2	238.2	237.7	265.0
Ontario	7 000.6	8 410.4	9 239.2	9 224.8	9 387.8	9 345.9
Manitoba	2 558.9	2 640.9	2 645.8	2 743.9	2 743.4	2 779.0
Saskatchewan	9 649.6	10 241.9	10 513.8	10 581.4	10 614.9	10 862.5
Alberta	12 578.6	13 005.1	12 853.8	13 930.5	15 596.0	17 075.4
British Columbia	4 774.9	4 879.5	4 894.0	5 042.1	5 087.5	5 177.1
Total	36 821.7	39 436.9	40 405.7	41 781.8	43 688.9	45 526.5
Distribution						
New Brunswick	51.5	51.5	51.5	51.5	146.1	146.1
Quebec	2 724.6	2 772.9	2 764.9	2 975.7	2 890.0	2 938.9
Ontario	26 718.3	26 385.2	27 395.9	28 033.2	28 715.7	29 378.8
Manitoba	2 748.8	2 850.1	2 937.1	2 655.4	2 738.8	2 815.1
Saskatchewan	4 099.0	4 362.9	4 615.6	4 789.4	4 966.3	5 078.8
Alberta	13 932.1	14 917.0	16 523.1	18 851.9	21 554.1	25 065.1
British Columbia	9 437.2	9 957.0	8 946.3	9 285.9	9 397.6	9 789.3
Total	59 711.5	61 296.5	63 234.4	66 643.0	70 409.5	75 212.1
Total Canada	108 210.6	113 711.1	117 501.4	123 930.9	133 376.6	141 453.8

Source: Statistics Canada.
ᵖPreliminary; — Nil.

tional $2 billion required to expand existing southern systems.

A third proposal was introduced in August 1976, when a consortium headed by Foothills Pipe Lines (Yukon) Ltd. filed an application with the NEB to construct 1 324 km of 1.06-m diameter gas pipeline in the Yukon Territory as its contribution to the proposed Alaska Highway Pipeline project to carry Alaska natural gas to United States markets. The system would follow the trans-Alaska crude oil pipeline to Fairbanks, Alaska, then parallel the Alaska highway to northeastern British Columbia where it would proceed directly to southern Alberta. Here it would split, one branch proceeding southwest to cross the British Columbia-United States border near Kingsgate, to serve markets in the United States northwest; the other branch proceeding southeast to intersect the Saskatchewan-United States border where it would be routed to the United States midcontinent region. In August 1977, the federal government, acting on most of the recommendations of the NEB, and giving full consideration to the findings of the Berger and Lysyk Commissions, approved the application of Foothills Pipe Line Ltd.'s Alaska Highway Pipeline project. In September 1977, both the United States and Canadian federal governments formally signed an agreement to construct this pipeline. Initially, it will carry only Alaska gas to United States markets; however, it is anticipated that eventually gas from the Mackenzie Delta will serve southern Canadian markets, possibly via a spur line that will be constructed from the Mackenzie Delta along the route of the Dempster Highway to join the trunk line somewhere between Dawson and Whitehorse. At the present time, insufficient gas reserves have been found in the Mackenzie Delta to justify the cost of constructing this line. Although initially, the Alaska Highway Pipeline project will do little to add to Canadian energy supply, it will provide immediate economic benefits to the Canadian economy in terms of jobs and industrial expansion. The 1.21 m, 4 432-km pipeline is estimated to cost $7.8 billion in 1976 dollars, of which $4.2 billion is earmarked for the Canadian portion of the pipeline. Including connecting pipelines in mainland United States, the overall cost of the system will likely exceed $14 billion. Tentative completion date for the project is 1983.

A third Arctic pipeline project, the Polar Gas Project, proposes construction of a 3 700 km, 1.2-m, island-hopping pipeline to deliver natural gas to southern markets from the Arctic Islands. The problem is not so much one of constructing the line, although it would be difficult, but rather establishing in the islands, gas reserves large enough to sustain the economic operation of the line long enough to justify the capital expenditures required for its construction. Current industry estimates place the minimum or "threshold" reserves required at 424 000 million m^3; unofficial estimates indicate that about three-quarters of this amount has already been found. Late in the year, Polar Gas applied to the NEB for permission to construct the pipeline. A final decision on the application will likely await the NEB's decision on natural gas supply-demand hearings scheduled for 1978.

Other modes of transporting natural gas from the Arctic Islands are now under consideration. The federal government, through the national oil company, Petro-Canada, is investigating the feasibility of transporting natural gas via ice strengthened tankers from the gas fields in the high Arctic to southern markets. A pilot project has been initiated involving gas production from the Drake Point field on Melville Island being piped to a barge-mounted, 71 million m^3/day liquefaction plant on the southeast corner of the island for transportation by two LNG tankers to a degasification plant somewhere on the east coast of Canada. The other participants in the study include Panarctic Oils Ltd. and five shipping companies. The pilot project is not intended to replace the Polar Gas pipeline proposal, but to obtain production operating experience in the Arctic and test the viability of this method of transporting Arctic gas in the event that pipeline transportation proves impractical.

Late in the year, NEB approved the Tenneco, Inc. project to import Algerian liquified natural gas into Lorneville, New Brunswick and export the regasified product to the United States. In so doing it granted a license for the import and export of 34 million m^3/year of Algerian gas for a 20-year period expected to commence in 1983. In addition, the NEB granted a certificate to TransCanada PipeLines (New Brunswick) Limited to build a 106 km, 0.91-m diameter pipeline from the plant to the United States border, at a cost of $68 million.

Markets and trade

Total natural gas sales increased by 4 per cent to an estimated 68 867 million m^3 in 1977. This growth rate was equally distributed between domestic and export markets. Demand in the domestic market showed gains in all sectors and exports also increased slightly, due to emergency authorizations to United States northern states last winter that amounted to almost 1 415 million m^3.

Gas sales to domestic customers amounted to 111 million m^3/d compared to 106 million m^3/d in 1976. Demand in the industrial sector accounted for much of the increase, largely because of increased use of natural gas in Alberta's petrochemical industry. During the past year construction commenced on several major petrochemical plants in Alberta. When all of these projects come on stream, it has been estimated they will require 6 552 milion m^3 of natural gas annually for feedstock. Commercial consumption increased by 1 per cent to 23 million m^3/d, while residential demand was up 0.3 per cent to 24 million m^3/d. Revenues from the sale of natural gas in Canada were in excess of $2 303 million, up 21.5 per cent from those in the previous year. Increases in gas prices that occured on January 1,

Table 11. Canada sales of natural gas by province, 1977p

	000 cubic metres	($000)	Average $/000 cubic metres	Number of Customers Dec. 31/77
New Brunswick	2 323	230	99.01	533
Quebec	2 309 710	180 181	78.01	180 734
Ontario	18 822 972	1 305 760	69.39	1 097 958
Manitoba	1 718 792	108 812	63.31	162 475
Saskatchewan	2 883 009	140 725	48.81	203 376
Alberta	10 999 530	361 195	32.84	476 496
British Columbia	3 810 718	206 317	54.14	369 130
Total Canada	40 547 054	2 303 220	56.80	2 490 702
Previous totals				
1972	32 457 954	740 383	22.81	2 039 095
1973	34 827 379	797 856	22.91	2 131 090
1974	37 231 875	980 395	26.33	2 219 549
1975	37 526 031	1 307 287	34.84	2 300 039
1976	38 834 918	1 895 543	48.81	2 399 824

Source: Statistics Canada.
p Preliminary.

1977 and again in mid-1977 were mainly responsible for the increased revenue from domestic sales. Ontario and Alberta accounted for the bulk of the increase in Canadian consumption in 1977 and Ontario remained the largest user, consuming 46 per cent of all gas used in Canada. Alberta is the second-largest consuming province and accounted for 27 per cent of all gas marketed in Canada in 1977. Sales in British Columbia declined, and sales in New Brunswick, Manitoba, Quebec and Saskatchewan remained at about the same level as in the previous year. The remaining three provinces: Nova Scotia, Prince Edward Island and Newfoundland, do not have natural gas service.

The prospects for future growth of consumption of natural gas in eastern Canadian markets is not favourable in the short term. Growing excess refinery capacity in this region has made markets for petroleum products, particularly heavy fuel oil, highly competitive. As a result, natural gas, which has little price elasticity in the market place, has been unable to compete with fuel oils as an energy source in both the industrial and commercial sectors during the past two years. This situation is likely to be further aggravated during the next few years when two major new refineries, nearing completion in Ontario, become fully operational.

There exists, in the longer term, a substantial opportunity to expand natural gas service in Quebec and the Maritime provinces. In this connection, Pan Alberta Gas Ltd. is planning to apply to the NEB to extend the marketing of Alberta gas to all the main population centres across eastern Quebec, New Brunswick and Nova Scotia. Q & M Pipe Lines Ltd. has requested Pan Alberta, an active marketer of Alberta gas, to develop this marketing program. Q & M Pipe Lines Ltd. is owned by The Alberta Gas Trunk Line Company Limited and Petro-Canada. The project goal is to provide a market outlet for a surplus Alberta gas supply, which is expected to develop over the next eight years. When these markets develop, they could also provide part of a longer-term outlet for consumption of natural gas produced in the Canadian Arctic Islands, of which first deliveries are planned for the 1980's through the Arctic pilot project in progress under the direction of Petro-Canada.

Export sales to the United States amounted to 77.6 million m^3/d in 1977, compared to 74.0 million m^3/d in 1976. Currently authorized export volumes to the United States average about 80.4 million m^3/d, including 54.7 million m^3/d scheduled for United States westcoast markets, about 23.4 million m^3/d to midwest and eastern customers, and 2.3 million m^3/d to Montana. The possibility of increasing gas exports over existing contractural levels on a long-term basis is remote. However, in July 1977, TransCanada PipeLines Limited applied to the NEB to remove limits on six natural gas export licenses to allow the company to increase short-term gas exports. If the limitations were lifted, there would not be any increase in authorized volumes, but predeliveries on existing contracts would be possible. In effect, TransCanada would try to export as much of the developing Alberta gas surplus as existing facilities could handle during the period before Alaska gas becomes available. The additional exports would be subtracted from long-term export commitments, so total exports authorized would not increase. A decision on whether or not gas exports will be allowed to increase will likely await the findings of the NEB inquiry into current and future natural gas requirements for Canada scheduled for late 1978.

In June, the federal government announced higher prices for Canadian oil and gas, in line with the government's two-pronged energy strategy for Canada — to increase energy supplies on the one hand and to decrease growth in demand on the other. The changes reflected the majority view of provincial energy minis-

Table 12. Canada, supply and demand of natural gas

	1976		1977[p]	
	(million cubic metres)	(million cubic metres)	(million cubic metres)	(million cubic metres)
Supply				
Gross new production		99 558		103 673
Field waste and flared		−1 293		−1 203
Reinjected		−10 581		−11 323
Net withdrawals		87 684		91 147
Processing shrinkage		−12 004		12 079
Net new supply		75 680		79 068
Removed from storage	3 763		4 046	
Placed in storage	−4 303		−4 994	
Net storage		−540		−948
Total net domestic supply		75 140		78 120
Imports		115		
Total supply		75 255		78 120
Demand				
Exports		27 013		28 320
Domestic sales				
Residential	8 862		8 892	
Industrial	21 619		23 230	
Commercial	8 354		8 425	
Total		38 835		40 547
Field and pipeline use				
In production	6 206		6 517	
Pipeline	2 755		2 535	
Other	940		1 431	
Adjustment metering differences	−175		−845	
Line pack changes	115		77	
Total field and pipeline use		9 726		9 715
Gas unaccounted for		−319		−462
Total demand		75 255		78 120
Total domestic demand		48 242		49 800
Average daily domestic demand		132		136

Sources: Statistics Canada and provincial government reports.
[p] Preliminary.

ters as stated at the Federal-Provincial Conference of early May.

In respect to natural gas, the Toronto city gas price will be subject to a two-step automatic increase in the full British thermal unit (Btu) equivalent of $1.00 per barrel on each of August 1, 1977 and February 1, 1978. This will bring the Toronto city gate price for 100 per cent load factor to $1.68 and $1.85 per million Btu on the respective dates. During the second quarter of 1978 the price of natural gas will again be reviewed.

The federal government raised the price of exported natural gas on September 21, 1977 to $U.S. 2.16 per million Btu. Export prices will be reviewed again early in 1978, at which time further price increases may be introduced.

In the realm of federal initiatives, the Petroleum Corporations Monitoring Bill was introduced for Parliamentary approval on November 2, 1977. The Act has been designed to provide assurance that revenue from increased oil and gas prices is being invested by industry in greater exploration and development. Under the terms of the Act, companies will be required to file reports on a biannual basis, listing details of all sources and use of funds. Information from these sources will be made public on an industry-wide basis, but individual company information will remain confidential unless disclosure is in the public interest.

Composition and uses of natural gas

Marketed natural gas consists chiefly of methane (CH_4), but small amounts of other combustible hydrocarbons such as ethane (C_2H_6) and propane (C_3H_8) may also be present. Methane is nonpoisonous and odourless, but a characteristic odour is usually introduced into marketed natural gas as a safety measure. The heat value of natural gas averages about 1 000 Btu/ft.^{3} (37.43 kJ/m^3) of gas. Raw natural gas, as it exists in nature, may vary widely in composition. Besides the usually-predominant methane, varying proportions of ethane, propane, butane and pentanes plus may be present. Water vapour is a normal constituent. Hydrogen sulphide, although not present in some Canadian natural gas, is commonly so abundant as to be an important source of sulphur. Other nonhydrocarbon gases that may be present, usually in small amounts, are carbon dioxide nitrogen and helium.

The largest use of natural gas is as a fuel. Residentially, gas is extensively used in space and water heating and cooking, but is becoming common as a fuel for air conditioners, incinerators, dishwashers and laundry equipment. In industrial areas, natural gas has been a boon to such industries as automobile plants, iron and steel complexes, metal-working firms, glass factories and food processors. For example, in steelworking, the clean, easily-controlled flame of natural gas enables the desired temperatures to be attained in rolling, shaping, drawing and tempering steel. Natural gas is also a major source of feedstock for the chemical industry. Ethane, seldom removed from natural gas at the field processing plant in the past, has become a valuable petrochemical feedstock, and ethane recovery on a large scale is now taking place. Natural gas supplies basic raw material for ammonia, plastics, synthetic rubber, insecticides, detergents, dyes and synthetic fibres such as nylon, orlon, and terylene. Important future uses may include fuel-cells and power-generator systems driven by gas turbines.

Canada continues to be one of the world's largest producers of elemental sulphur, a byproduct recovered in the processing of sour (hydrogen sulphide) gas from fields in western Canada.

Nepheline Syenite and Feldspar

G.H.K. PEARSE

Nepheline syenite is a white to whitish-grey, medium-grained igneous rock resembling granite in texture. It consists of nepheline, potash and soda feldspar, and accessory mafic minerals such as biotite, hornblende and magnetite. Although nepheline syenite is a rock type known to occur in many parts of Canada, its development for industrial application is limited to those deposits from which iron-bearing accessory minerals can readily be removed; its major uses are in the glass and ceramics industries.

The use of nepheline syenite as a raw material for glass, ceramic and the filler industries was first developed in Canada, which was the world's sole producer for many years. Canada's only competitor in the field, Norway, began nepheline syenite mining in 1961. Although the U.S.S.R. began mining nepheline syenite on the Kola Peninsula during the 1930s, the deposit was worked for its phosphate content. Byproduct nepheline from the Kola deposit became an important source of aluminum and is still being used for this purpose. Nepheline syenite is also quarried in the United States for use as aggregate, railway ballast, jettystone and roofing granules.

Canada's nepheline syenite industry began in 1932 with the staking of five claims on Blue Mountain, 40 kilometres (km) northeast of Peterborough. A long period of persistent efforts in technical and market research and in development was necessary before this unique industry became established. Today there are two mills in operation on Blue Mountain processing rock from several quarries.

Over the years nepheline syenite has become preferred to feldspar as a source of essential alumina and the alkalis in glass manufacture. Its use results in more rapid melting of the batch at lower temperatures than with feldspar, thus reducing fuel consumption, lengthening the life of furnace refractories and improving the yield and quality. Other industrial uses for nepheline syenite include ceramic glazes, enamels, and fillers in paints, papers, plastics and foam rubber.

Feldspar is the name of a group of minerals consisting of aluminum silicates of potassium, sodium and calcium. Feldspar is used in glassmaking as a source of alumina and alkalis, in ceramic bodies and glazes, in cleaning compounds as a moderate abrasive and as a flux coating on welding rods. High-calcium feldspars, such as labradorite, and feldspar-rich rocks, such as anorthosite, find limited use as building stones and for other decorative purposes. Potash feldspar is an essential ingredient in the manufacture of high voltage porcelain insulators. Dental spar, which is used in the manufacture of artificial teeth, is a pure white potash feldspar, free of iron and mica.

Feldspar occurs in many rock types, but commercially viable deposits are mostly restricted to coarse-grained pegmatites from which the mineral is concentrated by flotation or, less commonly, by handcobbing. It is then ground to the desired size. Nearly all of the feldspar produced in Canada has come from pegmatites in the Precambrian rocks of southern Ontario and southwestern Quebec.

Canadian production and developments

Nepheline syenite production comes from two operations on Blue Mountain in Methuen Township, Peterborough County, Ontario. The deposit is pearshaped, approximately 8 km long, and up 2.4 km wide. The iron content of the rock is distributed quite uniformly, but selective quarrying, blending of quarry material, and careful pit development are necessary to ensure a mill product capable of meeting consumer specifications. In general, the nepheline syenite zone is underlain by syenites and overlain by steeply dipping biotite schists. Nepheline syenite reserves are sufficient to satisfy demand for the foreseeable future.

Indusmin Limited, a subsidiary of Falconbridge Nickel Mines Limited, is the larger producer. Shipments in 1977 were reported to be a record 366 500 tonnes*, an increase of 4 per cent over those of 1976. Ore is currently being mined from five open pits. Rock

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Canada, nepheline syenite production, exports and consumption, 1976-77

	1976		1977^p	
	(tonnes)	($)	(tonnes)	($)
Production (shipments)	540 121	10 566 411	580 000	12 160 000
Exports				
United States	404 129	7 920 000	415 477	9 117 000
United Kingdom	4 789	86 000	11 942	300 000
Netherlands	109	4 000	10 510	197 000
Australia	2 488	138 000	2 206	84 000
France	658	22 000	1 067	45 000
Italy	990	38 000	867	33 000
Spain	329	10 000	501	20 000
Japan	108	4 000	308	13 000
Other countries	1 538	58 000	882	39 000
Total	415 138	8 280 000	443 760	9 848 000
	1975		1976^p	
		(tonnes)		
Consumption[1] (available data)				
Glass and glass fibre	62 539		70 975	
Mineral wool	18 117		18 503	
Whiteware	17 281		7 664^e	
Paints	2 529		2 978^e	
Rubber products	2 347		1 608	
Others[2]	961		1 513	
Total	103 774		103 241	

Source: Statistics Canada.
[1]Total and breakdown by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa. [2]Includes porcelain enamel, paper and paper products, plastics and other minor uses.
^{p}Preliminary; ^{e}Estimated.

is blasted from the pit face and loaded by electrically powered shovels into trucks for haulage to an adjacent mill at Nephton. The mill, which was built in 1956 and expanded over time to 1 200-tonne-a-day capacity, operates on three shifts a day, seven days a week, and produces several grades of nepheline syenite to meet a wide variety of markets. The various grades produced are based on combinations of different mesh sizes and iron content. Iron-bearing minerals are almost totally removed by electromagnetic methods. Finished products are transported by rail through Havelock, Ontario, 29 km south of the mill, to domestic and export markets. The United States accounts for as much as 75 per cent of Indusmin's sales.

A major expansion of the secondary milling circuit was completed in 1976 to meet strong demand for finely ground filler and extender-grade product.

IMC Chemical Group (Canada) Ltd. (formerly Sobin Chemicals (Canada) Ltd.), a wholly-owned subsidiary of International Minerals & Chemical Corporation, operates quarries and a plant about 6 km east of Indusmin's operation.

The mill was constructed in 1956 on a part of the deposit originally staked in 1932 by the Canadian Flint and Spar Company, Limited. Present capacity is 800 tonnes a day and shipments surpassed 200 000 tonnes in 1977. The mill operates three shifts daily, seven days a week, and produces a variety of products, based on mesh sizes and iron content, suitable for many industrial uses. Rock is mined from an open pit adjacent to the mill and a certain degree of blending from various parts of the pit is required to ensure an acceptable mill feed. Ore reserves are sufficient for many years.

IMC's production is railed to Havelock, Ontario for distribution to various markets; with up to 90 per cent being exported to the United States. The company produces three grades of nepheline syenite for glass, enamel, fibre and other applications.

In 1977 total nepheline syenite shipments amounted to a record 580 000 tonnes valued at $12 160 000, a tonnage increase of 7.4 per cent from 1976 and a value increase of 15 per cent, reflecting both price increases during the year and increased sales of high-value filler, pigment extender and glass grades. This was the second consecutive year of growth in the industry after the sharp decline in 1975.

During the 1950s and 1960s, shipments increased at the rate of 17 per cent a year and 8 per cent a year, respectively. This dramatic growth was largely because of recognition by glassmakers of the superior properties, consistent quality, long-term reliable supply, and low cost of nepheline syenite, compared with feldspar. Deceleration in growth over the years has occurred as markets formerly held by feldspar are nearing the saturation point. During the first half of the present decade growth was stagnant because of several factors, including strikes in the consuming industries, shortages of rail cars, and, finally, decreasing demand.

As a result of substitution of nepheline syenite, output of feldspar declined steadily from 55 000 tonnes in 1947 to 10 000 tonnes in 1961, a level that persisted throughout the 1960s and continues to be Canada's tonnage requirement. This competition led to closure of Canada's last feldspar producer, International Minerals & Chemical Corporation (Canada) Limited's Buckingham, Quebec mine in 1972. Several local producers of high-value dental spar had delivered small tonnages to the mill at Buckingham until the closure. In 1974, one operation shipped several tonnes to Sweden and an enquiry for several hundred tonnes, following assessment of a trial shipment, was received during 1975 from a North American manufacturer.

Tantalum Mining Corporation of Canada Limited mines tantalum and lithium at Bernic Lake, Manitoba from a pegmatite containing abundant feldspar. This company could recover a clean quartz-feldspar product, should market demand warrant.

Other domestic occurrences

Nepheline syenite is known to occur in many localities in Canada but, to date, only the Blue Mountain deposit has proven amenable to economic mining and milling to produce material suitable for the glass and ceramic markets. Other occurrences are either too high in iron content or too variable in chemical composition to allow large-scale, open-pit development.

An extensive body of nepheline syenite outcrops in the Bancroft area of Ontario. Small tonnages of this material were mined from 1937 to 1942, but the product proved unacceptable because of considerable variation in the nepheline content and an over-abundance of iron-bearing accessory minerals. Tontine Mining Limited (now Coldstream Mines Limited) discontinued exploration work in 1971 on a large nepheline syenite intrusive located near Port Coldwell, Ontario, after obtaining discouraging results from petrologic and metallurgical studies.

Nepheline syenite occurs in several localities in southern British Columbia, notably in the Ice River area, near Field, and in the Big Bend area on the Columbia River.

Nepheline is a common mineral constituent in the alkaline complexes of northern Ontario and southern Quebec, but none of these deposits are, as yet, of economic significance.

Feldspar is the major mineral constituent of pegmatite dykes, which are widely distributed in Canada. Any large deposit near potential markets warrants investigation. Feldspar accompanied by byproduct silica can also be produced from granitic rocks of suitable composition by flotation.

Markets

In 1977, 76 per cent of Canada's nepheline syenite output was exported. Sales to the United States increased 2.7 per cent to 415 477 tonnes, which accounted for 93 per cent of exports. Offshore sales exceeded 28 000 tonnes, more than double that of the last two years. The United Kingdom and the Netherlands together imported 22 400 tonnes of the offshore total.

Domestic shipments increased 9 per cent to an estimated 136 000 tonnes in 1977, or 23 per cent of

Table 2. Canada, nepheline syenite production and exports, 1960, 1965, 1970, 1975-77

	Production[1]	Exports
	(tonnes)	
1960	218 301	175 357
1965	308 426	224 256
1970	454 110	351 940
1975	468 427	356 366[r]
1976	540 121	415 138
1977[p]	580 000	443 760

Source: Statistics Canada.
[1]Producers' shipments.
[p]Preliminary; [r]Revised.

Table 3. Canada, feldspar consumption, 1975-76

	1975	1976[p]
	(tonnes)	
Consumption[1] (available data)		
Whiteware	5 386	3 911
Porcelain enamel	214	124[e]
Others[2]	30	18
Total	5 630	4 053

Source: Statistics Canada.
[1]Breakdown by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa. [2]Includes artificial abrasives and other minor uses.
[p]Preliminary; [e]Estimated.

producers' shipments. Of this, about 60 per cent was used in glass and glass fibre manufacture.

In the glass industry, 15 to 20 per cent by weight of the glass batch is nepheline syenite. Material with a size range of minus 30 mesh to plus 200 mesh and with an iron content of less than 0.1 per cent is required in the production of flintglass. An iron content as high as 0.6 per cent, expressed as Fe_2O_3, is allowable for the manufacture of coloured glass. A typical chemical analysis for high-quality nepheline syenite produced in Canada for glass manufacture is:

Silica SiO_2	–	60.00
Alumina Al_2O_3	–	23.60
Iron Fe_2O_3	–	0.07
Lime CaO	–	0.30
Magnesia MgO	–	0.10
Potash K_2O	–	5.30
Soda Na_2O	–	10.20
Loss-on-ignition	–	0.50

A growing market is developing for finely ground material in the whiteware industry. The finer grades used for ceramic applications are produced by reducing the basic minus 30 mesh material in pebble mills. In ceramics, nepheline syenite is used as both a body and a glaze ingredient. High-purity material in the minus 200/plus 375 mesh size and with an iron content of 0.07 per cent Fe_2O_3, or less, is most frequently used. Products utilizing this material include bathroom fixtures, vitreous enamels for appliances, china, ovenware, electrical porcelain and ceramic artwares.

Very finely ground material is being used increasingly as a filler in plastics, foam rubber and paints. Fine-grinding down to 10 microns is accomplished in pebble- and fluid-energy mills. The very fine grain size, high reflectance and low oil absorption are important physical characteristics which make nepheline syenite an excellent filler material in the above products, vinyl, and floor and wall tile.

A low-grade nepheline syenite is sold in bulk for use in the manufacture of fibre glass and for glazing on brick and tile. Some material with high iron content is used in the manufacture of mineral wool, and as an aggregate.

Substitution of alternative materials for feldspar in ceramic manufacture has been less severe than in the manufacture of glass. The principal reason is that raw materials costs are low in the ceramic industry in relation to total manufacturing costs, and manufacturers adopt a new raw material only after cautious trial use. Further, while the higher alumina content of nepheline syenite has been a decisive factor in the replacement of feldspar in glass manufacture, a high alumina content is less critical in ceramic manufacture. In ceramics, potash feldspar is used to bind the ceramic mix into what the industry terms a "body", and in the manufacture of electric porcelain for high voltage purposes, this mineral is essential. The domestic market for feldspar appears to be firm at around 9 000 tonnes a year.

World review

The Norsk Nefelin Division of Christiania Spiegerwerk is western Europe's only producer of nepheline syenite. Operations at the plant, near Hammerfest in northern Norway, began in 1961 and increased steadily from an output of 23 000 tonnes in 1963 to 200 000 tonnes in 1973. The latest expansion, completed in 1973, raised capacity from 175 000 to 225 000 tonnes a year. The lenticular deposit is about two km long and at least 250 metres (m) deep. Unlike Canadian producers, Norsk Nefelin mines underground, drilling and blasting by conventional techniques. Nepheline syenite is supplied to the glass, ceramic and enamel industries in two main grades; glass grade is about 28 Tyler mesh, and ceramic grade is 200 Tyler mesh. The finer-mesh, ceramic-grade material is usually shipped in bags, whereas the coarser glass-grade is shipped in bulk to European markets. The company employs a modern fleet of

Table 4. Canada, feldspar production and consumption, 1960, 1965, 1970, 1975-77

	Production[1]	Exports	Consumption
	(tonnes)		
1960	12 575	2 888	6 509
1965	9 892	3 398	7 564
1970	9 667	. .	6 840
1975	—	. .	5 630
1976	—	. .	4 053
1977[p]	—	. .	. .

Source: Statistics Canada.
[1] Producers' shipments.
[p] Preliminary; — Nil; . . Not available.

Table 5. World production of feldspar, 1976-77

	1976	1977[e]
	(tonnes)	
United States	671 000	694 000
West Germany	301 000	308 000
Italy	182 000	191 000
France	165 000	172 000
Sweden	50 000	54 000
Norway	45 000	54 000
Japan	41 000	45 000
Other countries	1 130 000	1 158 000
Total	2 585 000	2 676 000

Source: U.S. Bureau of Mines, Mineral Commodity Summaries, January 1978.
[e] Estimated.

coasters on long-term charter, and ships finished products to storage and distribution centres in major market areas. Exports declined from 218 100 tonnes in 1976 to 196 300 tonnes in 1977.

Nepheline syenite is an important source of alumina for aluminum production in the U.S.S.R. Very large deposits occur near Kirovsk in the Kola Peninsula and also in the Lake Baikal region of Siberia. The Kola deposits were first mined in the 1930s for phosphate. Byproduct nepheline that contains 30 per cent Al_2O_3 is recovered for use in aluminum production. In the process used to extract alumina, limestone is added to the nepheline concentrates and the mix is sintered and treated with caustic soda to yield anhydrous alumina, soda, potash and cement. Elsewhere in the world, rising bauxite prices and concern about raw material supply have stimulated research into alternative domestic sources of alumina such as nepheline and anorthosite.

Feldspar still retains a major share of its traditional markets outside North America, although Norwegian nepheline syenite has been making headway in these markets. World production of feldspar in 1977 is an estimated 2.7 million tonnes.

Outlook

The outlook for nepheline syenite continues to be good. Although the world economy has not recovered from the recession, nepheline syenite sales have grown strongly over the last two years. Housing starts in Canada and the United States were down in 1977 but are expected to increase significantly in 1978. This industry, of course, is a major consumer of glass, sanitary-ware, paint, etc. Canadian shipments offshore, mainly to Europe, more than doubled, returning to pre-1970 levels. This is believed to be because of undercapacity at Norsk Nefelin's plant. The scope for improving Canadian sales to Europe is not great, except perhaps for fine-ground material which is not produced in Norway. However, shipments outside North America amount to only 5 per cent of Canada's sales and therefore have little effect on overall developments in the industry.

Over the last several years, the market for micronized material used as a filler and extender in plastics, paint, rubber and paper has grown more rapidly than consumption for glassmaking, and further diversification and growth of these markets is expected.

The phenomenal growth rate enjoyed by the nepheline syenite industry during the 1950s and early 1960s has moderated as markets formerly supplied by feldspar approach saturation. Since 1970, average growth has been 4 per cent. With the recovery of the glass industry and continued expansion of other uses, a growth rate of 5 to 6 per cent a year is anticipated for the medium term.

With increasing requirements for electrical energy, the demand for essential feldspar could elevate this raw material to a position of prime importance. Notwithstanding the present slackness in the economy, supply for this purpose remains tight. Rising prices and growing markets could provide an opportunity to develop a suitable Canadian deposit in the near future.

Prices

Nepheline syenite prices vary from low-purity, crushed rock, in bulk, at about $6.00 a tonne, to over $30.00 a tonne for high-purity products. The price of nepheline syenite used in the glass industry is around $18.00 a tonne fob plant. The largest export market is the United States, where entry is duty free.

United States feldspar prices in U.S. currency as quoted in "Engineering and Mining Journal," January 1978.

(per short ton, f.o.b. mine or mill, carload lots, depending on grade)

	($)
North Carolina	
40 mesh, flotation	29.00-30.50
20 mesh, flotation	20.25
200 mesh, flotation	30.75-44.00
Georgia	
200 mesh	39.50-43.30
40 mesh, granular	29.00-30.50
Connecticut	
200 mesh	32.00
20 mesh, granular	24.50

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
29600-1	Feldspar, crude	free	free	free	free
29625-1	Feldspar, ground but not further manufactured	free	7½%	30%	free
29640-1	Ground feldspar for use in Canadian manufacturers	free	free	30%	free

United States

Item No.		
522.31	Crude feldspar	free
522.41	Feldspar, crushed, ground or pulverized	3.5% ad valorem

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. Tariff Schedule of the United States, Annotated (1978) T.C. Publication 843.

Nickel

GORDON R. PEELING

Canada's production of nickel in 1977 was 235 362 tonnes* valued at $1 196.8 million compared with 240 825 tonnes valued at $1 146.5 million in 1976. World mine production is estimated at 731 762 tonnes in 1977, a 4 per cent decline from the 760 525 tonnes in 1976. During 1977, Canada, the world's largest producer of nickel, accounted for 32.2 per cent of the total, up 0.5 per cent from 1976. The U.S.S.R., with about 17.5 per cent of world production, and New Caledonia with about 15.0 per cent, were the next two largest producers. Consumption of nickel in the non-communist world in 1977 was about 445 000 tonnes, about 10 per cent below the 1976 level.

The modest upturn in demand in 1976 did not carry through into 1977. A steadily deteriorating market situation left producer inventories, by the end of the year, at record levels estimated at between 360 000 and 390 000 tonnes, equivalent to about eight-months supply at 1977 consumption rates. The widening gap between production and demand forced most producers to undertake severe measures in the fourth quarter to reduce operating rates and costs, and to announce further production curtailment plans for 1978.

There was a 33-cent-a-pound decrease in the price of nickel during the year as weak demand resulted in a chaotic pricing picture. Discounts from list prices were common and in mid-year Inco Limited announced that it would no longer publish a price list and that prices charged would be considered confidential business information.

Canadian operations and developments

Four companies mined nickel ores in Canada during 1977. The largest producer was Inco Limited which operated mines in Ontario and Manitoba. Falconbridge Nickel Mines Limited, the second-largest producer, treated ores from its mines located in the same provinces. Inco and Falconbridge each have integrated mine-concentrator-smelter and refinery complexes where they process ore to the metal stage. The two other concentrate producers, Noranda Mines Limited and Union Minière Explorations and Mining Corporation, Limited (UMEX), operated mines in Ontario.

Inco Limited is the world's largest producer of nickel. In 1977 it produced 208 200 tonnes of finished primary nickel products compared with 209 561 tonnes in 1976. In Ontario the company operated 11 mines, four concentrators, two smelters and a nickel refinery in the Sudbury district; a mine and concentrator at Shebandowan, northwestern Ontario; and a nickel refinery and additive plant at Port Colborne. In Manitoba, Inco operated three mines, one concentrator, and a smelter and refinery at Thompson. During 1977, development work was deferred at the Levack East mine, where production was scheduled to begin in 1983, as was work at the Clarabelle open-pit extension, which was scheduled to resume production in 1978. Three mines; the Totten and Murray in Ontario and the Soab in Manitoba, were maintained on a standby basis. The proven ore reserves of the company in Canada are 369 million tonnes, containing 6.3 million tonnes of nickel and 3.9 million tonnes of copper.

A new rolling mill was built by Inco in the Sudbury district. It will produce by the direct rolling of metal powders, nickel and cupro-nickel alloy strip, primarily for coinage. Construction of the $25 million facility started in March 1976 and was put into production in the second half of 1977.

Worsening market conditions coupled with increasing inventories of finished nickel products forced the company to institute a series of increasingly austere production and cost-cutting measures for the last half of 1977 and for all of 1978. In July, Inco announced that it would slow down production and allow attrition of its work force. In September, it announced that it would close the old electrolytic nickel refinery at Port Colborne, Ontario and eliminate 425 jobs out of a total

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Canada, nickel production, trade and consumption, 1976 and 1977

	1976		1977p	
	(tonnes)	($)	(tonnes)	($)
Production[1]				
All forms				
Ontario	187 436	882 305 042	185 017	931 975 000
Manitoba	53 389	264 175 193	50 345	264 868 000
Total	240 825	1 146 480 235	235 362	1 196 843 000
Exports				
Nickel in ores, concentrates and matte[2]				
United Kingdom	37 232	174 077 000	41 114	213 512 000
Norway	26 893	106 104 000	35 127	139 552 000
Japan	8 545	35 765 000	4 303	19 008 000
United States	18	56 000	4	6 000
Total	72 688	316 002 000	80 548	372 078 000
Nickel in oxide				
United States	28 683	119 565 000	16 599	73 786 000
EEC	11 582	48 956 000	12 362	47 223 000
Other countries	7 693	32 098 000	6 044	37 211 000
Total	47 958	200 619 000	35 005	158 220 000
Nickel and nickel alloy scrap				
United States	1 550	3 588 000	1 266	3 740 000
Italy	727	3 422 000	502	2 455 000
South Korea	9	40 000	70	326 000
Japan	30	99 000	73	249 000
Other countries	186	430 000	262	196 000
Total	2 502	7 579 000	2 173	6 966 000
Nickel anodes, cathodes, ingots, rods				
United States	63 849	282 539 000	50 154	239 051 000
EEC	13 636	59 719 000	17 622	32 079 000
Other countries	10 296	47 031 000	6 855	84 503 000
Total	87 781	389 289 000	74 631	355 633 000
Nickel and nickel alloy fabricated material, nes				
United States	8 994	44 171 000	12 166	70 427 000
United Kingdom	1 063	4 641 000	814	3 928 000
South Africa	23	124 000	359	2 065 000
Thailand	—	—	227	1 255 000
Australia	164	763 000	135	658 000
Netherlands	30	134 000	145	560 000
Other countries	951	4 470 000	527	2 411 000
Total	11 225	54 303 000	14 373	81 304 000

Table 1. (concl'd)

	1976		1977p	
	(tonnes)	($)	(tonnes)	($)
Imports				
Nickel in ores, concentrates and scrap				
Australia	10 362	35 010 000	10 983	36 186 000
United States	5 449	6 729 000	8 855	9 134 000
United Kingdom	8 432	6 130 000	10 223	6 052 000
Japan	—	—	1 408	4 897 000
Other countries	319	698 000	1 346	1 448 000
Total	24 562	48 567 000	32 815	57 717 000
Nickel anodes, cathodes, ingots, rods				
Norway	16 417	82 168 000	2 089	10 706 000
United States	393	1 966 000	258	1 161 000
France	5	29 000	3	29 000
West Germany	12	65 000	56	14 000
United Kingdom	2	10 000	—	—
Total	16 829	84 238 000	2 406	11 910 000
Nickel alloy ingots, blocks, rods and wire bars				
United States	478	2 560 000	549	2 912 000
Belgium and Luxembourg	—	—	26	108 000
West Germany	—	—	4	31 000
Other countries	1	7 000	4	35 000
Total	479	2 567 000	583	3 086 000
Nickel and alloy plates, sheet, strip				
United States	1 817	12 539 000	2 090	15 961 000
West Germany	147	907 000	335	2 277 000
United Kingdom	11	88 000	11	52 000
Other countries	6	26 000	1	8 000
Total	1 981	13 560 000	2 437	18 298 000
Nickel and nickel alloy pipe and tubing				
United States	718	5 817 000	1 425	11 544 000
West Germany	501	6 246 000	354	5 481 000
Sweden	184	3 546 000	54	1 393 000
Belgium and Luxembourg	1	9 000	—	—
Total	1 404	15 618 000	1 833	18 418 000
Nickel and alloy fabricated material, nes				
United States	385	3 432 000	446	4 615 000
United Kingdom	54	383 000	41	395 000
West Germany	34	171 000	198	172 000
Other countries	150	716 000	15	119 000
Total	623	4 702 000	700	5 301 000
Consumption[3]	9 972	. .	9 033	. .

Source: Statistics Canada.
[1]Refined nickel and nickel in oxides and salts produced, plus recoverable nickel in matte and concentrates exported. [2]For refining and reexport. [3]Consumption of nickel, all forms (refined metal and in oxides and salts) as reported by consumers.
pPreliminary; — Nil; . . Not available; nes Not elsewhere specified.

of 1 300 at the plant. This was followed by an October announcement of a major employment and production cutback effective February 1978. The workforce at Thompson would be reduced by 650 and at Sudbury by 2 800. Production would be suspended for four weeks commencing July 17, 1978. The planned workforce level in Canada would be about 18 700 at the end of 1978. Overseas operations were also going to be scaled down.

Falconbridge Nickel Mines Limited operated six mines, two concentrators and one smelter in the Sudbury area of Ontario. In Manitoba, the company operated the Manibridge mine and concentrator. Four mines and one concentrator in Sudbury were maintained on a stand-by basis. Development of the Fraser mine on the north rim of the Sudbury basin continued, with the shaft being completed to a depth of 1 600 metres (m). Underground development is continuing but at a reduced rate. Construction work was also resumed on the $95 million smelter plant programme to improve the environment and productive efficiency of the Sudbury operations, with completion scheduled for the spring of 1978. Development work was completed at the Lockerby mine and by March 1977 it had exceeded 60 per cent of its designed operating rate.

Falconbridge was also forced to institute measures to curtail production and costs in the face of weak demand. The company shut down its operations from September 11 to October 9 inclusive, again in November for four days, and for a week between Christmas and New Year's Day. At the end of August, the company announced that it would reduce its workforce by about 350 by the end of the year. In December, plans to shut down for seven weeks during the following summer and a further reduction of 750 jobs effective April 1, 1978 were announced.

Sherritt Gordon Mines Limited announced in October that it planned to operate its refinery at a reduced annual rate.

The effect of these measures will reduce employment at Inco by about 24 per cent from January 1977 levels and by about 26 per cent at Falconbridge. The production curtailment will result in both companies operating their plants at about 50 to 60 per cent of capacity for 1978. In 1977, Sherritt Gordon's refinery was operated at about 70 per cent of capacity and is expected to be near this level in 1978. These cutbacks became the subject of much public controversy and the Ontario government established a select committee of the legislature to look into the matter and assess the possibility of undertaking special measures to alleviate the situation. It is scheduled to report in early 1978.

Mining difficulties at the Langmuir property of Noranda Mines Limited decreased output in 1977, and closure was announced for early in 1978.

Union Minière Explorations and Mining Corporation Limited (UMEX) completed its first full year of production at its Thierry mine near Pickle Lake, Ontario in 1977. The mine was operated below planned levels because of the weak copper market. The Thierry ore contains a minor amount of nickel, which is recovered in the copper concentrate.

The syndicate of Teck Corporation Limited, Metallgesellschaft Canada Limited and Domik Exploration Limited completed the initial drilling of their nickel-copper discovery 56 kilometres (km) northwest of Timmins. The syndicate is now recalculating the ore reserves and completing a feasibility study on bringing the property into production. Ore reserves were previously estimated at 3.2 million tonnes, averaging 1.44 per cent nickel and 0.68 per cent copper.

Uranerz Exploration and Mining Limited is evaluating two uranium-nickel orebodies discovered in the Key Lake area of northern Saskatchewan in 1975 and 1976. This project is a joint venture of Uranerz, Inexco Mining Company and Saskatchewan Mining Development Corporation, a provincial Crown Corporation. Although Uranerz expects to be producing nickel at a rate of about 2 500 tonnes a year starting in 1983. this depends on the outcome of the Cluff Lake Board of Inquiry presently investigating uranium mining in northern Saskatchewan.

World developments

Non-communist world producers reduced production during the year and at year-end were operating at less than 75 per cent of capacity. Production, while decreasing slightly from 1976 levels, was significantly above demand. Demand is not expected to reach the all-time high level of 1974 for at least two more years.

Many producers announced production cutbacks in the last quarter of the year. In September, Western Mining Corporation Limited in Australia dismissed 600 of its workforce and cut nickel output about 10 per cent by closing some of its lower-grade mines in Western Australia. Société Metallurgique Le Nickel (SLN) reduced its operating rate to 70 per cent of capacity and announced that it would not increase its nickel inventories in 1978. The Shangani Mining Corporation Limited in Rhodesia, The Hanna Mining Company in the United States, and Japanese smelters all moved to reduce operating levels; the move was designed to bring inventories under control and cut costs. AMAX Nickel, Inc. and Marinduque Mining and Industrial Corporation both deferred scheduled increases in production. AMAX increased production of briquettes at its Louisiana refinery to 50 million pounds (about 23 000 tonnes) in 1977. The refinery, with a rated capacity of 80 million pounds (about 36 000 tonnes) was scheduled to operate at capacity in 1978, but AMAX announced that it would continue operating at its present rate for at least the first six months of the year. The refinery processes matte obtained from Botswana, New Caledonia and South Africa. AMAX signed an agreement with the partners in the Agnew nickel project in Western Australia, under which AMAX will purchase the mine production up to a total of 13 500 tonnes of contained nickel a

Table 2. Canada, nickel production, trade and consumption, 1960, 1965, 1970, 1975, 1976 and 1977

	Production[1]	Exports: In matte etc.	Exports: In oxide sinter	Exports: Refined metal	Exports: Total	Imports[2]	Consumption[3]
				(tonnes)			
1960	194 505	67 050	12 027	98 293	177 370	1 598	4 410
1965	235 126	74 686	37 154	122 649	234 489	11 042	8 096
1970	277 490	88 805ʳ	39 821	138 983	267 609	10 728	10 699
1975	242 180	84 391	38 527	91 161ʳ	214 079	12 847	11 308
1976	240 825	72 688	47 958	87 781	208 427	16 829	9 972
1977ᵖ	235 362	80 548	35 005	74 631	190 184	2 406	9 033

Source: Statistics Canada.
[1]Refined metal and nickel in oxide and salts produced, plus recoverable nickel in matte and concentrates exported. [2]Refined nickel, comprising anodes, cathodes, ingots, rods and shot. [3]Consumption of nickel, all forms (refined metal, and in oxides and salts), as reported by consumers.
ᵖPreliminary; . . Not available; ʳRevised.

year for ten years from the start of commercial mine production in late 1978. The Agnew mine will have an initial capacity of 9 000 tonnes of nickel contained in concentrate, which will be toll-smelted by Western Mining Corporation Limited and the matte shipped to the AMAX refinery at Port Nickel, Louisiana. Marinduque, after suffering heavy losses on its nickel operations in the last two years, announced that production levels would remain at 22 700 tonnes a year, rather than being increased to the planned level of 31 800 tonnes in 1978. The company improved its mining performance during the year but continued to experience technical difficulties at its Nonoc Island refinery.

Two new producers, both controlled by Inco, began operating in 1977. P.T. International Nickel Indonesia started production of nickel matte in March at its Soroaka, Indonesia, laterite project. Mechanical and design problems in the new smelter will limit production for the next year. Work is continuing on the second stage of the project which will triple the annual capacity from 35 million pounds (about 15 000 tonnes) to over 100 million pounds (about 45 000 tonnes) of nickel contained in a 75 per cent nickel matte. The second stage, which includes a hydroelectric plant on the Larona River, is expected to start production in 1979. In July, the Guatemalan plant of Exploraciones y Explotaciones Mineras Izabal, S.A. (Exmibal) was officially opened. The plant is expected to be operating at its rated capacity of 28 million pounds (about 13 000 tonnes) of nickel contained in matte sometime in 1978; however, it too is suffering from technical start-up problems which may keep 1978 production below planned levels.

The Selebi-Pikwe project of Bamangwato Concessions Ltd. in Botswana has overcome most of its technical problems and has been operating at about 90 per cent of capacity. The Australian Greenvale nickel project of Freeport Minerals Company and Metals Exploration N.L., which started operating in 1975, produced close to its rated annual capacity of 25 000 tonnes of nickel.

A consortium of United States Steel Corporation, Amoco Minerals Company — a subsidiary of Standard Oil Company (Indiana) — Koninklijke Hoogovens of the Netherlands, and the Indonesian government plans to begin producing about 50 000 tonnes of nickel a year in 1984 from the Gag Island deposit of P.T. Pacific Nikkel Indonesia. U.S. Steel will manage the $1 billion project, whose reserves are reported to be sufficient for 50 years of operation.

The Government of Colombia wants the Cerro Matoso deposit in that country brought into production as soon as possible. The Hanna Mining Company has a one-third interest in the project and may be joined by the Shell Group of companies in developing the deposit. No production date has been announced, but construction of a 22 700-tonne-a-year ferronickel plant is to commence in 1978. The French government has reached agreements with both Inco Limited and AMAX Inc. which could lead to two new major nickel projects in New Caledonia in the mid-1980's. La Société Metallurgique Le Nickel is continuing the expansion of its New Caledonia facilities which will increase capacity from 70 000 tonnes to 90 000 tonnes a year by 1980. Cuba is reported to be progressing with its expansion program to add 30 000 tonnes to its capacity by 1980, and an additional 60 000 tonnes of capacity by 1985.

Two mining operations on Palawan Island in the Philippines commenced operations late in 1977, with full production scheduled to be achieved in 1978 (Table 5).

Table 3. Producing Canadian nickel mines, 1977 and (1976)

Company and Location	Mill or Mine Capacity	Grade of Ore: Nickel	Grade of Ore: Copper	Ore Produced	Contained Nickel Produced	Remarks
	(tonnes ore/day)	(%)	(%)	(tonnes)	(tonnes)	
Ontario						
Falconbridge Nickel Mines Limited Falconbridge, Strathcona, Hardy Open Pit, North, Lockerby and Longvack South mines Falconbridge	11 200 (12 790) 2 720 7 710 2 360	. . (. .) (Falconbridge) (Strathcona) (Fecunis Lake)	. . (. .)	2 599 318 (2 920 568)	15 825[1] (37 928)[1]	Hardy Pit and Longvack South mine closed during 1977. North mine prepared for shutdown at year-end. All operations shut down for five weeks during second half and work force reduced.
Inco Limited Coleman, Copper Cliff North Copper Cliff South, Crean Hill, Creighton, Frood-Stobie, Garson, Levack, Levack West, Little Stobie and Victoria mines Sudbury	61 235 (59 000) 31 800 21 800 5 400 10 300	1.41[2] (1.41)[2] (Clarabelle) (Frood-Stobie) (Levack) (Crieghton)	0.98[2] (0.97)[2]	17 611 258[3] (17 962 263)[3]	141 667[4] (185 898)[4]	Victoria mine closed permanently. Copper Cliff North and Creighton No. 3 operations put on standby in early 1978. Suspension at Crean Hill scheduled for mid-1978. Levack mill operations suspended with Frood-Stobie and Clarabelle mills operations reduced.
Shebandowan mine Shebandowan	. . (2 270)	. . (. .)	. . (. .)	See above[3] (See above)[3]	See above[4] (See above)[4]	
Kanichee Mining Incorporated Temagami	— (450)	— (. .)	— (. .)	— (5 213)	— (20)	Closed 1976; declared bankruptcy in 1977 and assets sold.
Noranda Mines Limited Langmuir Township	635 (635)	1.22 (1.51)	0.05 (. .)	201 999 (250 357)	2 443 (3 175)	Mining difficulties decreased output in 1977 and closure was scheduled for early 1978.
Union Minière Explorations and Mining Corporation, Limited (UMEX) Thierry mine Pickle Lake	3 600 (3 600)	0.13 (0.10)	1.26 (1.14)	875 815 (230 610)	177 (52)	Mine operated below capacity because of depressed copper markets.

Manitoba						
Dumbarton Mines Limited	—	—	—	—	—	Mine closed mid 1976.
Bird River	(—)	(1.04)	(0.29)	(128 112)	(1 005)	
Falconbridge Nickel Mines Limited	9 070	. .	. .	46 267	See above[1]	Mine closed in April, 1977.
Manibridge mine	(9 070)	(. .)	(. .)	(188 995)	(See above)[1]	
Wabowden						
Inco Limited	12 700	See above[2]	See above	2 982 522	See above[4]	Birchtree mine closed Dec. 1977.
Birchtree, Pipe and Thompson mines	(16 700)	(See above)[2]	(See above)	(2 751 960)	(See above)[4]	Development at Pipe No. 2 shaft
Thompson						suspended.
Sherritt Gordon Mines Limited	—	—	—	—	—	Mine closed in 1976.
Lynn Lake	(3 200)	(0.97)	(0.42)	(178 980)	(1 407)	

Sources: Company annual reports, and data provided by companies.
[1]Total nickel deliveries, includes Manibridge. [2]Includes Manitoba division. [3]Includes Shebandowan. [4]Total nickel deliveries.
. . Not available; —Nil.

Table 4. Prospective Canadian nickel mines

Company and Location	Mill Capacity and Ore Grade	Year Production Expected	Destination of Nickel Concentrates	Remarks
	(%)			
Quebec				
Renzy Mines Limited, Hainault Township	900 Ni (0.69) Cu (0.72)	. .	. .	Surface buildings destroyed by fire in 1974, will have to be rebuilt.
Ontario				
Falconbridge Nickel Mines Limited, Falconbridge	. . Ni (. .) Cu (. .)		Falconbridge	
East mine				Placed on standby, 1976.
Fecunis mine				Placed on standby, 1976.
Fraser mine				Development continuing at reduced rate
Onaping mine				Placed on standby, 1976.
Onex mine				Development deferred.
Thayer Lindsley mine				Development deferred.
Inco Limited, Sudbury	. . Ni (. .) Cu (. .)		Sudbury	
Clarabelle mine		. .		Open-pit mining finished in 1974. Mining to be resumed upon development of ore extension.
Copper Cliff North mine		. .		Placed on standby, 1977.
Crean Hill mine		. .		Will be placed on standby, mid-1978.
Levack East mine		. .		Development deferred.
Murray mine		. .		Placed on standby, 1971.
Totten mine		. .		Development suspended.
Great Lakes Nickel Limited, Pardee Township	66 million tonnes reserves Ni (0.20) Cu (0.40)	. .	. .	Development to bring property on at a rate of 2.25 million tonnes of ore a year have been suspended and the project put on standby, 1974.
Teck Corporation Limited, Montcalm Township	4.5 million tonnes reserves Ni (1.4) Cu (0.66)	. .	. .	Feasibility study completed. Development decision deferred pending an improvement in nickel markets.
Manitoba				
Inco Limited, Thompson	. . Ni (. .) Cu (. .)		Thompson	
Birchtree mine		. .		Production suspended and placed on standby, 1977.
Pipe No. 2 mine		. .		Development suspended 1977.
Soab mine		. .		Placed on standby, 1971.
Saskatchewan				
Uranerz Exploration and Mining Limited Key Lake	Gaertner deposit Ni (2.67) U_3O_8 (2.84) Deilmann deposit Ni (1.21) U_3O_8 (2.11)	1983		Estimated capital cost is $200 million Gaertner reserves are about 850 000 tonnes. Deilmann reserves are about 1 000 000 tonnes.

Source: Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
. . Not available.

Table 5. Prospective world nickel producers

Country Company Mine	Annual Capacity	Announced Date of Production	Destination of Concentrates	Remarks
	(tonnes of contained Ni)			
Australia				
Selection Trust Limited and M-I-M Holdings Ltd. Agnew deposit Western Australia	10 000	1978	Kalgoorlie, W.A.; Matte to Amax	Mine development, surface plant and townsite construction started in 1976.
Brazil				
Cia Niquel Tocantins Niquelandia	5 000	1980	Own smelter	Delayed from 1978.
Cia Vale do Rio Doce Piaui State	5 400	. .	Own smelter	Company plans to build a smelter near the ore deposit — 20 million tonnes grading 1.7% nickel.
Colombia				
The Hanna Mining Company, Billiton, N.V., and Industrial Development Institute of Colombia Cerro Matoso deposit	22 500	1983-85	Own smelter	Pilot plant tests and feasibility studies complete. Negotiating with the Government and sources of finance.
Cuba				
Cuban Government Cuban deposits	30 000 60 000	1980 1985	Own smelter Own smelter	Three new plants, each of 30 000 tonnes capacity are to be brought into production by 1985.
Greece				
Société Minière et Metallurgique de Larymna S.A. (LARCO) Larymna area	12 400	1980	Own smelter	Expansion from current level of 16 200 tonnes a year.
Indonesia				
P.T. International Nickel Indonesia Soroako deposit Sulawesi Island	30 000	1979	Own smelter	The first stage was completed in late 1977 but technical problems may delay the second stage.
P.T. Pacific Nikkel Indonesia Gag Island Irian Barat	50 000	1984	Own smelter	U.S. steel will be the operator.
New Caledonia				
SLN	20 000	1981	Own smelter	The Doniambo plant is being expanded from 70 000 tonnes.
AMAX and Bureau de Recherches Geologiques et Minieres (B.R.G.M.) Tiebaghi deposit	30 000	1985	Own smelter	

Table 5. (concl'd)

Country Company Mine	Annual Capacity	Announced Date of Production	Destination of Concentrates	Remarks
	(tonnes of contained Ni)			
Republic of the Philippines				
Rio Tuba Nickel Mining Corporation Palawan Island	9 000	1978	Japan	Initial production, late 1977, shipped direct to Japan, 500 000 tonnes per year.
Infanta Minerals and Industrial Corporation Palawan Island	2 500	1978	Japan	Ships ore direct to Japan. Initial production in late 1977.
Venezuela				
Societe Le Nickel and Venezuelan Government Loma de Hierro	18 000	1985	Own smelter	
Yugoslavia				
Feni -Ruduici Kavadarci	19 000	1984	Own smelter	Will produce ferronickel with 25-40 per cent nickel content. Cost of $187 million (U.S.)
Projmetal Kasovo Mitrovica	28 500	1980	Goles smelter Rzanovo smelter	Two smelters being built at cost of $92 million (U.S.) to treat ore from Kasovo mine — 20 000 tonnes of output for export market.

Source: Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
. . Not available.

United Nations — Law of the Sea

The sixth session of the third United Nations Conference of the Law of the Sea was held in New York from May 23 to July 15, 1977. Committee I of the Conference dealt with the problem of establishing a legal regime for those areas of the ocean beyond national jurisdiction. Nickel-bearing manganese nodules which occur on the ocean floor have attracted exploration, and seabed mining has become a focal point for discussion on the type of regime that should be embodied in an international treaty. While consensus was not reached on some contentious issues, many observers feel that real progress was made in the treaty-making process. On the basis of the discussions held, a new Informal Composite Negotiating Text (ICNT) was produced at the end of the conference. During the conference many formulations were drafted in an attempt to break the deadlock between industrialized and developing countries over access by private corporations to the seabed area and the nickel production ceilings to be applied to seabed mining. The formula contained in the ICNT would place a ceiling on seabed mining equivalent to the cumulative annual increase in world demand for nickel for seven years, starting in 1980. Afterwards, the ceiling would be 60 per cent of the cumulative increase in world demand. As it is unlikely there will be commercial nickel production from the seabed prior to 1985, seabed mining would have a production target to enable it to become established. The next session of the conference is scheduled to begin March 28, 1978 in Geneva.

Uses

Nickel uses have not changed appreciably from the traditional pattern. Resistance to corrosion, high strength over a wide temperature range, pleasing appearance and suitability as an alloying agent are the chief advantages in almost all the uses of nickel.

Stainless steel is the largest single outlet for nickel, followed by nickel plating and high-nickel alloys. Stainless steel use has increased in the field of rapid transit

Table 6. World production of nickel, 1976 and 1977

	1976	1977[e]
	(tonnes)	
Canada[1]	240 825	235 362
U.S.S.R.	130 000	128 000
New Caledonia	118 900	109 100
Australia	75 400	85 800
Cuba	36 800	36 000
Dominican Republic	24 400	24 200
South Africa	22 400	23 000
Rhodesia	16 000	16 000
Indonesia	13 800	14 000
Philippine Republic	18 800	13 100
United States	12 600	12 800
Botswana	12 300	9 800
Finland	6 400	5 800
Greece	16 400	3 300
Other	15 500	15 500
Total	760 525	731 762

Sources: World Bureau of Metal Statistics, April, 1977; Statistics Canada, for Canada.
[1] Production, all forms.
[e] Estimated.

and railway car manufacture, in fertilizer and food processing machinery, in petroleum refining and in architectural applications. High-nickel alloys are used in chemical, marine, electronic, nuclear and aerospace applications.

New end-use markets which will contribute to nickel's consumption growth are nuclear generating plants, gas turbine engines for surface applications, cryogenic containers, pollution abatement equipment, barnacle-resisting copper-nickel alloy hull-plating for boats, and nickel-cadmium batteries for standby power application. Long life zinc-nickel batteries are being developed to power electric automobiles.

Prices

During the year, there was little or no relationship between listed prices and sale prices. Discounting was already common at the end of 1976. Some producers did attempt to maintain an orderly market, but intensive competition led to larger discounts and an effective lowering of the price of nickel during the year. At the end of 1976, the listed price for Class I nickel, electrolytic and briquettes was $2.41 a pound, while Class II nickel was priced from $2.27 to $2.36 a pound. However, in the last quarter of 1976, AMAX offered discounts of 15 cents a pound for the first half of 1977, and 10 cents a pound below the producers' list price for the second half of the year on orders received before December. Falconbridge and Inco offered discounts on their Class II nickel products for the first quarter of 1977 deliveries. List prices did not change, but discounting was predominant. In March, Inco reduced the price of its oxide sinter from $2.27 to $2.07 a pound, and in April lowered the list price of its cathodes and pellets from $2.41 to $2.35. In May, in what appeared as an attempt to restore order to the nickel market, Inco reverted to its first-quarter list prices: $2.41 a pound for cathodes and pellets; $2.31 a pound for Incomet, minus an 8 cent discount; and $2.27 a pound, less a 7 cent discount, for sinter. However, any stability or firming of prices was short-lived. Although producer inventories continued to rise in the second quarter, the main producers announced that effective July 1, they would be narrowing the discounts being offered on selected products, mainly Class II products. On July 25, Inco announced that it was rescinding the nickel price increase of October 1, 1976 and that prices charged would be considered confidential business information. (The company felt that its listed price became a visible target from which its competitors applied discounts). Falconbridge soon followed Inco. The problem of over-production and price cutting in the non-communist world was compounded by reports of increased communist production and sales to Western Europe at prices said to be more than 15 cents a pound below the discounted prices of non-communist producers.

At the end of November, producers, led by Western Mining, started posting what were described as firm, nonnegotiable prices through the first quarter of 1978. Amax and Falconbridge reverted to revised list prices in December, but some other producers did not. Prices in December were: electrolytic nickel, regular or A grade, $2.08 a pound; electrolytic nickel, utility or B grade, $2.06 a pound; briquettes, $2.06 a pound; ferronickel and other class II products, from $2.00 to $2.10 a pound of contained nickel, depending on the product and its contained iron. All prices quoted are on a delivered basis in United States dollars.

One side-effect of the elimination of effective producer price lists was to throw confusion into the settling of smelter and other contracts. Inco's producer price of electrolytic nickel was the basis for arriving at a price for nickel ores, mattes and other nickel products. Japanese smelters, in particular, were forced to renegotiate the pricing basis on which they would purchase ores.

Outlook

The next several years are going to be difficult ones for the industry. At present there is a large excess in productive capacity. With 1977 consumption estimated at 490 000 tonnes and installed capacity at about 820 000 tonnes, there is a large adjustment facing the industry before a balance can be restored and economic operating levels reestablished. New capacity firmly scheduled to come on-stream in the 1978 to 1983 period will exacerbate this adjustment process, particularly so in light of the expectation for slow growth in the major industrial economies.

Table 7. Actual and projected world[1] capacity to produce finished nickel products

	1973	1974	1975	1976	1977	1978	1979	1980
				(000 tonnes)				
Europe	134.5	134.5	134.5	137.5	137.5	149.0	149.0	157.5
Africa	29.0	32.0	37.0	37.0	37.0	43.0	43.0	43.0
North America	330.3	366.3	366.3	366.3	366.3	342.7	342.7	342.7
South America	2.7	2.7	2.7	2.5	2.5	2.5	2.5	12.5
Asia	120.2	155.2	164.9	172.5	171.8	171.8	182.3	182.3
Oceania	84.0	84.0	94.0	104.0	104.0	104.0	109.0	116.0
Total	700.7	774.7	799.4	819.8	819.1	813.0	828.5	854.0

Source: Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
[1] Excludes communist countries, except Yugoslavia and Cuba.

Producers are also faced with the problem of finished nickel inventories, which are about three times normal in size and must be worked down to more manageable levels. Operating rates have been cut back and unless there is a strong upsurge in demand, they may be forced to maintain production levels that are equivalent to a 60 to 65 per cent utilization rate, industry-wide. Such a capacity utilization level would have a severe financial impact on the operators, and particularly on new producers facing a heavy debt repayment schedule.

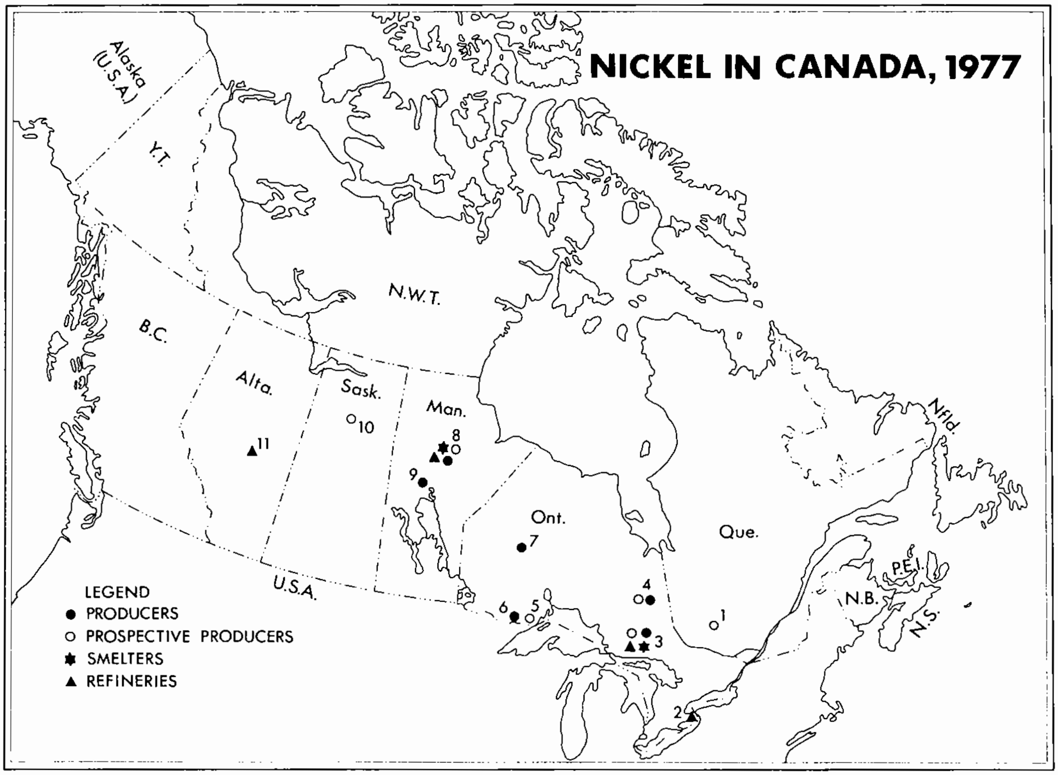
Nickel prices are expected to stabilize in 1978; further price reductions would not generate increased demand from consumers. Consumers have limited stocks and appear content to let producers carry the load. It would take a major upswing in capital spending before a shift of inventories from producer to consumer would happen. If demand for nickel in the period 1978 to 1985, using a 1976 base, grows at a rate of between 4 and 5 per cent per annum, and new projects which are firmly committed to entry during the period are not delayed, the industry will face a period of very low capacity utilization and inability to achieve plant operating economies, except at the risk of continued price instability and a squeeze on profits. There is also expected to be an increase in the availability of nickel from centrally-planned economies during this period.

In the longer term, the role that production from ocean nodules will play adds further uncertainty to prospects for the nickel industry.

Table 8. United States nickel prices, in United States dollars per pound, during 1977

	Jan. 1 Apr. 5	Apr. 6	Apr. 14	May 1	July 28	Nov. 29	Dec. 30
Major producer, cathode	2.410	2.350	2.350-2.410	2.410	n.a.	2.080	2.080
Amax, briquettes	2.410	2.410	2.350	2.350	2.410	2.410	2.060
Inco, pellets	2.410	2.350	2.350	2.410	. . .	. . .	. . .
Inco, sinter 75[1]	2.270	2.070	2.070	2.270	. . .	. . .	. . .
U.S. producer, ferronickel[1]	2.340	2.340	2.340	2.340	2.340	2.340	2.340

Source: *Metals Week.*
[1] Per pound of contained nickel.
n.a. No quote available; . . . List price suspended.



Producers, prospective producers and smelters, 1977

(numbers refer to locations on map above)

Producers

3. Falconbridge Nickel Mines Limited (Hardy open pit, Falconbridge, North, Strathcona, Lockerby and Longvack South)
   Inco Limited (Coleman, Copper Cliff North, Copper Cliff South, Crean Hill, Creighton, Frood-Stobie, Garson, Levack, Levack West, Little Stobie and Victoria Mines)
4. Noranda Mines Limited (Langmuir)
6. Inco Limited (Shebandowan mine)
7. Union Minière Explorations and Mining Corporation, Limited (Thierry Mine)
8. Inco Limited (Birchtree, Pipe and Thompson Mines)
9. Falconbridge Nickel Mines Limited (Manebridge Mine)

Prospective Producers

1. Renzy Mines Limited (Hainault Township)
3. Falconbridge Nickel Mines Limited (Fraser, Onex and Thayer Lindsley Mines)
   Inco Limited (Clarabelle, Levack East, Murray and Totten mines)
4. Teck Corporation Limited (Montcalm Township)
5. Great Lakes Nickel Limited (Pardee Township)
8. Inco Limited (Soab mine)
10. Uranerz Exploration and Mining Limited (Key Lake)

Smelters

3. Falconbridge Nickel Mines Limited (Falconbridge)
   Inco Limited (Sudbury)
8. Inco Limited (Thompson)

Refineries

2. Inco Limited (Port Colborne)
3. Inco Limited (Sudbury)
8. Inco Limited (Thompson)
11. Sherritt Gordon Mines Limited (Fort Saskatchewan)

Tariffs

Canada

Item No.		GSP[1]	British Preferential	Most Favoured Nation	General Preferential
32900-1	Nickel ores	free	free	free	free
33506-1	Nickelous oxide	10%	10%	15%	25%
35500-1	Nickel and alloys containing 60% or more nickel by weight, not otherwise provided for, viz: ingots, blocks, and shot; shapes or sections, billets, bars and rods, rolled, extruded or drawn (not including nickel processed for use as anodes); strip, sheet and plate (polished or not); seamless tube	free	free	free	free
35505-1	Rods containing 90% or more nickel, when imported by manufacturers of nickel electrode wire for spark plugs, for use exclusively in manufacture of such wire for spark plugs in their own factories	free	free	free	10%
35510-1	Metal alloy strip or tubing, not being steel strip or tubing, containing not less than 30% by weight of nickel and 12% by weight of chromium, for use in Canadian manufactures	free	free	free	20%
35515-1	Nickel and alloys containing 60% by weight or more of nickel, in powder form	free	free	free	free
35520-1	Nickel or nickel alloys, namely: matte, sludges, spent catalysts and scrap and concentrates other than ores	free	free	free	free
35800-1	Anodes of nickel	free	free	free	10%
37506-1	Ferronickel	free	free	5%	5%
44643-1	Articles of nickel or of which nickel is the component material of chief value, of a class or kind not made in Canada, when imported by manufacturers of electric storage betteries for use exclusively in manufacture of such storage batteries in own factories.	6½%	10%	10%	20%

United States

Item No.		On and after January 1, 1978
419.70	Nickel chloride	5%
419.72	Nickel oxide	free
419.74	Nickel sulphate	5%
419.76	Other nickel compounds	5%
423.90	Mixtures of two or more inorganic compounds in chief value of nickel oxide	free
426.58	Nickel salts: acetate	5%
426.62	Nickel salts: formate	5%
426.64	Nickel salts: other	5%
601.36	Nickel ore	free
603.60	Nickel matte	free
607.25	Ferronickel	free
620.03	Unwrought nickel	free
620.04	Nickel waste and scrap	free
620.08	Nickel plates and sheets, clad	12%
620.10	Other wrought nickel, not cold worked	5%
620.12	Other wrought nickel, cold worked	7%
620.16	Nickel, cut, pressed or stamped to nonrectangular shapes	9%
620.20	Nickel rods and wire, not cold worked	5%
620.22	Nickel rods and wire, cold worked	7%
620.26	Nickel angles, shapes and sections	9%
620.30	Nickel flakes	5¢ per lb
620.32	Nickel powders	free
620.40	Pipes, tubes and blanks, not cold worked	3%
620.42	Pipes, tubes and blanks, cold worked	4%
620.46	Pipe and tube fittings	9%
620.47	If Canadian article and original motor vehicle equipment	free
620.50	Electroplating anodes, wrought or cast, of nickel	5%
642.06	Nickel wire strand	7%
657.50	Articles of nickel, not coated or plated with precious metal	9%

Sources: For Canada, the Customs Tariff and Amendments, Revenue Canada, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1978) TC Publication 843.
[1]GSP — Generalized System of Preferences extended to all beneficiary developing countries; some GSP rates are subject to quotas or withdrawals.

Petroleum

W.G. LUGG

Some improvement was noted in the Canadian petroleum industry in 1977, nevertheless production continued to outstrip new additions to reserves by a wide margin. Production of crude oil and natural gas liquids decreased for the fourth consecutive year due to federally-regulated reductions in crude oil exports to the United States that commenced in 1975. Consumption of domestic crude oil increased, particularly in Quebec, as western Canadian crude oil shipments to the Montreal refining centre via the Montreal-Sarnia extension of the Interprovincial pipeline approached the rated capacity of the line.

Revenues from the sales of crude oil, natural gas liquids and natural gas increased by $1 586 million to an all-time high of $9 066 million. The 21 per cent growth rate reflects substantial increases in the well-head price of crude oil, as well as rises in both export and natural gas prices.

Crude oil and condensate accounted for $4 644 million of this total, while natural gas liquids sales amounted to $980 million. Expenditures for exploration and development for both oil and gas, including royalty payments, escalated by $1 595 million to $6 813 million. The gain in expenditures reflects a 10 per cent increase in industry activity, plus increased costs due to inflation and devaluation of the Canadian dollar.

Exploration, particularly for natural gas, surpassed the record industry activity attained in 1976. Drilling was at an all-time high — 6 123 wells being completed for a total of 6.3 million metres (m). Over 80 per cent of the drilling activity was concentrated on natural gas exploration and development. Increased exploratory drilling during 1977 resulted in a record number of new discoveries and a very high success ratio. Improved exploration techniques, primarily seismic technology, contributed to the improvement.

Most drilling activity and exploratory success occurred in Alberta, which accounted for 85 per cent of well completions and total metres drilled in Canada. In British Columbia and Saskatchewan the number of wells and metres drilled also increased substantially, while drilling activity in the frontier areas and Manitoba declined.

Refinery capacity was increased substantially in 1977, mainly because of the completion of Petrosar Limited's Sarnia petrochemical refinery complex. When fully operational, this plant will produce 18 238 cubic metres a day (m^3/d) of petroleum products and a wide range of petrochemicals from 25 438 m^3/d of western Canadian crude oil feedstock. By 1978 refinery capacity will have increased by another 23 400 m^3/d with the completion of Texaco Canada Limited's 15 100 m^3/d refinery at Nanticoke and other refinery expansions in western Canada. There has been a reduction in the growth of petroleum product demand during the last few years, caused mainly by a slowdown in economic growth, and energy conservation efforts. This has resulted in surplus refining capacity, primarily in eastern Canada. Therefore, refinery expansions during the next several years are expected to be confined to completion of projects already under way.

In oil sands development, construction of the Syncrude Canada Ltd. Athabasca tar sands project was 95 per cent complete by the end of 1977 with start-up scheduled for July, 1978. Elsewhere in the heavy oil belt, Imperial Oil Limited has applied to the Alberta Energy Resources Conservation Board (AERCB) to build and operate a major heavy oil recovery and upgrading project near Cold Lake. Farther south, in the Lloydminster area, both Pacific Petroleums Ltd. and Husky Oil Ltd. are assessing the feasibility of constructing major heavy oil upgrading plants.

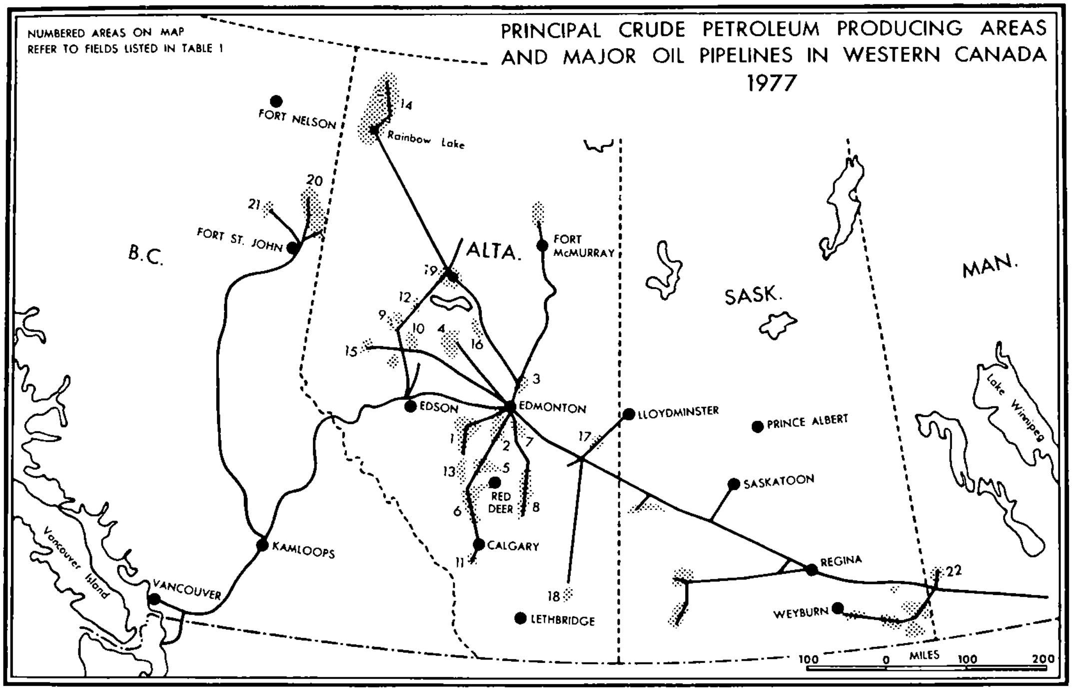
Outlook

The outlook for the Canadian oil and gas industry improved markedly in 1977 as realized potential for proving up significant amounts of new oil and gas reserves in western Canada was augmented by exploratory successes offshore in the Canadian Arctic. In 1977 significant new exploratory trends began to unfold in the West Pembina area of Alberta and offshore from the Mackenzie Delta in the Beaufort Sea. The possibility that these regions might ultimately yield significant quantities of oil in addition to gas is most timely, insofar as there has not been a major oil discovery anywhere in Canada since 1965.

During 1977, exploratory drilling reached record proportions, and from all indications activity will remain high in 1978, particularly if oil and gas prices continue to rise towards world levels.

Most of this activity was directed to natural gas exploration. Nevertheless, significant oil discoveries were made in 1977; and this is encouraging since oil reserves have been declining, and production has consistently outpaced additions to reserves since 1969. Recent exploratory successes and the incentive of possible increased netback to oil producers through improved royalty and tax structures could conceivably modify the trend of declining oil reserves, in the short term at least.

In 1978 production of crude oil will likely remain at 1977 levels or decrease marginally as exports will be reduced to about 36 000 m^3/d. The slack in production resulting from the reduction in exports will not be entirely offset by an expected increase in demand by eastern Canadian refiners and the start-up of Texaco Canada Limited's 15 103 m^3/d refining facility at Nanticoke, Ontario. Demands in the domestic market



PRINCIPAL CRUDE PETROLEUM PRODUCING AREAS AND MAJOR OIL PIPELINES IN WESTERN CANADA 1977

Table 1. Production of crude oil and condensate by province and field, 1976 and 1977
(Numbers in brackets following the names of the producing areas in this table indicate their location on the map above)

	1976		1977^p	
	(m^3)	(m^3/day)	(m^3)	(m^3/day)
Alberta				
Swan Hills (4)	6 157 591	16 824	5 540 257	15 179
Pembina (1)	5 055 094	13 812	4 732 346	12 965
Redwater (3)	4 245 492	11 600	4 203 083	11 515
Rainbow (14)	4 521 066	12 352	4 327 568	11 856
Judy Creek	3 335 651	9 114	3 284 008	8 997
Swan Hills South (4)	3 410 595	9 319	3 212 604	8 802
Bonnie Glen (2)	2 613 299	7 140	2 636 321	7 223
Mitsue (16)	2 320 220	6 339	2 310 181	6 329
Nipisi (19)	2 143 082	5 855	2 047 724	5 610
Wizard Lake (2)	1 981 761	5 415	2 017 035	5 526

Table 1. (cont'd)

	1976		1977[p]	
	(m^3)	(m^3/day)	(m^3)	(m^3/day)
Alberta (cont'd)				
Golden Spike (2)	1 345 236	3 675	1 179 055	3 230
Fenn Big Valley (8)	1 313 175	3 588	1 275 995	3 496
Virginia Hills	1 053 738	2 879	965 626	2 646
Carson Creek North (4)	1 071 238	2 927	1 087 004	2 978
Leduc-Woodbend (2)	995 498	2 611	797 102	2 184
Sturgeon Lake South	851 649	2 327	896 010	2 455
Willesden Green (13)	815 496	2 228	785 068	2 151
Kaybob (10)	640 871	1 751	615 776	1 687
Westerose (2)	646 753	1 767	635 086	1 740
Provost	594 086	1 623	586 164	1 606
Countess	512 619	1 401	744 351	2 039
Hartmattan East (6)	515 249	1 408	530 087	1 452
Innisfail (6)	411 007	1 123	434 300	1 190
Zama	483 983	1 322	452 670	1 240
Rainbow South (14)	635 326	1 736	637 460	1 746
Kaybob South (10)	615 322	1 681	575 760	1 577
Joarcam (7)	343 053	937	335 882	920
Medicine River (13)	428 922	1 172	446 688	1 224
Snipe Lake	443 828	1 213	429 165	1 176
Hartmattan Elkton (6)	421 285	1 151	442 834	1 213
Simonette (15)	351 660	961	342 159	937
Bellshill Lake	339 807	928	339 683	931
Wainwright (17)	410 854	1 123	443 248	1 214
Acheson (2)	603 386	1 649	603 633	1 654
Clive	396 725	1 084	409 819	1 123
Goose River	286 476	783	299 441	820
Bantry (18)	264 305	722	297 096	814
Red Earth	280 042	765	295 961	811
Virgo (14)	229 694	628	214 659	588
Grand Forks	337 071	921	718 814	1 969
Gilby (5)	264 940	724	268 533	736
Lloydminster	251 550	687	275 457	755
Ferrier	241 802	661	268 796	736
Sundre	215 369	588	189 053	518
Twining	243 825	666	241 506	662
Stettler	174 447	476	167 362	459
Joffre (5)	231 682	633	238 726	654
Boundary Lake South	192 803	527	202 915	556
Utikuma Lake	187 165	511	223 856	613
Meekwap	165 647	452	167 293	458
St. Albert Big Lake	161 354	441	148 834	408
Turner Valley	182 388	498	190 647	522
Cessford	184 855	505	189 218	518
Sylvan Lake	171 170	468	187 415	513
West Drumheller	126 575	346	148 274	406
Garrington	161 937	442	162 954	444
Other fields and pools	7 280 334	19 892	5 195 179	14 233
Total	63 820 046	174 371	60 592 767	166 368
Total value ($)	3 424 078 000		3 897 325 000	

Table 1. (concl'd)

	1976		1977^p	
	(m^3)	(m^3/day)	(m^3)	(m^3/day)
Saskatchewan[1]				
Total	8 912 511	24 352	9 766 609	26 758
Total value ($)	440 055 000		580 418 000	
British Columbia				
Boundary Lake (20)	1 100 206	3 006	1 065 132	2 918
Peejay	274 443	750	234 145	641
Inga (21)	265 358	725	237 581	651
Milligan Creek (20)	171 651	469	104 315	286
Weasel	149 749	409	130 850	358
Other fields and pools	424 356	1 160	427 898	1 172
Total	2 385 763	6 519	2 199 921	6 026
Total value ($)	116 597 000		134 696 000	
Manitoba				
North Virden Scallion (22)	303 270	828	291 501	799
Virden-Roselea (22)	161 220	441	163 819	449
Other fields and pools	169 233	462	175 146	480
Total	633 723	1 731	630 466	1 728
Total value ($)	33 441 000		40 433 000	
Ontario				
Total	98 572	269	98 047	269
Total value ($)	5 971 000		6 627 000	
Northwest Territories				
Total	142 453	389	156 209	428
Total value ($)	4 041 000		4 295 000	
New Brunswick				
Total	477	1	795	2
Total value ($)	24 000		40 000	
Canada				
Total[2]	75 993 545	207 633	73 446 415	201 223
Total value ($)	4 024 207 000		4 663 834 000	

Sources: Provincial government reports and Statistics Canada.
[1]Saskatchewan lists production by formation rather than by field. [2]Does not include synthetic crude oil production.
^{p} Preliminary.

will likely increase by only 3 per cent to 183 630 m^3/d next year, as conservation measures are expected to make their presence felt. Production of natural gas liquids will likely increase slightly over 1977 levels to about 47 000 m^3/d.

The National Energy Strategy for Self-Reliance, adopted by the federal government, is directed at minimizing the national economic and political risks inherent in over-dependency on imported oil. If Canada is to attain this goal, then development of indigenous energy resources in the frontier areas and the heavy oil belt of eastern Alberta and western Saskatchewan must be speeded up. To date, exploratory success in the frontier areas has been below expectations, but substantial amounts of natural gas have been found. At the same time, development of Alberta's oil sands and heavy oils has not proceeded at the pace necessary for major impact on predicted future domestic oil shortages. However, prospects for development of these resources received a major boost in 1977 when fairly firm plans for two major new projects were announced, while a third project was in the negotiation stage.

Nevertheless, Canada became a net importer of petroleum in 1976, and the gap between production and supply widened in 1977. The shortfall in indigenous oil supplies is expected to increase in the medium term, but large scale development of nonconventional oil resources and anticipated additions to reserves by new discoveries will likely limit it to between 95 000 and 130 000 m^3/d in the 1990s.

Reserves

According to the Canadian Petroleum Association (CPA) Canada's proven liquid hydrocarbon reserves, which include conventional crude oil and natural gas liquids, amounted to 1.253 billion m^3 at the end of 1977. This is comprised of 0.949 billion m^3 of crude oil and 0.304 billion m^3 after an annual production rate of 76.4 million m^3. Natural gas liquids reserves increased by 58.9 million m^3 after an annual production rate of 17.3 million m^3 because of the inclusion (for the first time) of ethane reserves in Alberta. At the 1977 annual production level of 93.8 million m^3, the life index (reserve-to-production ratio for conventional crude oil and natural gas liquids) remained at 13.3 years. There was no decrease because of the addition of ethane to natural gas liquid totals. With the exception of Alberta, the reserve position of all provinces declined. The decline in crude oil reserves in Alberta amounted to 38.3 million m^3, but this was more than compensated for by a gain of 58.9 million m^3 natural gas liquids, primarily ethane.

Table 2. Production of natural gas liquids by province, 1976 and 1977

	1976		1977[p]	
	(000 m^3)	(m^3/day)	(000 m^3)	(m^3/day)
Alberta				
Propane	5 241	14 318	5 342	14 636
Butane	3 436	9 388	3 501	9 591
Pentanes plus	7 420	20 273	7 343	20 117
Condensate	120	329	120	330
Total	16 217	44 308	16 306	44 674
Saskatchewan				
Propane	81	221	79	216
Butane	37	101	38	104
Pentanes plus	24	65	23	63
Condensate	23	62	22	60
Total	165	449	162	443
British Columbia				
Propane	88	241	91	250
Butane	110	300	111	305
Pentanes plus	167	458	180	493
Condensate	18	50	24	67
Total	383	1 049	406	1 115
Canada				
Propane	5 410	14 780	5 512	15 102
Butane	3 583	9 789	3 650	10 000
Pentanes plus	7 611	20 796	7 546	20 673
Condensate	161	441	166	457
Total	16 765	45 806	16 874	46 232
Returned to formation	6	16	5	13
Total net production	16 759	45 790	16 869	46 219

Source: Provincial government reports.
[p] Preliminary.

In Alberta, where the West Pembina and Suffield oil fields were notable discoveries in 1977, reserves attributed to new discoveries totalled only 5.0 million m^3. The reason for this relatively small addition is that calculated reserves in newly discovered reservoirs are initially only a small part of the total that may ultimately be assigned to the field. The CPA estimated Alberta's remaining recoverable reserves of crude oil at 0.82 billion m^3 and natural gas liquids at 58.9 million m^3. Together, these accounted for 88.5 per cent of Canada's proven reserves. Saskatchewan's reserves of liquid hydrocarbons declined from 104 million m^3 to 99 million m^3 in 1977 and accounted for 7.8 per cent of the national total.

Natural gas liquids from the recently discovered, but as yet unproduced, gas fields in the Mackenzie Delta, are included in the estimates; however, oil from the frontier regions is not, because discovered reserves of crude oil in the Territories are negligible and currently well beyond economic reach.

Production

Average production of crude oil, including synthetic and natural gas liquids, totalled 255 633 m^3/d — 1 per cent or 1 294 m^3/d more than in 1976. Crude oil production including synthetic crude oil, increased by 1 000 m^3/d to 209 000 m^3/d. Synthetic crude oil output was 7 237 m^3/d down 458 m^3d from the previous year. Natural gas liquids production increased slightly to 46 219 m^3/d, consisting of 21 117 m^3/d of pentanes plus and condensate and 23 102 m^3/d of propane and butane. Alberta's crude oil production of 174 380 m^3/d declined by 1 355 m^3/d and accounted for 83 per cent of total Canadian output. Saskatchewan's crude oil production at 26 698 m^3/d was up 2 228 m^3/d from 1976 and accounted for 13 per cent of the Canadian total. British Columbia's production decreased to 5 959 m^3/d and accounted for 3.0 per cent of total national production. Manitoba accounted for 0.5 per cent and Ontario and the Northwest Territories together, 0.2 per cent. Alberta, at 75 per cent of potential, was the only province that did not produce at capacity.

In the Athabasca tar sands area, production at the Great Canadian Oil Sands Limited's oil extraction plant, the only one yet completed, declined in 1977 to 7 237 m^3d. A lengthy downtime, resulting from a major maintenance operation, was responsible for the decline. However, early in 1978 the federal government, in order to encourage oil sands development, announced that it would allow Great Canadian to charge the world price for its synthetic oil production once it proceeds with a planned expansion of its oil sands plant. It is now anticipated that Great Canadian will expand its operation by 2 384 to 3 179 m^3d to qualify for the world price on its production. Once the expansion has been completed, all production from the plant will qualify for the world price. Expanded and more rapid development of Canada's oil sands resources is a cornerstone of Canada's overall energy strategy. To this end, the Alberta, Saskatchewan and federal governments will likely provide a more lenient fiscal regime in 1978 for future oil sand developers.

Table 3. Value of natural gas liquids, 1976 and 1977

	1976	1977[p]
	($000)	
Alberta	783 321	948 411
Saskatchewan	7 674	8 764
British Columbia	16 382	23 175
Total	807 377	980 350
Volume (000 m^3)	16 773	16 870

Source: Statistics Canada.
[p] Preliminary.

Exploration and development

Alberta. The record level of exploratory activity attained in 1976 continued in 1977 as the number of wells drilled increased by 2.3 per cent. Total number of wells drilled in all categories amounted to 5 078, for an aggregate depth of 5 200 000 metres. This is 407 000 metres more than was drilled in 1976. Most of the increase occurred in the exploratory category.

The highlight of exploration in 1977 was the discovery of oil in the West Pembina area of central Alberta. The discovery was made by Chevron Standard Limited in what was confirmed as an isolated Devonian (Nisku) pinnacle reef. The discovery well encountered 59 m gross pay and on test, the well flowed up to 506 m^3/d of 41.3 gravity crude oil. Since the initial discovery, 25 more exploratory wells have unofficially been reported to have encountered oil or gas in similar reef structure at depths in the 3 352 to 3 652 range. At year-end, over 30 exploratory wells were either drilling or being evaluated in the West Pembina area. No estimates have been given of the areal extent of the reefs or the ultimate limits of the producing trend. Nevertheless, the Nairb well is undoubtedly the most significant new oil discovery made in Alberta during the past 12 years and has initiated a major new cycle of oil exploration.

In the heavy oil producing region of southeastern Alberta, Westcoast Petroleum Ltd. has achieved considerable success on the 105 000-acre Suffield Area "A" block held by the Alberta Energy Company Ltd. and in which Westcoast has earned a 30 per cent working interest in all "deep" rights. Westcoast announced that the 91 deep-zone wells drilled to date on the Suffield "A" block have successfully identified 13 separate oil pools and 19 separate gas pools. In several instances multiple zone discoveries occur in a single well. Of the 91 exploratory wells, 50 have been completed as oil wells and 11 as gas wells. Unofficially, it has been estimated that more than 300 million barrels of heavy crude oil, similar to Lloydminster type crude, have been found in the Suffield Block. Approximately 10 per cent of this oil can be recovered by primary and secondary recovery methods, but it is anticipated the recovery factor will eventually be raised substantially by tertiary recovery techniques.

Elsewhere in Alberta, several additional oil discoveries were made, but all of them would appear to be relatively insignificant.

In oil field development, most of the development drilling was confined to gas field development, as no significant oil discovery was made in Alberta until 1977. Much of the oil field development was restricted to the heavy oil producing trend that straddles the Saskatchewan-Alberta border. Some infill drilling was carried out in the Wainwright field while farther south, step-out drilling enlarged the boundaries of the newly discovered heavy oil fields in the Suffield Block.

In oil sands development, construction of the $2.15 billion Syncrude Canada Ltd. Athabasca tar sands project was 95 per cent complete by the end of 1977. When fully operational, the 19 875 m^3/d facility will employ two production trains. The first will go on stream in July 1978, with output expected to reach 12 719 m^3/d by September the same year. The second train is scheduled to be operational 12 to 18 months later, increasing production to about 17 170 m^3/d. Full production of 19 875 m^3/d is expected between 1980 and 1982. During 1977, preliminary discussions were held between officials of the federal, Alberta and Saskatchewan governments relative to a fiscal regime that would encourage further company development of the tar sands and heavy oil areas. In this connection, Shell Canada Limited announced early in 1978 that 10 companies have expressed interest in joining them to resolve with governments the terms and conditions that will enable them to develop a third oil sands mining project in the Athabasca region.

Development of the huge oil sand resources of the Cold Lake area, located about 289 kilometres (km) east of Edmonton, is also progressing. Imperial Oil Limited, in November 1977, applied to the Alberta Energy Resources Conservation Board (AERCB) to build and operate a major heavy oil recovery and upgrading project near Cold Lake. Initially, the heavy asphaltic oil, which is too thick to flow in its natural state, would be recovered at a rate of 25 438 m^3/d by a thermal method from a depth of 457 m. Once recovered, the heavy oil would be converted by a new upgrading facility to between 19 078 and 23 053 m^3/d of high-grade synthetic crude oil. The synthetic crude oil would then be further processed by existing Canadian refineries into a broad range of petroleum products. This project, when completed, would bring to fruition more than a decade of laboratory and field research by Imperial costing more than $40 million. Total cost of the project is estimated at $4 billion; and following government approval, construction could start by 1981 and be completed by 1985.

Farther south, Husky Oil Ltd. has tentatively proposed construction of a 15 898 m^3/d heavy crude oil upgrading facility in Lloydminster, Alberta. The plant is designed to upgrade Lloydminster, Cold Lake and possibly other heavy crude oils for ready processing by most existing Canadian refineries without additional capital costs or modifications. Petro-Canada and a group of companies headed by Pacific Petroleums Ltd. also have plans for heavy oil resource development and upgrading plants.

Table 4. Canada, crude oil production, trade and refinery receipts, 1966-77

	Production	Imports[1]	Exports[1]	Refinery Receipts[2] Domestic	Refinery Receipts[2] Imports	Refinery Receipts[2] Totals
			(m^3)			
1966	50 962 233	23 224 372	19 665 353	35 008 467	24 206 931	60 215 398
1967	55 851 019	27 152 643	23 902 877	35 703 749	25 938 587	61 642 336
1968	60 319 190	28 258 178	26 628 460	37 549 362	28 187 357	65 736 719
1969	65 342 179	30 704 398	31 374 672	38 480 450	30 283 755	68 764 205
1970	73 321 772	33 011 020	38 299 028	41 172 360	33 123 391	74 295 751
1971	78 339 251	38 947 402	43 049 070	41 851 685	38 828 645	80 680 330
1972	89 347 195	44 781 024	54 254 874	43 441 393	45 908 256	89 349 649
1973	104 272 315	52 056 975	66 784 203	47 715 892	49 491 498	97 207 390
1974	97 741 735	46 290 090	53 015 317	55 249 631	47 582 182	102 831 813
1975	82 802 176	47 415 986	41 727 024	50 963 152	47 776 787	98 739 939
1976	76 075 000	43 929 995	29 029 963	56 455 301	41 871 323	98 326 624
1977[p]	76 447 000	39 592 771	19 783 048	65 420 176	38 818 721	104 238 897

Source: Statistics Canada.
[1] Trade of Canada (SC) data. [2] Includes condensate and pentanes plus.
[p] Preliminary.

Table 5. Canada, year-end reserves of crude oil, 1976 and 1977

	1977	% of Total 1976	% of Total 1977	Net change 1977 over 1976
	(000 m^3)			(000 m^3)
Alberta	818 816	86.2	86.3	−38 282
Saskatchewan	97 455	10.3	10.3	−5 143
British Columbia	20 235	2.2	2.1	−1 275
Northwest Territories	5 997	0.6	0.6	−159
Manitoba	5 252	0.6	0.5	−559
Eastern Canada	1 538	0.1	0.2	−86
Total	949 293	100.0	100.0	−45 504

Source: Canadian Petroleum Association.

Saskatchewan and Manitoba. Encouraged by improving royalty and tax schedules in Saskatchewan, both exploratory and development drilling were up substantially in 1977. Total number of wells drilled in all categories amounted to 530 for an aggregate depth of 434 686 m. This compares to 251 wells and 226 297 m drilled in 1976.

Although exploration declined in Saskatchewan in 1976, it almost doubled in 1977 and was rewarded with considerable success. Much of the success was attained in exploration for natural gas; nevertheless, several new discoveries were made in the Lloydminster heavy oil producing region. The significance of these discoveries will become more apparent with future delineation drilling. Almost all of the development drilling was also confined to the Lloydminster area, where the field boundaries of the Tangleflags and Northminster fields were considerably enlarged.

In Manitoba the number of wells and metres drilled declined in 1977. Aggregate drilling amounted to 9 359 m for the 11 wells that were drilled. No new discoveries were made, and development was confined to minor infill drilling within established field boundaries. However, at year-end, recent Cambro-Ordovician sandstone discoveries in North Dakota adjacent to the southeast corner of the province triggered renewed interest in that area, and several exploratory wells are scheduled for 1978. Industry is beginning to show renewed interest elsewhere in the province, as major leasing programs have been carried out in the Kirkella, Boissevain and Souris River areas preparatory to drilling exploratory wells.

British Columbia. The upswing in exploration that occurred in British Columbia during 1976 accelerated in 1977. Exploratory drilling at 490 324 was up 210 830 m from 1976. Almost all drilling was restricted to exploration for, and development of, natural gas. Nevertheless, Scurry-Rainbow Oil Limited made a very significant oil discovery in the Eagle area just west of Cecil Lake in the Fort St. John region. Oil production was obtained from several formations ranging in age from Devonian to Cretaceous. By year-end, 20 producing oil wells and 6 gas wells had been completed on this prospect with the ultimate limits of the producing trend as yet undetermined. Preliminary estimates suggest that this field has the productive capacity to provide 15 to 20 per cent of the province's future production.

Table 6. Canada, liquid hydrocarbon reserves at end of 1977

	Natural Gas Liquids	Crude Oil Plus Natural Gas Liquids	% of Total
	(000 m^3)	(000 m^3)	
Alberta	291 490	1 110 306	88.6
Saskatchewan	1 466	98 921	7.9
British Columbia	5 039	25 274	2.0
Other areas	6 132	18 919	1.5
Total	304 127	1 253 420	100.0

Source: Canadian Petroleum Association.

Other interesting oil discoveries in the province include Murphy Oil Company Ltd's discovery northwest of the Boundary Lake field and Woods Petroleum of Canada, Ltd.'s Wilder discovery, 10 km east of Fort St. John. These discoveries require further evaluation before their true potential will be known.

Yukon Territory, Northwest Territories and Arctic Islands. In the territorial regions, exploration continued at the reduced level that commenced in 1976. Twenty-six wells were drilled for a total of 80 766 m, compared to 27 wells and 83 807 m in 1976. Except for the deeper water prospects in the Beaufort Sea, the success ratio in northern Canada was negligible in 1977. Land-based and offshore drilling in the Mackenzie Delta have come to a virtual standstill, as the exploratory results have been poor and no significant new discoveries have been made.

Offshore from the Mackenzie Delta in the Beaufort Sea, Dome Petroleum Limited completed drilling the final well of its 1977 three-well exploratory drilling program in October. Drilling at all three wells was suspended before reaching total depth and will be completed during the 1978 summer drilling season.

Preliminary evaluation indicates that all of these wells are significant discoveries, although one well, Kopanoar M-13, has not been tested. The Nektoralik K-59 well yielded substantial flows of oil and condensate from three separate zones on test, and the other confirmed discovery, Ukalerk C-50, tested a 24 m thick gas reservoir with flow rates in excess of 5 million m^3/d. Since all three of these wells are located on large structural features and may encounter other productive horizons when deepened, they could prove to be major field class discoveries. Coupled with these three finds and last year's discovery by the Tingmiark K-91 well in the same general area, Dome has identified 40 additional large structural features within the 305 m water depth lines that are considered to have excellent potential for oil and gas accumulations. The three drillships will be wintered at Booth and Herschel Islands.

Exploration in the Arctic islands is in its 17th year with a total of 125 wells drilled, including 116 exploratory. To date, seven gas and one oil field have been discovered. At year-end, Panarctic Oils Ltd. had 20 gas wells in six fields. Dome had two gas finds, one categorized as a field. Proved and probable marketable gas reserves presently total 322 811 million m^3 in the seven fields, with an additional 39 600 million m^3 possible. Two of the fields are among the largest in Canada. Drake has 152 910 million m^3 of reserves and Hecla 104 772 million m^3. There were no significant new discoveries of either oil or gas made in the Arctic islands in 1977.

In August of 1977 the federal government announced amendments to the Canadian Oil and Gas Land Regulations. These amendments are intended as interim regulations pending the introduction of the final draft of Canada's new oil and gas regulations,

Table 7. Canada, wells completed and metres drilled

	1960		1975		1976		1977^p	
	(no.)	(m)	(no.)	(m)	(no.)	(m)	(no.)	(m)
Western Canada								
Westcoast offshore								
New field wildcats	–	–	–	–	–	–	–	–
British Columbia								
New field wildcats	60	111 501	12	29 656	6	16 305	12	20 406
Other exploratory	11	16 992	35	54 962	77	131 662	118	207 016
Development	72	101 115	33	43 870	90	131 527	175	262 902
	143	229 608	80	128 488	173	279 494	305	490 324
Alberta								
New field wildcats	338	663 641	350	413 714	336	475 244	321	470 830
Other exploratory	223	356 945	847	1 043 549	1 235	1 489 092	1 292	1 844 590
Development	1 131	2 171 961	2 449	2 191 907	3 388	2 832 655	3 465	2 889 527
	1 692	3 162 547	3 646	3 649 170	4 959	4 796 991	5 078	5 204 947
Saskatchewan								
New field wildcats	113	142 801	55	47 788	51	56 876	62	57 331
Other exploratory	28	30 237	52	41 442	89	73 650	200	143 173
Development	461	547 411	160	108 648	111	95 771	268	234 182
	602	720 449	267	197 878	251	226 297	530	434 686
Manitoba								
New field wildcats	10	9 298	4	3 628	10	7 400	1	762
Other exploratory	3	1 942	–	–	3	3 011	9	7 987
Development	54	33 550	3	3 059	1	750	1	610
	67	44 790	7	6 687	14	11 161	11	9 359
Yukon and Northwest Territories and Arctic islands								
New field wildcats	32	32 299	31	78 805	16	54 222	18	57 312
Other exploratory	–	–	2	7 569	2	3 885	–	–
Development	–	–	10	26 844	9	25 700	8	23 454
	32	32 299	43	113 218	27	83 807	26	80 766
Total Western Canada								
New field wildcats	553	929 541	452	573 591	419	610 047	414	606 641
Other exploratory	265	406 116	936	1 147 522	1 406	1 701 300	1 619	2 202 766
Development	1 718	2 854 036	2 655	2 374 328	3 599	3 086 403	3 917	3 410 675
	2 536	4 189 693	4 043	4 095 441	5·424	5 397 750	5 950	6 220 082

Table 7. (concl'd)

	1960		1975		1976		1977ᵖ	
	(no.)	(m)	(no.)	(m)	(no.)	(m)	(no.)	(m)
Eastern Canada								
Eastcoast offshore								
New field wildcats	–	–	9	26 313	10	22 793	2	7 742
Other exploratory	–	–	–	–	–	–	–	–
	–	–	9	26 313	10	22 793	2	7 742
Hudson's Bay offshore								
New field wildcats	–	–	–	–	–	–	–	–
Other exploratory	–	–	–	–	–	–	–	–
	–	–	–	–	–	–	–	–
Ontario								
New field wildcats	39	20 846	49	28 788	40	26 459	46	29 357
Other exploratory	55	33 479	16	8 302	15	8 862	8	4 683
Development	213	69 552	73	28 611	89	37 951	111	55 408
	307	123 877	138	65 701	144	73 272	165	89 448
Quebec								
New field wildcats	5	1 307	3	3 037	4	8 543	6	13 233
Other exploratory	–	–	–	–	–	–	–	–
Development	1	73	–	–	–	–	–	–
	6	1 380	3	3 307	4	8 543	6	13 233
Atlantic provinces								
New field wildcats	3	6 969	7	17 134	2	3 271	–	–
Other exploratory	–	–	–	–	–	–	–	–
Development	–	–	–	–	–	–	–	–
	3	6 969	7	17 134	2	3 271	–	–
Total Eastern Canada								
New field wildcats	41	29 122	68	75 272	56	61 066	54	50 332
Other exploratory	55	33 479	16	8 302	15	8 862	8	4 683
Development	214	69 625	73	28 611	89	37 951	111	55 408
	316	132 226	157	112 185	160	107 879	173	110 423
Total Canada								
New field wildcats	600	958 662	520	648 863	475	671 113	468	656 973
Other exploratory	320	439 595	952	1 155 824	1 421	1 710 163	1 627	2 207 449
Development	1 932	2 923 662	2 728	2 402 939	3 688	3 124 355	4 028	3 466 083
	2 852	4 321 919	4 200	4 207 626	5 584	5 505 631	6 123	6 330 505

Source: Canadian Petroleum Association
ᵖPreliminary; – Nil.

anticipated in 1978. The amendments opened up more than one billion acres of land under federal jurisdiction in the north and offshore areas for oil and natural gas exploration, ending a five-year moratorium on issuance of exploration permits. The amendments, effective immediately, inaugurated a new system for the exploration and development of oil and gas in Canada's north and offshore frontiers. The new system will enable the processing of current applications for oil and gas leases on some 31 million acres now held under permit. It will also open the door for the selective granting of new exploration rights on about 700 million acres of Crown reserve lands, lands that were once held under permit or lease but surrendered to the Crown. In addition, more than 600 million acres of Canada lands, both onshore and offshore, that have never been covered by permit or lease will become available for exploration on a carefully selected basis. The amendments provide special options for Petro-Canada to obtain up to 25 per cent of those lands available within a year of the date of the amendment of the regulations, as well as up to 25 per cent of any lands surrendered to the Crown over a period of seven years from that date.

Eastern Canada. Aggregate drilling in Ontario increased 22 per cent to 89 448 m in 1977. Development drilling, primarily in Lake Erie, accounted for all of the drilling increase. As in previous years, the bulk of exploration effort in Ontario has been directed to exploration for and development of natural gas. Nevertheless, Ram Petroleums Limited recorded an oil discovery in the Michigan Basin, Silurian pinnacle reef trend in Lambton County, Ontario early in 1978. The discovery well encountered 50 m of net pay zone in an 83m- thick isolated reef. It is the second reef discovery by Ram in 1978, the first being gas bearing. In 1977 Ram had drilled five exploratory wells in the same area and were rewarded with two pinnacle reef gas discoveries, one with oil, one gas and one successful extension well.

In Quebec six wells were drilled in 1977 — all of them by the Quebec Crown corporation, Quebec Petroleum Operations Company, (SOQUIP). There were no oil discoveries, but one potential gas discovery was made in the St. Flavien area south of Québec City. Three other marginal gas producers have been drilled in the some general area, with some potential for commercial development.

Offshore from the east coast of Canada, drilling commenced in 1966, and since then eight oil and gas discoveries have been made. The two most important of these occurred in 1973 and 1974 on the Labrador Shelf. The potential of these two discoveries in terms of producibility and reserves is still not known, as all drilling in this area has been suspended pending settlement of the jurisdictional dispute between the federal and Newfoundland governments. This area is considered to be the most favorable for discovery of commercial oil and gas accumulations on Canada's eastern seaboard.

On the Grand Banks and Scotian Shelf, costly and disappointing results have curtailed exploration. The only discoveries in this region have been made in the vicinity of Sable Island where the initial discovery was made in 1971 on the southwestern tip of the island. None of these discoveries is considered commercial at present.

In 1976 and 1977 exploration on the Scotian Shelf and Grand Banks was revitalized to some degree by Petro-Canada, when it embarked on a multi-well drilling program which commenced early in 1976. The program involved three separate exploration agreements with major oil companies active in the east offshore area for several years. However, the results of this drilling program proved unsuccessful. Neverthe-

Table 8. Wells drilled, by province, 1976 and 1977

	Oil		Gas		Dry[1]		Total	
	1976	1977[p]	1976	1977[p]	1976	1977[p]	1976	1977[p]
Western Canada								
Alberta	550	705	3 193	2 953	1 216	1 420	4 959	5 078
Saskatchewan	154	359	16	83	81	88	251	530
British Columbia	13	38	86	148	74	119	173	305
Manitoba	3	9	—	—	11	2	14	11
Yukon and Northwest Territories and Arctic islands	4	—	9	8	14	18	27	26
Westcoast offshore	—	—	—	—	—	—	—	—
Subtotal	724	1 111	3 304	3 192	1 396	1 647	5 424	5 950
Eastern Canada								
Ontario	3	9	67	93	74	63	144	165
Quebec	—	—	2	—	2	6	4	6
Atlantic provinces	—	—	—	—	2	—	2	—
Eastcoast offshore	—	—	—	—	10	2	10	2
Hudson's Bay offshore	—	—	—	—	—	—	—	—
Subtotal	3	9	69	93	88	71	160	173
Total Canada	727	1 120	3 373	3 285	1 484	1 718	5 584	6 123

Source: Canadian Petroleum Association.
[1] Includes suspended and abandoned wells but excludes miscellaneous wells and service wells.
[p] Preliminary; — Nil.

less, early in 1878 Petro-Canada and Chevron Standard Limited announced plans to drill a well on the edge of the continental shelf, 217 km southeast of Halifax. The well will earn Chevron a 40 per cent interest and Petro-Canada 60 per cent of a half interest in 1 million acres held jointly by Shell Canada Resources Limited and Shell Explorer Limited.

Transportation

Crude oil and product pipeline construction declined in 1977 as only 600 km of new pipeline were put into operation. The lack of new oil discoveries and regulated cutbacks in crude oil production were responsible for the decline. Almost all of the construction was confined to medium- and small-diameter line.

Dome Petreleum's ethane-ethylene pipeline complex was the largest single construction project of the year. This project (Cochin Pipeline) consists of 2 896 km of 0.30 pipeline from Fort Saskatchewan, Alberta to Sarnia, Ontario. More than half the system was constructed through the United States. The Canadian portion of the line comprises 99 km of 0.30 m line from Fort Saskatchewan, Alberta, to Elmore Saskatchewan, 43 km of 0.20 m line from the Cochrane gas plant to Joffre and 195 km of a combination line from the South Edmonton gas separation and ethane recovery plant to the Joffre plant and the underground storage at Fort Saskatchewan.

Major oil and fuel gas transmission lines were completed this year to service the Syncrude project. Alberta Oil Sands Pipeline Ltd. completed the remaining 186 km of the 457 km, 0.55 m synthetic crude oil pipeline from the Syncrude plant to Edmonton, Alberta. Earlier in the year, Syncrude Canada Ltd. completed 260 km of 0.40 m gas transmission line from the Atmore field to the Syncrude plant. The gas will be used in upgrading raw bitumen to synthetic crude oil.

In regard to future projects, Kitimat Pipe Line Ltd. revived its plans for a major oil receiving port at the British Columbia coastal town of Kitimat and an oil terminal to Edmonton following the United States government's decision to curtail expansion of facilities in the Cherry Point, Washinghton area. As a result, Kitimat Pipe Line applied to the National Energy Board (NEB) late in the year seeking approval of its project. The immediate thrust of this pipeline project would be to deliver North Slope Alaska oil to United States markets. In the longer term, these facilities could conceivably be involved in the receipt and delivery of offshore crude oil to Canadian refining centres. However, early in 1978 the NEB was commissioned by the Honorable Alastair Gillespie, Minister of Energy, Mines and Resources, to investigate the range of possible oil supply situations over the course of the next 10 to 15 years and the import dependency that might develop for British Columbia consumers as well as for eastern Canadians. The hearings will commence on May 24, 1978 and will precede hearings on Kitimat's proposal. In fact, acceptance or rejection of the Kitimat application will likely hinge directly on the findings of the NEB's enquiry into Canada's oil supply and import dependency.

Petroleum refineries

Canadian refinery capacity increased by 26 948 m^3/d in 1977 to 384 399 m^3/d, primarily reflecting the addition of Petrosar Limited's petrochemical refinery in Sarnia. Other refinery growth was restricted to minor additions to existing plants. The number of refineries operating in Canada increased to 38 in 1977. This total includes Newfoundland Refining Company Limited's Come-by-Chance refinery in Newfoundland, which has temporarily suspended operations due to financial problems.

In the Atlantic provinces, refinery expansion was confined to minor expansions to existing facilities, and in Quebec refinery growth was negligible.

Table 9. Oil wells in western Canada at end of 1976 and 1977

	Producing Wells		Wells Capable of Production	
	1976	1977	1976	1977
Alberta	11 166	11 592	15 663	16 224
Saskatchewan	5 938	6 777	7 769	8 063
Manitoba	688	701	821	804
British Columbia	522	527	702	733
Northwest Territories and Arctic islands	33	35	59	59
Total	18 347	19 632	24 014	25 883

Sources: Provincial and federal government reports.

Table 10. Length of pipelines in Canada for transporting crude oil, natural gas liquids and products

Year-end	Kilometres	Year-end	Kilometres[1]
1960	13 576	1969	27 480
1961	15 376	1970	27 459
1962	16 153	1971	28 706
1963	17 070	1972	29 467
1964	18 900	1973	30 146
1965	19 819	1974	31 262
1966	20 913	1975	31 831
1967	22 780	1976	32 863
1968	23 870	1977	33 463

Source: Statistics Canada.
[1] Includes producer gathering lines for 1969 to 1977.
[p] Preliminary.

In Ontario, Petrosar Limited's refinery came on stream in April of 1977. It is Canada's first integrated world-scale petrochemical refinery and when fully operational will produce 48 590 tonnes of ethylene annually and 18 283 m^3/d of petroleum products from 25 438 m^3/d of western Canadian crude oil feedstock. During the first six months of operation, output was limited to petroleum products only, which included gasoline, light fuel oil and residual fuel oil. In October the plant began to produce petrochemicals, and it is anticipated that design capacity of 254 378 m^3/d of crude will be reached by early 1980. Construction of Texaco Canada Limited's 15 103 m^3/d Nanticoke plant on the north shore of Lake Erie is proceeding on schedule and is expected to start up by mid-summer 1978 and be fully operational before the end of the year. Initial throughput is expected to approximate 8 903 m^3/d, which is about 60 per cent of its design capacity. Elsewhere in Ontario, Sunoco Inc. increased the capacity of its Sarnia plant by 715 m^3/d to 15 103 m^3/d.

On the Prairies, Consumers' Cooperative Refineries Limited will finalize a three-year expansion program early in 1978. When complete, the program will increase crude capacity from the current level of 4 292 m^3/d to 8 000 m^3/d and add a 1 589 m^3/d catalytic reformer and a 1 589 m^3/d naphtha hydrotreater. In Alberta, Gulf Oil Canada Limited has increased the capacity of its Edmonton refinery by 874 m^3/d to 12 700 m^3/d and Turbo Resources Limited has revived its plan to construct a 15 898 m^3/d facility, which would use crude oil and condensate feedstock to produce 3 180 m^3/d of gasolines and naphtha. The remainder would be returned to the pipeline and a lube oil recycling plant near Edmonton. The proposal is currently being reviewed by the Alberta Energy Resources Conservation Board (AERCB).

In British Columbia, Husky Oil (Alberta) Ltd. will increase the capacity of its Prince George refinery from its present capacity of 1 224 m^3/d to 1 598 m^3/d and at the same time install a 461 m^3/d fluid catalytic cracker. Also in British Columbia, Mohawk Oil Co. Ltd. is still contemplating the construction of a 3 179 m^3/d refinery and is actively seeking a location.

Imperial Oil remained Canada's largest refiner. The company's six refineries comprise 23 per cent of Canadian refinery capacity, Gulf Oil Canada Limited's eight plants constitute 16 per cent of Canadian refinery capacity; and Shell Canada Limited, third largest refiner, operates six refineries, which account for 12 per cent of the total.

Table 11. Deliveries of crude oil and propane by company and destination 1976 and 1977

Company and destination	1976	1977
	(million m^3)	
Interprovincial Pipe Line Limited		
Western Canada	7.2	7.2
United States	26.5	26.1
Montréal, Quebec	4.8	13.5
Ontario	30.3	34.3
Total	68.8	81.1
Trans Mountain Pipe Line Company Ltd.		
British Columbia	7.4	7.2
State of Washington	5.8	1.5
Westridge terminal	0.5	0.5
Total	13.7	9.2

Sources: Company annual reports.
— Nil.

Table 12. Crude oil refining capacity by regions

	1976		1977	
	m^3/day	%	m^3/day	%
Atlantic provinces	86 807	24.3	87 267	22.8
Quebec	102 674	28.7	102 674	26.7
Ontario	87 379	24.5	112 578	29.3
Prairies and Northwest Territories	54 532	15.2	55 645	14.4
British Columbia	26 057	7.3	26 233	6.8
Total	357 450	100.0	384 398	100.0

Source: Department of Energy, Mines and Resources, *Petroleum Refineries in Canada* (Operators List 5) January, 1978.

Marketing and trade

Crude oil deliveries to Canadian refineries during 1977 averaged 285 586 m^3/d, up 16 000 m^3/d from 1976. Deliveries of domestic crude oil to Canadian refineries increased by 37 500 m^3/d to 179 100 m^3d for a 16 per cent gain. Much of this increase could be attributed to an increase of 22 500 m^3/d in shipments of western Canadian crude oil to Montreal markets. These shipments began during the latter half of 1976; and since then, there has been a gradual increase in requirements, which reached a maximum level of 41 000 m^3/d during the latter half of 1977.

On the other hand, use of imported crude oil by Canadian refineries in Quebec and the Atlantic provinces decreased to 106 352 m^3/d, 8 200 m^3/d less than in 1976. Countries in the Middle East collectively remained the largest source of imported crude oil to Canada, accounting for 46 per cent, or 48 787 m^3/d, of total Canadian imports. Middle East sources of imported oil were Iran, Saudi Arabia, Iraq, Kuwait and

Table 13. Canada, crude oil received at refineries, 1977 and 1976

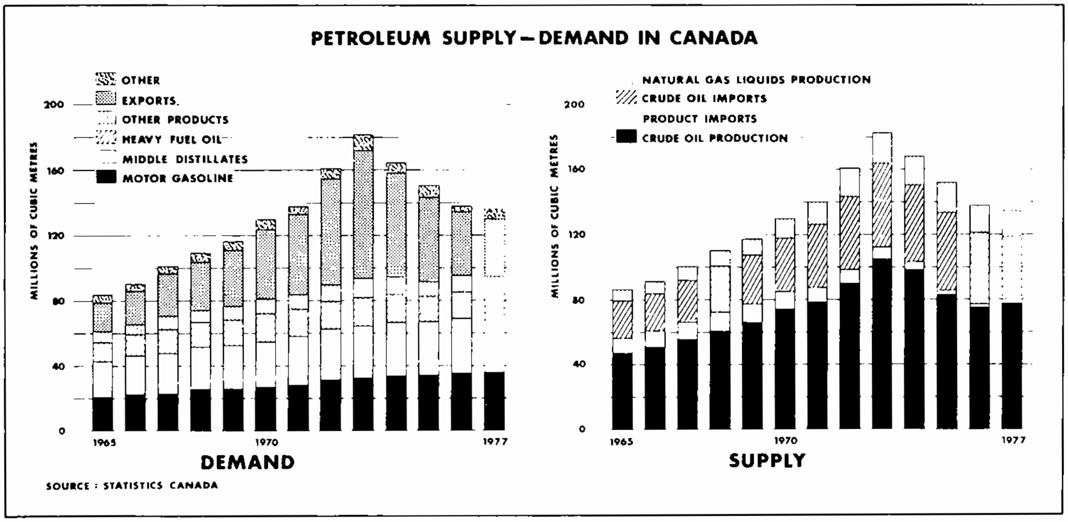
Location of Refineries		Country of Origin							
		Canada	Middle East	Trinidad	Venezuela	Africa	Colombia	Other	Total Received
		(m³)							
Atlantic provinces	1977	—	11 193 376	146 564	5 478 329	—	—	55 486	16 873 755
	1976	28 337	9 416 694	61 440	5 175 230	196 819	—	16 713	14 895 233
Quebec	1977	13 316 974	6 614 149	52 553	9 505 611	263 872	—	2 479 077	32 232 236
	1976	4 835 282	11 094 543	—	10 490 137	2 619 794	—	2 475 734	31 515 490
Ontario	1977	26 201 814	—	—	—	—	—	3 029 704	29 231 518
	1976	26 169 833	—	—	—	—	—	324 219	26 494 052
Prairies	1977	16 981 210	—	—	—	—	—	—	16 981 210
	1976	16 565 341	—	—	—	—	—	—	16 565 341
British Columbia	1977	8 784 380	—	—	—	—	—	—	8 784 380
	1976	8 711 079	—	—	—	—	—	—	8 711 079
Northwest Territories and Yukon	1977	135 798	—	—	—	—	—	—	135 798
	1976	145 429	—	—	—	—	—	—	145 429
Total	1977	65 420 176	17 807 525	199 117	14 983 940	263 872	—	5 564 267	104 238 897
	1976	56 455 301	20 511 237	61 440	15 665 367	2 816 613	—	2 816 666	98 326 624

Source: Statistics Canada.
— Nil.

Table 14. Consumption of petroleum products by province, 1977p

	Motor Gasoline	Kerosene, Stove Oil, Tractor Fuel	Diesel Fuel Oil	Light Fuel Oils No. 2 and 3	Heavy Fuel Oils No. 4, 5 and 6
			(m^3)		
Newfoundland	596 171	138 027	392 456	465 311	471 160
Atlantic provinces	2 419 987	321 866	979 884	1 941 949	3 895 950
Quebec	8 523 033	753 550	2 302 288	5 674 610	5 937 204
Ontario	12 623 014	324 868	2 888 128	5 263 532	4 584 453
Manitoba	1 587 468	119 296	669 036	217 418	158 296
Saskatchewan	2 041 330	183 745	923 182	208 918	10 432
Alberta	4 048 223	74 027	1 987 096	184 229	4 370
British Columbia	3 843 122	159 743	1 813 962	944 973	1 432 686
Northwest Territories and Yukon	91 682	45 498	214 025	110 201	19 605
Total	35 774 030	2 120 620	12 170 057	15 011 141	16 514 156

Source: Statistics Canada.
pPreliminary



the Trucial States. Imports from Venezuela decreased by 4.4 per cent to 41 050 m^3/d, but that country continued to be Canada's second-largest source of imported crude oil. Imports of African oil from Nigeria and Libya were negligible this year.

The increase in demand for domestic crude oil was almost compensated for by a 25 440 m^3/d, or 32 per cent, decline in exports to the United States, which averaged 54 200 m^3/d in 1977. This figure includes exchanges that amounted to 9 380 m^3/d. In 1978 it is anticipated that exports will be further reduced to 36 570 m^3/d, and of this amount 9 698 m^3/d will be comprised of exchanges. The remainder will consist of 18 130 m^3/d of difficult-to-market heavy oils and 8 740 m^3/d of light and medium crude oils.

United States refiners east of the Rocky Mountains took an average of 50 000 m^3/d of Canadian crude oil in 1977, 16 300 m^3/d less than in the previous year, while refiners west of the Rockies in the Puget Sound area imported about 4 000 m^3/d of Canadian crude oil, about 11 900 m^3/d less than in 1976.

Exports of petroleum products in 1977 including propane and butane amounted to 32 610 m^3/d, about 4 425 m^3/d more than in 1976. Much of the increase could be attributed to two circumstances. Firstly, a build-up in inventories of gas plant production of

Table 15. Canada, exports and imports of refined petroleum products, 1976 and 1977

	Exports		Imports	
	1976	1977^p	1976	1977^p
	(000 m^3)			
Propane and butane	6 695	7 312	13	17
Aviation gasoline	—	—	6	2
Motor gasoline	501	490	7	—
Aviation turbo fuel	—	7	28	32
Kerosene, stove oil and tractor fuel	9	—	56	—
Diesel fuel oil	10	41	66	53
Light fuel oil no. 2 and 3	108	426	49	127
Heavy fuel oil no. 4, 5 and 6	2 644	3 021	1 098	1 243
Asphalt	—	20	17	131
Petroleum coke	—	—	545	753
Lubricating oils and greases	—	5	221	212
Other products	322	583	148	63
Total, all products	10 289	11 905	2 254	2 633

Sources: Statistics Canada and National Energy Board.
^{p}Preliminary; — Nil.

Table 16. Canada, supply and demand of oils, 1976 and 1977

	1976	1977^p
	(000 m^3)	
Supply		
Production		
Crude oil and condensate	76 075	76 447
Other natural gas liquids	16 759	16 869
Net production	92 834	93 316
Imports		
Crude oil	43 930	39 593
Products	2 254	2 633
Total imports	46 184	42 226
Change in stocks		
Crude and natural gas liquids	−302	+808
Refined petroleum products	+2 017	−2 363
Total change	+1 715	−1 555
Oils not accounted for	−57	−71
Total supply	140 676	133 916
Demand		
Exports		
Crude oil	29 030	19 783
Products	10 289	11 905
Total exports	39 329	31 688
Domestic sales		
Motor gasoline	35 423	35 774
Middle distillates	31 008	29 302
Heavy fuel oil	16 720	16 514
Other products	13 281	14 949
Total sales	96 432	96 539
Uses and losses		
Refining	5 975	6 487
Field plant and pipeline	+158	−39
Losses and adjustments[1]	−1 218	−579
Total uses, losses and adjustments	4 915	5 869
Total demand	140 676	133 916

Sources: [1]Statistics Canada and provincial government reports.
^{p}Preliminary.

propane exceeded domestic requirements, and as a result it was licensed for export. Secondly, a surplus of heavy fuel oils developed in eastern Canada, and this situation was aggravated by a lack of domestic markets for these products from Petrosar's new petrochemical refinery in Sarnia. To reduce excessive inventories, some of the heavy fuel oil products were also licensed for export.

Imports of petroleum products remained stationary at 7 200 m^3/d in 1977. With the current surplus of refinery capacity in Canada, particularly in the eastern provinces, the trend to reduced imports of petroleum products is expected to continue (with the exception of specialty products) until imports are almost entirely eliminated. Including exports of gas plant production of natural gas liquids, Canada became a net importer of crude oil and products for the second consecutive year as imports exceeded exports by 28 920 m^3/d in 1977.

Escalation of oil and gas prices, which commenced in 1974, continued in 1977. In June, the federal government announced higher prices for Canadian oil and gas, in line with the government's two-pronged energy strategy for Canada — to increase energy supplies on the one hand, and to decrease growth in demand on the other. The changes reflected the majority view of the provincial energy ministers as stated at the Federal-Provincial Conference in May. As of July 1, 1977, the Canadian crude oil price increased by $1 a barrel, and there will be three subsequent $1 a barrel increases at six-month intervals: January 1 and July 1, 1978 and January 1, 1979.

Finally, in the realm of federal initiatives, the Petroleum Corporation's Monitoring Bill was introduced for Parliamentary approval on November 2, 1977. The Act has been designed to provide assurance that revenue from increased oil and gas prices is being invested by industry in exploration and development in Canada. Under the terms of the act, companies will be required to file reports on a biannual basis, listing details of all sources and use of funds. Information from these sources will be made public on an industry-wide basis, but individual company information will remain confidential unless disclosure is in the public interest.

Phosphate

A.F. KILLIN

World fertilizer demand increased in 1977 and production and sales of phosphate rock showed a significant rise over the 1975 and 1976 figures. Production and apparent consumption were in virtual balance in 1977 at about 115.7 million tonnes*. Export sales increased by 17 per cent to 49.5 million tonnes and domestic sales by 9 per cent to 60.7 million tonnes. Much of the increased domestic shipment of rock in 1977 was processed into phosphoric acid and fertilizer for export.

Phosphate is a term applied to a rock, mineral, or salt containing one or more phosphorous compounds. About four-fifths of the world's phosphate consumption is for agriculture — largely as fertilizers. World demand for phosphate rock expanded at unprecedented rates from 1963 to 1967 to meet the needs of a rapidly developing phosphate fertilizer industry. The demand eased considerably between 1968 and 1971 because of overcapacity in the industry, resulting in decreased prices; and a lessening demand for fertilizer arising from lower farm product prices. A worldwide food shortage that assumed serious proportions in 1970-1971, carried through to 1974. This shortage was accompanied by higher food prices and a sharp increase in the demand for fertilizers, including phosphates. The fertilizer price increases in 1974 and 1975 broke the trend and in spite of an increase in the need for fertilizer to boost food production, sales did not recover until 1977.

In Canada, imports of phosphate rock continued to decline and in 1977, at 2 338 247 tonnes, were 4 per cent less than in 1976. The value of imports at $55 012 000 rose by 1 per cent over 1976. Imports of phosphate fertilizer, principally from the United States, rose sharply in 1977 to 177 003 tonnes valued at $25 024 000, from the 140 867 tonnes valued at $19 257 000 imported in 1976. The increase represents low-cost competition from integrated mine-fertilizer plants in the United States.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Phosphate rock

Phosphate rock contains one or more suitable phosphate minerals, usually calcium phosphate, in sufficient quantity for use either directly or after beneficiation in the manufacture of phosphate products. Sedimentary phosphate rock, or phosphorite, is the most widely used phosphate raw material; apatite, which occurs in many igneous and metamorphic rocks and can be represented by the formula $Ca_5(PO_4)_3$ (F,C1,OH), is second in importance. Other sources of phosphate include guano and a basic slag byproduct of some steel mills. Phosphate rock can be decomposed by three methods: acid treatment, thermal reduction, or thermal treatment without reduction. Canadian phosphate producers use the first two methods.

Phosphate rock is graded either on the basis of its P_2O_5 equivalent (phosphorus pentoxide) or $Ca_3(PO_4)_2$ content (tricalcium phosphate or bone phosphate of lime — TPL or BPL). For comparative purposes, 0.458 P_2O_5 equals 1.0 BPL, and one unit of P_2O_5 contains 43.6 per cent phosphorus.

Occurrences in Canada

Although there are numerous occurrences of low-grade phosphate rock in Canada, there is no commercial production. Large quantities of rock are imported, mostly from the United States, for use in the manufacture of agricultural and industrial products sold in the domestic and export markets.

Known Canadian deposits are limited and fall into three main categories: apatite deposits within Precambrian metamorphic rocks in eastern Ontario and southwestern Quebec; apatite deposits in some carbonate-alkaline complexes (carbonatites) in Ontario and Quebec; and Late Paleozoic-Early Mesozoic sedimentary phosphate rock deposits in the southern Rocky Mountains.

The Precambrian metamorphic apatite deposits of Ontario and Quebec occur in pyroxenites as small, irregular, scattered pockets and veins with phlogopite mica and pink calcite. Most of the outcrops are in the Rideau Lakes region of eastern Ontario and the Lievre

Table 1. Canada, phosphate rock imports and consumption, 1976 and 1977

	1976		1977p	
	(tonnes)	($)	(tonnes)	($)
Imports				
United States	2 236 885	54 254 000	2 309 645	54 000 000
Netherlands Antilles	4 001	210 000	2 399	232 000
Morocco	—	—	26 203	780 000
Israel	200	8 000	—	—
Total	2 241 086	54 472 000	2 338 247	55 012 000
	1975		1976p	
Consumption[1] (available data)				
Fertilizer, stock and poultry feed	1 851 620		1 420 065e	
Other[2]	243 748		162 796	
Total	2 095 368		1 582 861	

Source: Statistics Canada.
[1]Breakdown by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa. [2]Includes amounts for chemicals, refractories and food processing.
pPreliminary; — Nil; eEstimated.

River area of southwestern Quebec, where many deposits were worked extensively between 1869 and 1900 before low-cost Florida rock entered world markets.

Carbonatites usually occur as roughly circular plugs intruding older metamorphic rock. In August 1975, International Minerals & Chemical Corporation (Canada) Limited (IMCC) reported a phosphate deposit in a carbonatite complex in Cargill Township, Ontario. Part of the complex was described in 1967 by the Ontario Department of Mines as being cut by very coarse white calcite veins containing up to 20 per cent apatite.

In 1976 IMCC completed the first-phase feasibility study. The study, based on 190 drillholes, reports reserves of 56 700 000 tonnes grading 20 per cent P_2O_5. IMCC also has rights to phosphate in another carbonatite plug north of Lake Superior now being drilled for uranium by New Insco Mines Ltd. Other important apatite-bearing carbonatites are the Nemegos deposit, 15 miles southeast of Chapleau, Ontario, held by Multi-Minerals Limited; and the Oka deposit 20 miles northwest of Montreal, currently being mined for columbium (niobium) by St. Lawrence Columbium and Metals Corporation.

Sedimentary phosphate beds are fairly common in the Rocky Mountains. Most of the exposures occur along the Alberta-British Columbia border between the International Boundary and Banff. Beds at the base of the Fernie shale have received considerable attention during recent years.

Canadian phosphate industry

Elemental phosphorus. Elemental phosphorus is produced in Canada by the thermal reduction method, which involves the smelting of phosphate rock with carbon (coke) and a siliceous flux. Coproducts of the process are ferrophosphorus, carbon monoxide and calcium silicate slag. About nine tons of phosphate rock grading 66 to 68 per cent BPL are required to manufacture one ton of phosphorus. Although elemental phosphorus can be used for making fertilizers, it is generally

Table 2. Canada, phosphate rock imports and consumption, 1960, 1965, 1970, 1975, 1976 and 1977

	Imports	Consumption
	(tonnes)	
1960	854 566	809 113
1965	1 537 947	1 457 769
1970	2 240 792	1 720 524
1975	3 282 257	2 095 368
1976	2 241 086	1 582 861
1977p	2 338 247	. .

Source: Statistics Canada.
pPreliminary; . . Not available.

used in the manufacture of chemicals, insecticides, detergents and other industrial compounds. There are two plants producing elemental phosphorus in Canada.

Erco Industries Limited has rebuilt its No. 2 furnace at the Long Harbour, Nfld. phosphorus plant. The new unit brings the plant back up to its original capacity of 72 500 tonnes per year.

Phosphate fertilizers. Phosphate fertilizers are normally produced by decomposing phosphate rock with a strong mineral acid. In Canada only the two most common acidulents, sulphuric acid and phosphoric acid, are used in commercial practice; the former is by far the most common.

When phosphate rock is treated with sulphuric acid, either single superphosphate or phosphoric acid (correctly named orthophosphoric acid, H_3PO_4) is produced. For the former, the rock is treated with sufficient acid to convert the tricalcium phosphate into water-soluble monocalcium phosphate; the coproduct of the reaction, calcium sulphate, remains in the mixture. Normal raw material requirements to produce one ton of superphosphate, grading 20 per cent P_2O_5 equivalent, are 0.64 ton of phosphate rock (70-72 per cent BPL) and 0.47 ton of sulphuric acid (100 per cent basis).

To produce phosphoric acid, larger quantities of sulphuric acid are added to maintain a fluid slurry that facilitates removal of calcium sulphate by filtering. Filtered acid containing 30 to 32 per cent P_2O_5 equivalent may be used, either directly in the manufacture of phosphate fertilizers, or concentrated by evaporation to as high as 54 per cent P_2O_5 equivalent prior to further use or sale as merchant acid. Typical raw material requirements for one ton P_2O_5 equivalent produced are 3.1 tons of phosphate rock (74 to 75 per cent BPL) and 2.6 tons of sulphuric acid (100 per cent basis). Also, for every ton P_2O_5 equivalent produced, about 4.5 tons of waste calcium sulphate are generated.

Most of the acid is then neutralized with ammonia to form ammonium phosphate fertilizers. Common grades are 16-20-0 (16 per cent N, 20 per cent P_2O_5 equivalent, and 0 per cent K_2O equivalent), 11-48-0 and 18-46-0. At some plants, phosphoric acid is used to acidulate phosphate rock, in which case the end product is triple superphosphate, normally grading 46 per cent P_2O_5 equivalent.

There are 10 phosphoric acid plants in Canada with a combined annual productive capacity of 1 015 000 tonnes P_2O_5 equivalent. The balance of Canada's P_2O_5 productive capacity, amounting to 18 900 tonnes annually, consists of plants capable of producing single and/or triple superphosphate.

St. Lawrence Fertilizers Ltd. of Valleyfield, Quebec shut down in April 1976, reportedly because of depressed economic conditions, and Canadian Industries Limited closed its plant at Beloeil, Quebec.

Table 4. Canada, phosphate fertilizer production, years ended June 30, 1960, 1965, 1970, 1975, 1976 and 1977

	tonnes P_2O_5 equivalent
1960	181 047
1965	339 431
1970	450 308
1975	713 381^r
1976	786 708^r
1977^p	692 988

Source: Statistics Canada.
^{p}Preliminary ^{r}Revised.

Table 3. World production of phosphate rock, 1975, 1976 and 1977

	1975	1976	1977^p
		(000 tonnes)	
United States	44 285	44 670	46 500
U.S.S.R.	24 146	24 310	24 375
Morocco	13 548	15 285	17 500
People's Republic of China	3 400	3 750	4 000
Tunisia	3 481	3 294	3 614
Togo	1 161	2 068	2 857
South Africa	1 651	1 631	2 250
Jordan	1 353	1 702	1 750
Senegal	1 677	1 580	1 630
Vietnam	1 400	1 500	1 600
Christmas Island	1 342	1 037	1 260
Nauru	1 533	754	1 146
Other countries	7 428	5 601	6 602
Total	106 405	107 182	115 084

Source: The British Sulphur Corporation Ltd., Phosphorus and Potassium.

World developments

Shipments of phosphate rock were made from stockpiles at the BuCraa mine in Sahara to the El Aaiun beneficiation plant of Fosbu Craa, now owned 60 per cent by l'Office Chérifien des Phosphates. Shipments of rock totalling 25 145 tonnes were made in 1977.

Yugoslavia intends to exploit phosphate reserves of 100 million tonnes in the Bosiljgrade-Lisine area. Mines will be developed at Bosiljgrade and Lisine with total output of 3.6 million tonnes of crude phosphate rock a year.

In the United States, CF Industries, Inc. has started dredging at its new mine in Hardec County, Florida. Contracts have been let for the construction of a 1-million-short ton-a-year phosphate rock beneficiation plant at the site, to be completed in January 1979.

Table 5. Canada, phosphorus and phosphate fertilizer plants, 1977

Company	Plant Location	Annual Capacity[1]	Principal End Products	Basis for H_2SO_4 Supply for Fertilizer Plants
		(tonnes)		
Elemental phosphorus				
Erco Industries Limited	Varennes, Que.	18 000	el ph	
	Long Harbour, Nfld.	72 500	el ph	
Total elemental phosphorus		90 500		
Phosphate fertilizer		(P_2O_5eq.)		
Canada Wire and Cable Limited[2]	Belledune, N.B.	136 000	am ph	SO_2 smelter gas
Canadian Industries Limited	Beloeil, Que. (closed)	18 000	ss	sulphur
	Courtright, Ont.	87 000	am ph	SO_2 pyrrhotite, Copper Cliff
Cominco Ltd.	Kimberley, B.C.	114 000	am ph	SO_2 smelter gas
	Trail, B.C.	76 000	am ph	SO_2 smelter gas
International Minerals & Chemical Corporation (Canada) Limited	Port Maitland, Ont.[3]	118 000	H_3PO_4, ss ts, ca ph	sulphur, SO_2 smelter gas
Green Valley Fertilizer & Chemical Co. Ltd.	North Surrey, B.C.	900	ss	SO_2 smelter gas Trail
Esso Chemical Canada	Redwater, Alta.	218 000	am ph	sulphur
St. Lawrence Fertilizers Ltd.[4]	Valleyfield, Que. (idle)	45 000	ts, am ph	SO_2 smelter gas
Sherritt Gordon Mines Limited	Fort Saskatchewan, Alta.	48 000	am ph	sulphur
Simplot Chemical Company Ltd.	Brandon, Man.	. .	am ph	imports H_3PO_4
Western Co-operative Fertilizers Limited	Calgary, Alta.	100 000	am ph	sulphur
	Medicine Hat, Alta.	73 000		
Total, phosphate fertilizer		1 033 900		

[1]Revised from company information 1977.
el ph Elemental phosphorus; P_2O_5 eq. Phosphorus pentoxide equivalent; am ph Ammonium phosphates; ss Single superphosphate; ts Triple superphosphate; ca ph Food supplement calcium phosphate; . . Not applicable, H_3PO_4 is made elsewhere. [2]Noranda Mines Limited acquired full ownership of Belledune Fertilizer Limited, effective April 1, 1972, name changed to Canada Wire and Cable Limited, June 5, 1972. [3]Operates at less than annual capacity because of environmental restrictions. [4]Closed in April 1976.

Production, trade and consumption

Canada's major market for phosphate fertilizers is the United States. Under foreign aid programs, shipments are made to southeast Asian countries. In 1977, imports of phosphate rock continued the decline that started in 1975. Phosphate fertilizer production in 1977 decreased from the 1976 output of 786 708 tonnes to 692 988 tonnes P_2O_5 equivalent.

Imports of phosphate fertilizers increased 25.6 per cent as the large, integrated phosphate rock-fertilizer producers in the United States expanded their penetration of the Canadian market. In spite of increased competition from the United States producers, Canadian exports of phosphate fertilizers rose to 512 265 tonnes in 1977 from the 469 672 tonnes exported in

Table 6. Canada, trade in selected phosphate products, 1976 and 1977

	1976		1977p	
	(tonnes)	($)	(tonnes)	($)
Imports				
Calcium phosphate				
United States	17 709	4 651 000	16 233	4 910 000
United Kingdom	18	10 000	—	—
Total	17 727	4 661 000	16 233	4 910 000
Fertilizers:				
Normal superphosphate, 22% P_2O_5 or less				
United States	1 367	126 000	371	50 000
Triple superphosphate, over 22% P_2O_5				
United States	26 248	2 384 000	23 074	2 230 000
Phosphate fertilizers, nes				
United States	140 572	19 192 000	176 591	24 836 000
Belgium and Luxembourg	258	87 000	249	105 000
Israel	—	—	162	82 000
Netherlands	4	2 000	1	1 000
United Kingdom	33	16 000	—	—
Total	140 867	19 297 000	177 003	25 024 000
Chemicals:				
Potassium phosphates				
United States	1 979	1 196 000	1 102	771 000
France	—	—	18	12 000
West Germany	—	—	5	4 000
Total	1 979	1 196 000	1 125	787 000
Sodium phosphate tribasic				
United States	709	240 000	404	186 000
Netherlands	28	6 000	10	2 000
Total	737	246 000	414	188 000
Sodium phosphate, nes				
United States	4 321	2 358 000	3 928	2 611 000
West Germany	127	70 000	126	78 000
United Kingdom	—	—	2	2 000
Total	4 448	2 428 000	4 056	2 691 000
Exports				
Nitrogen-phosphate fertilizers, nes				
United States	363 546	49 187 000	391 057	47 934 000
Thailand	15 884	1 284 000	84 742	8 796 000
Pakistan	16 964	3 778 000	32 676	4 615 000
New Zealand	—	—	3 500	575 000
Nicaragua	—	—	177	29 000
Paraguay	—	—	113	13 000
Italy	44 506	6 397 000	—	—
Other countries	28 772	9 294 000	—	—
Total	469 672	69 940 000	512 265	61 962 000

Source: Statistics Canada.
p Preliminary; nes Not elsewhere specified; — Nil.

1976. However, the value of exports decreased from $69.94 million in 1976 to $61.96 million in 1977, reflecting the increasing competition in North American and offshore markets.

Outlook

The proliferation of phosphate rock mines, phosphoric acid plants and fertilizer manufacturing plants around the world indicates that there will probably be a surplus of production over consumption in the next one to three years. A balanced supply-demand position should follow if the predicted world growth of 5 per cent a year in consumption of phosphate fertilizer is achieved. Canadian producers will face continued competition from U.S. producers in the domestic market and no expansion of the domestic phosphate fertilizer industry is foreseen.

Table 7. Canada, phosphate fertilizer consumption and trade, years ended June 30, 1960, 1965, 1970, 1975, 1976 and 1977

	Consumption	Imports[1]	Exports
	(tonnes P_2O_5 equivalent)		
1960	139 020	40 860	89 193
1965	266 493	60 422	88 185
1970	280 683	10 245	198 221
1975	501 765[r]	29 976	180 561
1976	502 657	95 310	202 527
1977[p]	503 181	67 522	210 579

Source: Statistics Canada.
[1]Excludes nutrient content of mixtures and of orthophoric acid.
[p]Preliminary; [r]Revised.

Table 8. Listed export prices[1] for Florida phosphate rock (fob Tampa or Jacksonville)

Grade	January 1976	January 1977	July 1977
	($U.S. per tonne fob Tampa or Jacksonville)		
77/76% TPL	. .	. .	39.00
75/73% TPL	47.00	31.00	37.00
72/70% TPL	41.00	28.50	34.00
70/68% TPL	37.00	26.50	32.00
68/66% TPL	33.00	25.00	30.00
66/64% TPL	30.00	23.00	28.00

Source: British Sulphur Corporation Limited.
[1]These prices do not include the charge for severance tax in Florida.
. . No quote.

Platinum Metals

J.J. HOGAN

The platinum group metals consist of platinum, palladium, rhodium, iridium, ruthenium and osmium, the first two being by far the more abundant and important. The metals are usually found in basic and ultrabasic rocks, generally associated with nickel and copper sulphides; and in placer deposits, although production from placers is now of minor importance. The major sources of platinum metals are mines worked principally for these metals, mainly in the Republic of South Africa, and byproduct from the treatment of nickel-copper ores. A small amount of platinum is recovered from the refining of copper ores.

The major producers, ranked in decreasing order of production volume, are the Republic of South Africa, the U.S.S.R. and Canada. Minor producers are Colombia, the United States, Japan, Australia and the Philippines.

Canadian production of platinum group metals in 1977 was estimated at 14 588 kilograms (kg) valued at $61 772 000 compared with 12 964.6 kg in 1976 valued at $50 143 112. Volume of production increased by 12.5 per cent and dollar value by 23.2 per cent, largely because of a higher average price for platinum in 1977 and the decline in the value of the Canadian dollar. Platinum metals output in Canada is derived as a byproduct of nickel-copper refining operations, mainly in the Sudbury district of Ontario and the Thompson district of Manitoba.

World primary production of platinum group metals in 1977 was estimated by the United States Bureau of Mines (USBM) at 201 208 kg compared with 185 953.4 kg in 1976. To correct the imbalance that existed between production and demand for platinum during 1977 and to improve the price of platinum, the major producer in the Republic of South Africa announced in early November 1977 that its output was to be reduced by 10 to 20 per cent.

South Africa was the leading world producer of platinum metals in 1977 followed closely by the U.S.S.R. These two countries accounted for 92.0 per cent of the world output in 1977 and Canada, the third-largest producer, accounted for 7.3 per cent.

Japan and the United States were the leading consumers of platinum metals in the non-communist world in 1977; Japan accounting for an estimated 54 656 kg and the United States 53 049 kg. Japan is the world's largest consumer of platinum, taking about 50 per cent of total world consumption. Demand for platinum in Japan declined in 1977 by an estimated 4.7 per cent to an estimated 35 573 kg because of lower business activity and lower sales of platinum jewellery. The jewellery trade accounted for an estimated 72 per cent of the country's total platinum consumption.

The USBM estimated the platinum group metals sold to industry in the United States in 1977 at 51 193 kg. The percentage of platinum group metals sold to the U.S. consuming industries were: platinum, 49.6; palladium, 44.0; rhodium, 3.2; ruthenium, 2.0; iridium, 0.8 and osmium, 0.1.

The major users of platinum metals in the United States are the automotive, electrical and chemical industries, which together accounted for 69.5 per cent of the total. The automotive industry was the largest consumer of platinum metals, mainly in catalytic converters. Preliminary estimates show the consumption of platinum in the U.S. automotive industry at approximately 15 432 kg, up about 5 per cent from the previous year. The present ratio of platinum to palladium in catalytic converters is about 2.3 to 1. The USBM reports the stocks of platinum group metals held by refiners, importers and dealers in the United States, including metals in depositories of the New York Mercantile Exchange, but not platinum metals contained in the United States government stockpile, at the end of 1977 at 32 563 kg compared with 32 271 kg at the end of 1976.

Canadian operations and developments

The platinum group metals produced in Canada were recovered as a byproduct from the treatment of nickel-copper sulphide ores. The two major Canadian producers of platinum metals are Inco Limited, by far the larger, and Falconbridge Nickel Mines Limited, both in

Table 1. Platinum metals, production and trade, 1976 and 1977

	1976		1977[p]	
	(grams)	($)	(grams)	($)
Production[1]				
Platinum, palladium, rhodium, ruthenium, iridium	12 964 582	50 143 112	14 588 000	61 772 000
Exports				
Platinum metals in ores and concentrates				
United Kingdom	12 025 693	39 178 000	12 390 818	48 373 000
United States	45 722	120 000	—	—
Total	12 071 415	39 298 000	12 390 818	48 373 000
Platinum metals, refined				
United States	892 483	2 970 000	1 023 087	4 112 000
West Germany	30 512	197 000	67 495	191 000
United Kingdom	724 804	2 846 000	27 651	91 000
Other countries	6 875	8 000	996	6 000
Total	1 654 674	6 021 000	1 119 229	4 400 000
Platinum metals in scrap				
United States	637 217	2 930 000	938 096	3 212 000
West Germany	—	—	43 545	69 000
United Kingdom	334 113	1 683 000	2 830	16 000
Total	971 330	4 613 000	994 471	3 297 000
Re-export[2]				
Platinum metals, refined and semiprocessed	383 972	1 618 233	1 039 540	3 180 000
Imports				
Platinum lumps, ingots, powder and sponge				
United States	186 714	825 000	272 809	1 514 000
United Kingdom	5 536	13 000	44 571	217 000
Total	192 250	838 000	317 380	1 731 000
Other platinum group metals				
United States	706 484	2 103 000	677 496	1 816 000
South Africa	410 566	593 000	90 636	183 000
United Kingdom	16 018	36 000	5 008	62 000
Total	1 133 068	2 732 000	773 140	2 061 000
Total platinum and platinum group metals				
United States	893 198	2 928 000	950 305	3 330 000
United Kingdom	21 554	49 000	49 579	279 000
South Africa	410 566	593 000	90 636	183 000
Total	1 325 318	3 570 000	1 090 520	3 792 000

Table 1. (concl'd)

	1976		1977^p	
	(grams)	($)	(grams)	($)
Imports (concl'd)				
Platinum crucibles[3]				
United States	697 433	4 711 000	701 788	5 627 000
Total	697 433	4 711 000	701 788	5 627 000
Platinum metals, fabricated materials, not elsewhere specified				
United Kingdom	791 770	4 343 000	391 220	2 447 000
United States	302 326	1 341 000	250 974	1 299 000
Other countries	62 642	142 000	41 896	91 000
Total	1 156 738	5 826 000	684 090	3 837 000

Source: Statistics Canada.
[1]Platinum metal, content of concentrates, residues and matte shipped for export. [2]Platinum metals, refined and semiprocessed, imported and re-exported in the same form as when imported. [3]Includes spinners and bushings.
^{p}Preliminary; — Nil.

the Sudbury district of Ontario. Inco also recovers platinum metals from its mines in the Thompson area of Manitoba. Langmuir mine, near Timmins, which is owned 51 per cent by Noranda Mines Limited and 49 per cent by Inco, is a small producer of platinum metals. The copper-nickel sulphide concentrates from this mine are shipped to Inco's plant at Sudbury for treatment. The mine is scheduled for closure in 1978. The ore deposit of Union Minière Explorations and Mining Corporation Limited (Umex), near Pickle Lake, Ontario, contains minor amounts of nickel and platinum metals. These metals are recovered in the copper concentrates at its 3 600 tonne-a-day concentrator. The concentrates are shipped to the Noranda smelter in Quebec for recovery of the contained metals.

Because of the relatively low world prices for platinum and palladium there was little activity on the Lac des Iles platinum metals prospect of Boston Bay Mines Limited in northwestern Ontario. In December 1976, a single deep hole, which was drilled to prove the downward extension of the main mineralized zone, intersected it at about 400 metres. Exploratory work carried out on the property to date has outlined two zones of mineralization reported to contain about 35 000 tonnes* a vertical metre grading 5.75 grams of platinum metal a tonne, 0.2 per cent copper-nickel and 0.62 grams of gold. Preliminary work indicated the ratio of palladium to platinum to be about 8 to 1.

Foreign developments

Republic of South Africa. The Republic of South Africa is the world's largest producer of platinum group metals. It is the only country among the major world producers that mines platinum metals-bearing ores primarily for the recovery of these metals. The deposits, which occur in the Merensky Reef of the Bushveld Complex near Rustenberg, also contain some gold, copper and nickel. The estimated platinum metals contained in the Merensky Reef occur in the following proportion: platinum, 61 per cent; palladium, 25 per cent; and other platinum group metals, 14 per cent. Small amounts of osmium and iridium are recovered as a byproduct from treatment of Witwatersrand gold ores.

The depressed world market for platinum in 1977 and the resultant low price for the metal adversely affected the South African platinum producers. The operating costs continued to rise throughout the year because of higher power costs, labour rates and cost of supplies and marketing. One of the mines reported that the operating cost to produce an ounce of platinum and the cost of capital items had doubled since 1974. Labour shortage was experienced in the first part of the year by the mines, but they had the normal complement of employees at year-end.

On December 6, 1977 the Republic of Bophuthatswana achieved independence within the Republic of South Africa. The new nation consists of six separate territorial areas totalling 37 943 km^2 in the Transvaal and the Orange Free State, and bordering on Botswana to the north. A large percentage of the platinum produced in South Africa comes from this new state. Bophuthatswana also contains a large proportion of the Merensky Reef, the source of present production and of potential future production. In the immediate future it is expected that the operations of the mines will not be affected by the creation of this new republic.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Rustenberg Platinum Holdings Limited, the largest producer of platinum group metals in the non-communist world, operates three major mines, a smelter and two refineries in the Transvaal district of the Republic of South Africa and one refinery in the United Kingdom. One of its mines is located in the Rustenberg district and the other two in the Union district of the Transvaal. The refining of copper, nickel and platinum metals is carried out in the Republic of South Africa and in the United Kingdom by Matthey Rustenberg Refiners (Proprietary) Limited, a company jointly owned by Rustenberg and Johnson, Matthey & Co., Limited of the United Kingdom.

To offset the effects of inflation and increased production costs related to mining at increased depth, Rustenberg is concentrating on methods to improve productivity. A long wall system of mining that is expected to lead to increased productivity and improved ventilation and supervision is being developed. Mechanical methods of mining are being introduced wherever possible. The new facilities of Matthey Rustenberg Refiners' plant operated satisfactorily during the year, but the costs incurred in the refining of the copper and nickel were high. In the short term, steps are being taken to modify part of the plant to reduce costs; but in the long term, investigations are being conducted to evaluate the economics of installing a new base metal recovery process. Recent developments have reduced the time required for the refining of the platinum group metals.

The first of three units at Rustenberg's Amandelbat mine was completed in May and operated at its rated capacity of 1 865 kg of platinum metals a year. Lower costs resulting from mining being carried out relatively close to the surface should improve the company's profitability.

On October 19. 1977 Rustenberg acquired the property of Atok Platinum Mines (Proprietary) Limited, near Pieterburg for 2.2 million rand. The rated capacity of this plant is 1 200 kg of platinum metals a year. The treatment of the ore from this mine in the integrated smelting and refining facilities of Rustenberg should reduce the cost of producing the platinum metals from this mine.

Production of platinum at Rustenberg in 1977 was about 31 000 kg. On november 1, 1977 the company announced that it would cut back on production between 10 and 20 per cent to improve the demand/supply balance and to reduce the pressure on the financial resources of the company caused by low prices and sales. Capital expenditures required to increase the overall annual plant capacity to 57 700 kg of platinum are continuing but have been curtailed.

To date, all production from the Rustenberg operation comes from the Merensky Reef of the Bushveld Complex. A second reef, which contains chrome and platinum group metals and is known as the Upper Group No. 2 Reef (UG2), occurs beneath the Merensky Reef. The company continued to operate its pilot plant at Driehap, in the eastern Transvaal, to develop a process to economically recover chromium and the precious metals. Successful recovery of the metals in this zone will add to the large reserves of platinum metal already defined in the Merensky Reef and develop another source of chrome.

Impala Platinum Limited operates a mine-concentrator-smelter-refinery complex near Rustenberg. In 1977, Impala operated slightly below its planned output of 21 770 kg because of a shortage of labour. At year end, labour requirements were normal. Planned production for 1978 is at the rate of 21 770 kg a year, but the rate of output will be subject to periodic review of market conditions and level of refinery stocks.

Western Platinum Limited, jointly owned by Lonrho Limited, Falconbridge Nickel Mines Limited

Table 2. Canada, platinum metals, production and trade, 1960, 1965, 1970, 1975-77

	Production[1]		Exports				Imports[4]	
			Domestic[2]		Re-export[3]			
	(grams)	($)	(grams)	($)	(grams)	($)	(grams)	($)
1960	15 041 766	28 873 508	12 542 166	16 068 728	6 207 103	8 404 563	. .	12 951 420
1965	14 404 860	36 109 799	17 138 700	30 103 254	10 013 764	11 389 395	7 265 865	13 461 546
1970	15 005 188	43 556 597	15 327 731r	44 174 000r	634 480	2 365 735	1 889 381	3 123 000
1975	12 417 099	56 493 077	15 530 930	50 244 000	538 899	2 928 000	1 896 410	6 061 000
1976	12 964 582	50 143 112	13 726 089	45 319 000	383 972	1 618 233	1 325 318	3 570 000
1977p	14 588 000	61 772 000	13 510 047	52 773 000	1 039 540	3 180 000	1 090 520	3 792 000

Source: Statistics Canada.
[1]Platinum metals, content of concentrates, residues and matte shipped for export. [2]Platinum metals in ores and concentrates and platinum metals, refined. [3]Platinum metals, refined and semiprocessed, imported and re-exported after undergoing no change or alteration. [4]Imports, mainly from United States and United Kingdom, of refined and semiprocessed platinum metals, derived from Canadian concentrates and residues, a large part of which is re-exported.
pPreliminary; rRevised; . . Not available.

and Superior Oil Company, operated a mine-concentrator-smelter-refinery complex in the Transvaal district of South Africa which has an annual rated capacity of 4 666 kg of platinum metals. Production of platinum group metals for the fiscal year ending September 30, 1977 was 4 137 kg compared with 4 075 kg in 1976. Western Platinum uses the NIM process, which was developed by the National Institute of Metallurgy, for the recovery of platinum metals. The NIM process reduces the recovery time of platinum metals from about four months to 20 days, sharply reduces labour requirements compared to other processes and lowers capital cost because of the smaller space requirements for equipment.

U.S.S.R. In the U.S.S.R. platinum metals are derived mainly as a byproduct in the processing of nickel-copper ores in the Norilsk region of northwestern Siberia and the Kola Peninsula of northwestern Russia. Some platinum metals are recovered from the placer deposits in the southern Urals, once the major source of U.S.S.R. output. The United States Bureau of Mines estimated the U.S.S.R. production of platinum metals at 91 755 kg for the year 1977 compared with 87 090 kg in 1976. The U.S.S.R. is carrying out a major expansion program to develop nickel-copper deposits in the Norilsk region to substantially increase the output of these metals. The expansion program is being carried out on a series of phases, and the overall program is expected to be completed by 1980. This undertaking should add to the quantity of platinum metals, especially palladium, produced in the U.S.S.R. The platinum metals recovered from the U.S.S.R. ores contain about 60 per cent palladium, 30 per cent platinum and 10 per cent other platinum metals.

United States. Mine production of platinum metals in the United States during 1977 was derived as a by product of copper refining. The United States also recovered a substantial quantity of platinum metals from secondary sources. The USBM estimated new and secondary platinum metals recovered during the year by refiners in the United States at 6 532 kg. Mine production in 1977 was estimated at 156 kg.

Platinum group metals are found in the rocks of the Stillwater complex, Sweetgrass County, southwestern Montana. Johns-Manville Corporation has carried out an extensive development program consisting of surface diamond drilling, drifting and underground drilling. Significant values in platinum metals have been encountered, as well as small amounts of coppernickel sulphides, silver and gold.

Colombia. Mine production of platinum metals in Colombia in 1976 was estimated by the USBM at 622 kg. The platinum metals are recovered as a coproduct from placer operations in the Chaco and Narimo districts of Colombia.

Recycling

Recycling plays an important role in the supply of platinum metals to the market. It is estimated that over 80 per cent of the platinum metals consumed by industry is recycled. This is important to industrial consumers because it helps offset the generally high initial cost of materials containing platinum metals. In the United States, one of the few countries that keeps detailed statistical data on platinum metals, an estimated 6 430 kg were recovered from secondary sources in 1977. This does not include toll-refined platinum metal, estimated at more than 31 000 kg.

Uses

The main applications for the platinum group metals are the jewellery, automotive, chemical, petroleum refining, glass and electrical industries. The industrial use of platinum group metals is based on special properties, the principal ones being: catalytic activity, resistance to corrosion and to oxidation at elevated temperatures, good electrical conductivity characteristics, high melting point, high strength, ductility and aesthetic qualities. The use of platinum metals in the catalyst field is the major application. Platinum and

Table 3. World mine production of platinum group metals, 1975-77

	1975	1976[p]	1977[e]
		(grams)	
Republic of South Africa	80 869 000[e]	83 979 000[e]	93 310 000
U.S.S.R.	82 424 000[e]	87 090 000[e]	91 755 000
Canada	12 417 099	12 964 582	14 588 000
Colombia	687 822	809 000	622 000
United States	588 478	190 229	156 000
Other countries	728 070	920 631	777 000
Total	177 714 469	185 953 442	201 208 000

Sources: U.S. Bureau of Mines, *Mineral Trade Notes*, Vol. 74, No. 11, November 1977; U.S. Bureau of Mines, Mineral Commodity Summaries, January 1978 for 1977; and Statistics Canada for Canadian production.
[e] Estimated; [p] Preliminary.

palladium are the major platinum metals. The others — iridium, osmium, rhodium and ruthenium — are used mainly as alloying elements with platinum and palladium, but small amounts are also used individually in special applications.

With the view of promoting an increased use of platinum in the jewellery trade, a major South African producer launched an aggressive advertising campaign beginning in 1975, in Japan, the United States, the United Kingdom and West Germany. It is difficult to appraise the result of this promotion because other world factors have affected the market. The jewellery trade accounts for about 70 per cent of the platinum consumed in Japan. Consumption in this application declined by about 5 per cent because of a slowdown in the Japanese economy which resulted in lower consumer spending. In the United States about 3 per cent of total platinum consumed is for jewellery, and in western Europe the figure is about 7 per cent. It is evident that a large potential market exists for the use of platinum in jewellery manufacturing in these two countries. However, it will take time and effort to develop this market, since gold has been the traditional precious metal used for jewellery. The recent sharp increase in the price of platinum in relationship to gold could further deter its use in the jewellery industry.

The recent development of platinum and palladium in catalytic converters for the control of automotive exhaust emissions has been a major factor in increasing the demand for these metals and was responsible for the recent expansion of production facilities in the Republic of South Africa. The Environmental Protection Agency (EPA) of the United States and the Japanese government have established automotive emission standards that can best be met by platinum-palladium converters.

In August 1977 the United States Congress passed a bill amending the Clean Air Act. One of the amendments granted a two-year extension to model-year 1979 on the automotive exhaust emission standards now in force and established revised emission standards for model-year 1980 and beyond. The automotive manufacturers could not have met the stringent emission standards that would have been necessary to comply with the law.

The present platinum-palladium converters do not control the nitrogen oxide emissions. In order to meet the stricter nitrogen oxide emission of the future it appears that rhodium will be the third metal used in catalytic converters. Converters containing rhodium are being installed on an experimental basis on some model-year 1978 automobiles manufactured for the Californian market. The rhodium-type converter developed to date could not be adopted universally because the supply of the metal would not be sufficient to meet requirements. The amendments to the Clean Air Act will give the manufacturers time to research the development of a technology that uses considerably less rhodium. The ideal converter would be one that contains platinum/rhodium in the same ratio as that occurring in the South African ores.

Platinum catalysts are used in the petroleum industry for the production of high-octane gasoline. A platinum-rhenium catalyst has been found effective in this application, but a drawback to its use is the small potential supply of rhenium metal.

Platinum alloyed with other platinum group metals finds wide application as a catalyst in the chemical industry, an important application being in the production of nitric acid from the combination of ammonia and oxygen. The platinum metal catalysts are also used in the production of other industrial chemicals, pharmaceutical products and in the food processing industry.

The electrical industry is a major consumer of platinum. It is used in the electronic industry in printed circuits, alone and with other precious metals; in electrical furnaces, thermocouples and electrical contacts. Platinum is also used in the cathode protection of ships' hulls. A major use of palladium is in electrical contacts for telephone equipment. The metal was used alone in this application, but the high price prevailing in 1974 led to the development of a palladium-silver alloy containing 60 per cent palladium and 40 per cent silver, which has substantially reduced the consumption of palladium in this field.

A platinum-rhodium alloy is contained in bushings and spinnerets used in the production of fibreglass and synthetic fibres, and it is also used in the glass manufacturing industry. The jewellery trade is a substantial consumer of platinum, especially in Japan.

Platinum metals are used: in dental applications, laboratory equipment; in the field of medicine and medical research, and in fuel cells for direct generation of electric current. Because of its resistance to corrosion at high temperatures, iridium crucibles are used for the growing of laser crystals and synthetic gems.

Considerable research is being done to develop new uses for platinum metals. A new application for platinum could result from the successful industrial development of a fuel cell as a source of power in which platinum-coated electrode acts as a catalyst for the direct conversion of chemical energy into electrical energy. Conversely, research is being carried out to lower the consumption of platinum in many of its present applications.

Prices

A slow recovery in the industrial demand for platinum metals, caused in part by lower capital spending and a decline in Japanese jewellery consumption in 1977, resulted in a comparatively stable pattern for both producer and dealer prices throughout the year.

The average producer and dealer prices for platinum for 1977 were $U.S. 162.54 and $U.S. 157.71 an ounce respectively. Corresponding figures for palladium were $U.S. 59.70 and $U.S. 49.34 an ounce.

Platinum. The producer price for platinum remained unchanged at $U.S. 162 an ounce until it was increased to $U.S. 175 an ounce on November 28, 1977 and to $U.S. 180.00 an ounce on December 23. The price rise was a result of a planned reduction in output by a South African mine, reduced purchases of platinum jewellery by the Japanese and the withholding of platinum metal from the market by the U.S.S.R. The dealer price of the metal fluctuated between $U.S. 145.25 to $U.S. 165.00 an ounce for the first ten months of the year. At year-end the price had increased to $U.S. 185.00 an ounce.

Palladium. The producer price of palladium was increased from $U.S. 55.00 an ounce to $U.S. 60.00 an ounce on January 27, 1977, and it remained at this price throughout the year. For the first five months of 1977 the dealer price of palladium was quoted between $U.S. 50 and $U.S. 59 an ounce. The dealer price began to decline and for the next five months varied from $U.S. 41 to $U.S. 46 an ounce. In the last two months of the year the price moved up into the area of $U.S. 52 an ounce, reportedly based on speculative buying.

Rhodium. On March 9, 1977 the producer price of rhodium was increased from $U.S. 400 to $U.S. 450 an ounce to bring it more in line with an advancing dealer price. Increased purchases of rhodium by the chemical and petroleum industries forced the dealer price up from its opening at $U.S. 375 to a high of $U.S. 441 an ounce in early March. The price declined gradually until it reached a low of $U.S. 377 an ounce on October 27. It increased sharply in December to a range of $U.S. 435 to $U.S. 445 an ounce on increased consumer demand. Stocks of rhodium are not large, and any upsurge in demand tends to force a sharp increase in the dealer price.

Iridium, ruthenium and osmium. Both the producer and dealer price were stable for iridium, ruthenium and osmium during 1977. The producer price for iridium was $U.S. 300 an ounce, and for ruthenium $U.S. 60 an ounce. The producer price for osmium was lowered to $U.S. 150 an ounce on September 20 from $U.S. 200 an ounce. The dealer price for iridium was in the area of $U.S. 280 an ounce for the first four months of 1977 and declined to $U.S. 230 an ounce at the end of the year. The dealer price for 1977 was approximately $U.S. 34 an ounce for ruthenium and $U.S. 130 an ounce for osmium.

Outlook

In the short-term view the supply of the platinum group metals is adequate to meet demand. In the Republic of South Africa the mine operators have adjusted their platinum metals output to meet world requirements. In November 1977 the largest producer announced that it was reducing output by 10 to 20 per cent. Canadian production is also expected to decline in 1978 due to reduced nickel production. A moderate increase in demand can be met by restoring part or all of these production cutbacks. Expansion programs to increase the annual rate of platinum metals output in South African mines are being implemented on a flexible basis and can be accelerated if the demand for these metals increase appreciably. However, there are no developments on the horizon that could substantially increase the demand for platinum metals.

In the immediate future it appears that the use of platinum metals in catalytic converters will continue to be the best method of attaining the automotive emission standards established by the United States Environmental Protection Agency (EPA). Research projects on other methods to control automobile exhausts, by either the development of a new type of engine or by the development of a new catalyst, have not reached the efficiency of a platinum metals converter. The improvement in car sales in 1977 resulted in a small increase in the consumption of platinum and palladium for catalytic converters. It is expected that the consumption of these metals in catalytic converters will remain near the present level for some time. The platinum metals required to meet this demand will come largely from primary production, but in a few years the market pattern could change, with these metals coming on the market from recycled converters.

There are a number of factors that could affect the market performance of the platinum group metals. The United States government has established the strategic stockpile objective for platinum at 42 246 kg, an increase of 27 693 kg over the present stockpile of 14 553 kg. The stockpile objective for palladium has been increased from the present level of 40 349 kg to 70 769 kg. It is expected that purchases of these metals for a stockpile program will be made over a period of years, and in such a manner as to be least disruptive to the market. Russia has withheld platinum from the market since the latter part of 1977. Although details outlining the reasons for this action are not available, it is thought that some platinum metal is being stockpiled for the minting of platinum Olympic coins.

In the long-term the consumption of platinum metals in present applications should show a steady growth pattern. The large reserves of platinum group metals contained in the Merensky Reef in the Republic of South Africa can be developed to keep supply in balance with demand. New nickel mines are being developed in the U.S.S.R., and the platinum metals, especially palladium, recovered from the treatment of these nickel ores may have a strong impact on the platinum metals market.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential[1]
36300-1	Platinum wire and platinum bars, strips, sheets or plates; platinum, palladium, iridium, osmium, ruthenium and rhodium, in lumps, ingots, powder, sponge or scrap	free	free	free	free
48900-1	Crucibles of platinum, rhodium and iridium and covers therefore	free	free	15%	free

United States

Item No.		Rate of Duty
601.39	Precious metals ores	free
605.02	Platinum metals, unwrought, not less than 90% platinum	free
		% ad valorem
605.03	Other platinum metals, unwrought	20
605.05	Alloys of platinum, semimanufactured, gold-plated	25
605.06	Alloys of platinum, semimanufactured, silver-plated	12
605.08	Other platinum metals, semimanufactured including alloys of platinum	20
644.60	Platinum leaf	20

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa; Tariff Schedules of the United States, Annotated (1978) TC Publication 843.
[1]General Preferential Tariff rate from July 1, 1974 to June 30, 1984.

Potash

A.F. KILLIN

World production of potash in 1977 increased 7 per cent over 1976 output to 25 651 000 tonnes*. The major portion of this increase was accounted for by: Canada, 1 295 000 tonnes; U.S.S.R., 390 000; West Germany, 305 000; German Democratic Republic, 83 000; and the United States, 25 000. Congo, −173 000 tonnes; Israel, −90 000; and France −23 000, had decreased production in 1977. World consumption increased by 1 214 000 tonnes to 22 400 000 tonnes for the fertilizer year 1976-1977 from 1975-1976. Demand for coarse and granular grades remained strong and high inventories of standard grade were reduced during the year.

The bulk of world potash production is in the form of potassium chloride (KCl), known in the industry as muriate of potash, and used in the production of fertilizer. All Canadian potash production is marketed as the chloride, with a potassium content of about 50 per cent (60 to 62 per cent K_2O equivalent). This product is marketed in the United States, in offshore countries and domestically. A high percentage of exports results in Canada's 38 per cent share of the international potash market.

Production and developments in Canada

Saskatchewan. There are ten potash mines in Canada (all in the province of Saskatchewan) with an installed capacity of 12 350 000 tonnes of potassium chloride (7 570 000 tonnes K_2O equivalent). In 1977 the industry operated at 80 per cent of capacity responding to increased demand in North American and export markets.

Canadian production at 6 088 587 tonnes was 22 per cent higher than in 1976; in the same period shipments increased by 13 per cent to 5 910 000 tonnes. The value of potash shipments totalled $421 281 000, an increase of 19 per cent over the 1976 value. The Potash/Phosphate Institute of North America reported producer stocks at the beginning and end of 1977 at 1 371 106 tonnes and 1 778 385 tonnes.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois. Unless otherwise noted, potash tonnages are in tonnes of K_2O equivalent.

New Brunswick. The two companies active in potash and salt exploration in New Brunswick continued examination and evaluation of their properties in the province. Potash Company of America completed a feasibility study on a mine proposal at Sussex, approximately 60 kilometres (km) east of Saint John, and signed a development agreement with the New Brunswick government to develop a mine and plant capable of producing about 900 000 tonnes of KCl a year. Construction will start in 1978 and production at 650 000 tonnes a year KCl is scheduled for 1981. Employment at the site will rise to about 500 in the construction period and stabilize around 300 when production reaches its peak. International Minerals & Chemicals Corporation (IMC) continued a program of exploration by diamond drilling at its potash prospect at Salt Springs, about 19 km southwest of Sussex. IMC is expected to sign a mining lease agreement with the New Brunswick government in 1978. The company expects that a further three years of exploration and planning will be required before a development decision can be made.

Ontario. Shamrock Chemicals Limited will reactivate its potassium sulphate plant at Port Stanley in 1978. Operations were halted in 1973 soon after the commissioning of this 220-tonne-a-day plant because of pollution problems. The rehabilitated plant will operate initially on one reactor at 110 tonnes a day. Potassium sulphate will be produced for the domestic and export market. Byproduct hydrochloric acid and liquid calcium chloride will be sold in the domestic market, replacing imports.

Government-industry relations

The major events in 1977 were: the overturning by the Court of Appeal for Saskatchewan of the finding by Judge Disbery that the Prorationing Regulations were *ultra vires*, and the acquisition by Potash Corporation of Saskatchewan of two more potash mines.

In a judgment filed on January 7, 1977, the Court of Appeal for Saskatchewan allowed an appeal by the Attorney General of Saskatchewan and overturned the judgment by Judge Disbery that the Potash Conserva-

Table 1. Canada, potash production, shipments and trade, 1976 and 1977

	1976		1977p	
	(tonnes)	($)	(tonnes)	($)
Production, potassium chloride				
Gross weight[1]	8 169 700	. .	9 956 922	. .
K_2O equivalent	4 995 863	. .	6 088 587	. .
Shipments				
K_2O equivalent	5 215 435	353 504 466	5 910 000	421 281 000
Imports, fertilizer potash				
Potassium chloride				
United States	4 178	267 000	11 818	776 000
United Kingdom	21	2 000	15	10 000
Total	4 199	269 000	11 833	786 000
Potassium sulphate				
United States	7 831	776 000	11 429	1 229 000
Mexico	—	—	18	3 000
Total	7 831	776 000	11 447	1 232 000
Potash fertilizer, nes				
United States	45 134	2 449 000	82 356	5 158 000
Potash chemicals				
Potassium carbonate	987	349 000	760	325 000
Potassium hydroxide	5 375	1 304 000	4 932	1 395 000
Potassium nitrate	1 691	433 000	1 967	507 000
Potassium phosphate	1 979	1 196 000	1 125	787 000
Potassium bitartrate	76	97 000	121	104 000
Potassium silicates	865	293 000	675	250 000
Total potash chemicals	10 973	3 672 000	9 580	3 368 000
Exports, fertilizer potash				
Potassium chloride				
United States	6 636 074	317 199 000	7 278 030	367 084 000
Japan	542 164	29 762 000	615 805	30 741 000
Brazil	216 092	11 686 000	372 766	19 699 000
India	155 924	8 554 000	216 979	11 182 000
South Korea	212 132	11 691 000	197 885	10 444 000
Singapore	110 923	6 114 000	139 065	7 274 000
Australia	71 062	4 016 000	86 054	4 555 000
Sri Lanka	20 500	1 130 000	32 749	2 523 000
Taiwan	153 665	8 402 000	48 998	2 501 000
People's Republic of China	—	—	49 829	2 497 000
Other countries	159 568	9 058 000	182 146	9 769 000
Total	8 278 104	407 612 000	9 220 306	468 269 000

Sources: Statistics Canada; Potash Institute of North America for K_2O production figures.
[1] Based on a conversion factor of K_2O x 1.64 for standard, special standard, granular and coarse grades, and K_2O x 1.60 for soluble and chemical grades.
p Preliminary; — Nil; . . Not available.

Table 2. Canada, potash production and sales by grade[1] and destination, 1976 and 1977

	1977					1977	1976
	Standard[2]	Coarse	Granular	Soluble	Chemical	Total	Total
	(tonnes K_2O equivalent)						
Production	1 268 107	2 328 266	1 765 690	656 778	69 746	6 088 587	4 995 863
Sales							
Domestic	11 007	215 359	13 903	8 923	—	249 192	234 621
United States	646 009	1 704 302	1 398 657	448 766	—	4 197 734	4 043 517
Offshore							
Australia	6 572	20 946	19 426	22	—	46 966	53 477
Bangladesh	—	12 193	—	—	—	12 193	6 391
Brazil	6 469	200 825	33 017	—	—	240 311	129 032
Chile	—	—	—	—	—	—	12 354
China	30 344	—	—	—	—	30 344	—
Costa Rica	3 194	—	—	—	—	3 194	6 403
Denmark	27 334	—	—	—	—	27 334	—
Guatemala	1 162	—	—	—	—	1 162	—
India	132 091	—	—	3 932	—	136 023	84 209
Italy	—	—	—	19 785	—	19 785	18 791
Japan	220 199	61 636	—	103 670	—	385 505	285 868
Kenya	213	—	—	—	—	213	—
Korea	133 886	—	—	—	—	133 886	93 162
Malaysia	70 722	4 938	—	217	—	75 877	45 323
New Zealand	11 601	—	—	—	—	11 601	—
Nicaragua	—	—	1 907	—	—	1 907	—
Philippines	30 365	—	—	—	—	30 365	24 554
Romania	23	—	—	—	—	23	—
South Africa	5 876	15 624	—	—	—	21 500	18 215
Sri Lanka	13 614	—	—	—	—	13 614	19 353
Taiwan	29 816	—	—	—	—	29 816	90 711
United Kingdom	1 040	—	—	—	—	1 040	7 167
Vietnam	9 367	—	—	—	—	9 367	—
Offshore total	733 888	316 162	54 350	127 626	—	1 232 026	895 010
Total sales	1 390 904	2 235 823	1 466 910	585 315	—	5 678 952	5 173 148

Source: Potash Institute of North America.
[1]Common specifications are: standard — 28 to + 65 mesh, special standard —35 to + 200 mesh, coarse —8 to + 28 mesh, granular —6 to + 20 mesh, each grading a minimum of 60 per cent K_2O equivalent, soluble and chemical grade a minimum of 62 per cent K_2O equivalent. [2]Standard includes Special Standard, production of which was 200 051 tonnes K_2O equivalent in 1977, and 159 235 in 1976, and sales of chemical grade.
— Nil.

tion Regulations, 1969, were *ultra vires*. The judgment by the appeal court also assessed court costs against Central Canada Potash Co. Limited and set aside the award of $1.5 million damages assessed against Saskatchewan in favour of Central Canada Potash. Central Canada Potash has appealed the judgment to the Supreme Court of Canada but no decision has yet been announced.

Potash Corporation of Saskatchewan (PCS), the provincial Crown corporation set up to acquire 50 per cent of the potash productive capacity in the province, acquired certain assets of two corporations during the year and was also carrying out evaluation of two more properties. The Potash Corporation of Saskatchewan was established by Order-in-Council on February 4, 1975 and continued under the Potash Corporation of Saskatchewan Act of April 1, 1976. Two subsidiary companies were incorporated under the Companies Act of the Province of Saskatchewan: Potash Corporation of Saskatchewan Mining Limited (PCSML) — Cory Division, Rocanville Division, and Lanigan Division — and Potash Corporation of Saskatchewan Sales Limited (PCSSL).

On April 22, 1977 PCS purchased the potash mining operations of Hudson Bay Mining and Smelting Co., Limited for $144 million (Canadian). PCSML will operate the mine as the Rocanville Division. In November, PCS purchased the mine and operations of Alwinsal Potash of Canada Limited at Lanigan, which will be operated by PCSML as the Lanigan Division. The purchase involved $56.5 million in cash, a $20 million non-negotiable 6 per cent promissory note payable on October 31, 1981, and assumption of Alwinsal's liability for potash reserve tax of up to $9 million. PCSML has announced expansion plans for the Cory and Rocanville mines. Cory capacity will be increased to about 830 000 tonnes K_2O equivalent by increased mill efficiency, raising the hoisting speed to about 1 100 metres a minute and by expanding underground storage to 5 450 tonnes. Completion is expected by June 1979. Rocanville will be expanded in two stages to reach an annual capacity of 1 110 000 tonnes K_2O equivalent by 1981. Employment created during the construction phase will total about 250 jobs and when expansion is complete there will be a total of approximately 90 new permanent positions. PCS was evaluating the mines and reserves of APM Operators Ltd. at Allan, and AMAX Potash Ltd. at Esterhazy to determine the advisability of making a purchase offer for these assets.

Funds for the PCS program have been obtained from two sources: transfer of proceeds from the sale by the province of $75 million of bearer bonds at 8-3/8 per cent interest (PCS must repay the bonds in three annual installments from 1982 to 1984 and assume liability for the interest), and a loan from the province of $229 429 000 from the Energy and Resources Fund. No interest or repayment terms have been specified for this loan.

Markets

About 95 per cent of the world's potash output is used for fertilizers, the balance being used for industrial purposes, including the manufacture of soaps, glass, ceramics, textiles, dyes, explosives and numerous chemicals.

Sales of potash in Canada in 1977 increased 7 per cent over those in 1976 to 259 079 tonnes K_2O equivalent. Of the material sold, 83 per cent was coarse grade, for agricultural use. Ontario and Quebec continued as Canada's largest users of potash, consuming 79.6 per cent of Canadian sales in 1977. Nonagricultural sales of potash in Canada in 1977 were 16 044 tonnes, an increase of 50 per cent over 1976 sales. Alberta, at 9 353 tonnes, consumed 58 per cent of total nonagricultural sales.

Canadian sales of potash to the United States in 1977 were 4 197 734 tonnes (K_2O equivalent), a rise of 168 436 tonnes from the 1976 total. Coarse and granular grades accounted for 77 per cent of total sales to the United States in 1977. The United States market is supplied from three major sources; Canada, New Mexico and imports from offshore, in that order. Of the 49 states using potash, 17 consume over 100 000 tonnes a year. The "corn belt" states: Illinois, Indiana, Iowa, Minnesota, Ohio and Wisconsin, each consume over 300 000 tonnes a year and, in each case, Canada supplies more than 94 per cent of annual consumption. Canadian potash penetrates the United States market as far south as Louisiana, Mississippi and Texas but the percentage of total sales in these areas is small, varying from 1 per cent in Texas to 13 per cent in Louisiana.

Offshore imports into the United States in 1977 amounted to 201 632 tonnes, from: Israel, 60.8 per cent; Spain, 14.3 per cent; West Germany, 6.7 per cent; U.S.S.R., 6.3 per cent; East Germany, 5.2 per cent; France, 4.2 per cent and Italy, 2.5 per cent.

Canadian offshore sales of potash increased 37.7 per cent to 1 232 026 tonnes in 1977. Increased sales were mainly to Brazil, People's Republic of China, Denmark, India and Japan.

Prices

In 1977 the average list price for standard grade muriate of potash, fob plant in Saskatchewan, basis 61 per cent K_2O content, was $45.39 (Canadian) a tonne. The comparable price for coarse grade was $50.49 a tonne. The average realized price is a few percentage points lower because of volume discounts, seasonal discounts, and sales in some highly competitive markets such as Europe.

Rail freight rates on potash are an important component of fertilizer costs, e.g. freight charges to Ontario and Quebec in 1977 averaged $38.65 a tonne, and to the Maritimes about $40.00 a tonne.

External developments

The United States District Court, Northern District of Illinois, dismissed an indictment, filed on June 29, 1976 charging six U.S. companies, and subsidiaries of two of the companies, with conspiracy to restrain interstate and foreign trade and commerce by restricting production, export and import of potassium chloride, and by price-fixing. All charges filed by the United States court against unindicted co-conspirators, including some Canadians, have been dropped. An out-of-court agreement has been reached to settle civil suits filed against the same U.S. companies, but will not be finalized until 1978.

World developments

Fertilizer demand recovered in 1977 from the depressed levels evident since the oil/commodity crisis of 1973-74. Potash production in Canada, U.S.S.R. and Europe responded to the increased demand, and shipments were the highest since 1973-74. The Soviet potash industry increased production by 400 000 tonnes in 1977 and three new mines are being prepared for production. The German Democratic Republic (East Germany) increased production by 100 000 tonnes and

Table 3. Canada, potash production and trade, years ended June 30, 1960, 1965, 1970, 1975, 1976 and 1977

	Production	Imports[1]	Exports
	(tonnes K_2O equivalent)		
1960	. . .	77 855	. . .
1965	1 067 219	45 160	892 267
1970	3 565 837	24 512	3 309 758
1975	5 063 635	28 764	4 583 648
1976	4 833 296	16 445	4 314 150
1977[p]	4 803 015	24 289	4 175 473

Source: Statistics Canada.
[1]Includes potassium chloride, potassium sulphate, except that contained in mixed fertilizers.
[p]Preliminary; . . . Not applicable.

Table 4. Canada, consumption of potash fertilizers, years ended June 30, 1960, 1965, 1970, 1975, 1976 and 1977

	In Materials	In Mixtures	Total
	(tonnes K_2O equivalent)		
1960	3 980	77 009	80 989
1965	16 569	106 269	122 837
1970	36 718	137 896	174 614
1975	62 945	143 867	206 813
1976	84 649	157 428	242 077
1977[p]	76 591	157 641	234 232

Source: Statistics Canada.
[p]Preliminary.

was aggressive in export markets. In Western Europe, production was increased in West Germany and Spain. The U.K. mine at Boulby produced only about 80 000 tonnes K_2O in 1977 but is expected to produce to capacity in 1978-79.

The mine of Cie. des Potasses du Congo in the Congo was flooded and abandoned in 1977. No plans for rehabilitation or resumption of production have been announced. The loss of production from this mine has been made up by increased West European output.

In the Carlsbad district of New Mexico in the United States, Mississippi Chemical Corporation resumed production at its expanded mine and refinery. Annual capacity has been increased to 270 000 tonnes K_2O from 110 000 tonnes, and mining efficiencies have been introduced through modified longwall techniques and the utilization of continuous mining methods.

Exploration for potash continued in the Montana-North Dakota regions of U.S.A., in Thailand and Brazil. In the United Kingdom Consolidated Gold Fields Australia Ltd. has applied for a permit to install a solution mine and plant near Whitby in Yorkshire. Initial plans call for production of 450 000 tonnes a year of KCl.

Outlook

The medium-term outlook for potash remains strong, and an annual average growth rate of 5 per cent a year is expected. In the short-term, however, adverse weather conditions, late planting seasons and agricultural set-asides have brought about reduced demand in late 1977 and early 1978, which, in the absence of production adjustments, resulted in increased inventories. It is likely that production curtailments will be necessary in 1978 to clear out inventories and stabilize prices.

Table 5. Canada, potash sales by product and area, 1976 and 1977

		Agricultural					Industrial			
		Standard	Coarse	Granular	Soluble	Total	Standard	Soluble	Total	Total Sales
		(tonnes K_2O equivalent)								
Alberta	1976	1 069	1 715	5 227	1 936	9 947	5 299	202	5 501	15 448
	1977	496	1 678	6 403	523	9 100	6 552	2 717	9 269	18 369
British Columbia	1976	57	3 275	1 952	57	5 341	199	–	199	5 540
	1977	92	2 762	3 315	113	6 282	232	14	246	6 528
Manitoba	1976	–	1 004	1 989	24	3 017	–	–	–	3 017
	1977	–	2 213	2 627	14	4 854	24	13	37	4 891
New Brunswick	1976	–	10 210	160	–	10 370	–	–	–	10 370
	1977	24	6 413	55	2	6 494	–	–	–	6 494
Northwest Territories	1976	–	–	–	–	–	908	–	908	908
	1977	–	–	–	–	–	–	631	631	631
Nova Scotia	1976	–	5 222	55	–	5 277	–	–	–	5 277
	1977	–	4 818	–	–	4 818	–	–	–	4 818
Ontario	1976	1 251	115 263	7 838	836	125 188	792	3 101	3 893	129 081
	1977	950	131 849	1 152	515	134 466	963	4 183	5 146	139 612
Prince Edward Island	1976	–	8 568	–	–	8 568	–	–	–	8 568
	1977	–	9 333	–	–	9 333	–	–	–	9 333
Quebec	1976	4 381	48 667	2 847	–	55 895	23	–	23	55 918
	1977	1 605	55 968	–	–	57 573	45	–	45	57 618
Saskatchewan	1976	13	117	62	257	449	43	2	45	494
	1977	9	325	351	–	685	15	198	213	898
Totals	1976	6 771	194 041	20 130	3 110	224 052	7 264	3 305	10 569	234 621
	1977	3 176	215 359	13 903	1 167	233 605	7 831	7 756	15 587	249 192

Source: Potash Institute of North America.
– Nil.

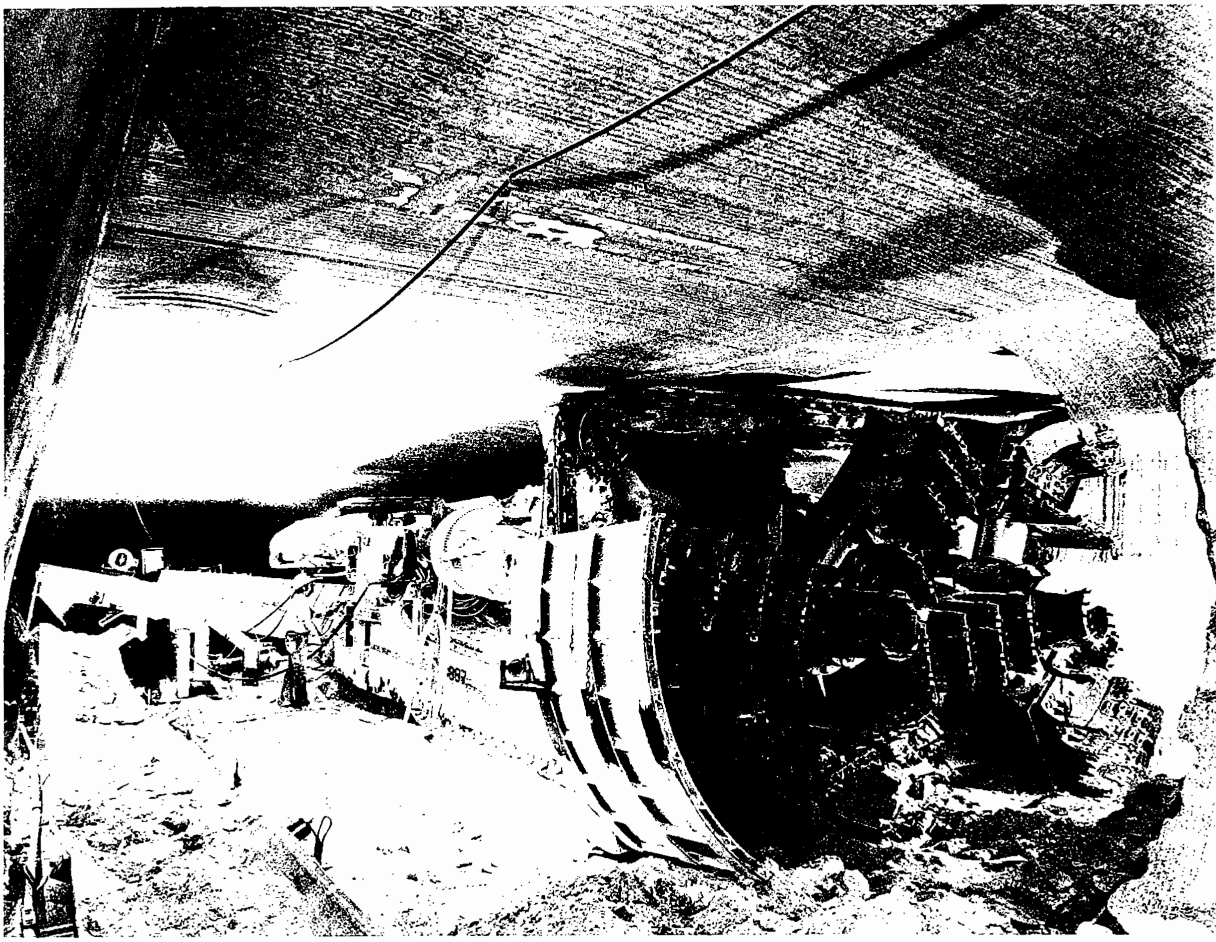
Table 6. World potash production, sales and inventories, 1975-77

	1975		1976		1977[p]	
	Production	Sales	Production	Sales	Production	Sales
	(000 tonnes K_2O equivalent)					
U.S.S.R.	7 944	7 600	8 310	8 310	8 700	8 700
Canada	5 436	4 638	4 096	5 186	6 089	5 679
East Germany	3 019	3 016	3 161	3 100	3 244	3 500
West Germany	2 222	2 130	2 036	2 148	2 341	2 362
United States	2 294	1 891	2 206	2 305	2 231	2 055
France	1 920	1 800[1]	1 603	1 950	1 580	2 259
Israel	716	. .	690	. .	600	. .
Spain	459	368	535	562	563	615
Italy	141	. .	140	. .	148	. .
United Kingdom	15	. .	45	. .	81	. .
Congo	286	. . [1]	254	236	81	167
Other countries	—	. .	—	875	—	829
Total	24 452		23 976		25 658	

Year-end producer inventories

	1975	1976	1977[p]
Canada	990	799	1 183
United States	574	445	431

Sources: Potash Institute of North America, and *Phosphorus and Potassium* 1977.
[1]1975 French sales figure includes sales from Congo.
[p]Preliminary; — Nil; . . . Not available.



The massive cutting head of the Marietta continuous miner used to extract raw potash from the deposit at the Cominco Ltd. mine at Vade, Saskatchewan is prominent here, along with the distinctive cutting patterns left on the tunnel by the rotors. The belt system used to carry the broken potash to the shaft is at left.

Cominco photo

Rare Earths

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The rare earth elements, sometimes called the lanthanons or lanthanides, are a group of 15 chemically similar metals having atomic numbers 57 to 71 in Group III of the periodic table of elements. Scandium and yttrium are similar to the rare earth elements in many respects and are usually classed with them.

These elements are neither rare nor earths. By comparison, cerium is more abundant than tin or cobalt and almost three times as abundant as lead. Thulium, less common than all other rare earths except promethium, is more abundant than silver, gold and platinum combined. The metals were originally classified "rare" because they are seldom concentrated in nature like most other elements and their widespread occurrence in the earth's crust was recognized only in recent times. The term "earth" is derived from earlier terminology when insoluble oxides, the common compounds of rare earths, were simply referred to as earths.

Lanthanon-bearing minerals contain all members of the rare earth elements, but either the light (cerium) group or the heavy (yttrium) group predominates in each mineral. The rare earth metals are typically associated with alkalic intrusive igneous rocks and also occurs as secondary concentration in placer, beach sand and phosphatic sedimentary deposits. Commercial production has been derived from carbonatite occurrences, placer and beach sand deposits, uranium ores, and phosphatic rocks. The relative abundance of the various rare earths in the ores presently being mined is not directly related to the market demand for the individual products. As a result, some rare earths products are readily available at low cost, while others, particularly high-purity metal and compounds, are considerably more expensive. Research continues to explore the properties of the rare earth metals to identify potential new markets; but, for some, no significant use has yet been found. Development has proceeded; first, to find markets for those compounds that are available; and, second, to find and develop sources of supply to meet changing industrial requirements.

New uses have developed steadily in recent years. Beginning with the traditional cigarette lighter flints and carbon-arc uses, rare earth elements have now found application in glass polishing, petroleum catalysts, television tube phosphor, nodular iron, high-strength low-alloy steel and high-strength magnet applications. The latest uses of rare earth elements are at the forefront of technological development, in refractory ceramics, lighting, data storage, the energy field, catalysts used to reduce oxides of nitrogen to nitrogen and in hydrogen sponge alloys.

New markets for specific members of the rare earth group have resulted in increased production of all rare earth metals because of their natural association in ores. Similarly, production costs for some rare earth members, byproducts of the refining process, have diminished. Availability and declining costs have been important factors in the development of new uses. There is growing optimism that the rare earth metals industry will expand at a steady rate now that industrial uses are becoming more diverse.

Canadian industry

Canadian production of rare earths since 1967 has undergone drastic adjustments; yttrium concentrate suppliers reduced shipments each successive year until 1971, when deliveries stopped. Shipments of yttrium concentrate from one Canadian producer, Denison Mines Limited, were resumed in 1973 and continued up to the present.

From 1966 to 1970 the world's major source of yttrium concentrate was the uranium mines in the Elliot Lake district of Ontario. All rare earths, except promethium, have been detected in these ores. The Elliot Lake ores contain about 0.11 per cent uranium oxide (U_3O_8), 0.028 per cent thorium oxide (ThO_2) and 0.057 per cent rare earth oxides (REO).

Denison Mines Limited (Denison), which resumed the production and shipment of yttrium concentrate in 1973, continued to produce during 1977. Under a contract negotiated with a United States company, Molycorp Inc. (Molycorp), Denison has a commitment to ship yttrium concentrate to Molycorp until March 1977. Denison had previously shipped yttrium concentrate to Michigan Chemical Corporation, but production was terminated in mid 1970 when that company experienced difficulty in marketing the product. Shipments in 1977 amounted to 23 300 kilograms (kg) of Y_2O_3 in yttrium concentrate.

During 1966 and 1967 Rio Algom Limited recovered thorium and rare earth concentrate at its Nordic mill, but did not resume production when the milling of uranium ores was transferred to the Quirke mill.

Table 1. Rare earth elements

Atomic No.	Name	Symbol	Abundance in Igneous Rocks
	Light rare earths		(parts per million)
21	Scandium	Sc	5.0
57	Lanthanum	La	18.3
58	Cerium	Ce	46.0
59	Praseodymium	Pr	5.5
60	Neodymium	Nd	23.8
61	Promethium	Pm	(Not measurable)
62	Samarium	Sm	6.5
63	Europium	Eu	1.1
64	Gadolinium	Gd	6.3
	Heavy rare earths		
39	Yttrium	Y	28.0
65	Terbium	Tb	0.9
66	Dysprosium	Dy	4.5
67	Holmium	Ho	1.1
68	Erbium	Er	2.5
69	Thulium	Tm	0.2
70	Ytterbium	Yb	2.6
71	Lutetium	Lu	0.7
		Total	153.0

Rare earth elements, primarily the light element group, are associated with apatite in the Nemegos No. 6 magnetite deposit, which is located in the Chapleau area of Ontario. Multi-Minerals Limited is seeking to develop the deposit, and was trying at last report in 1975 to determine the feasibility of promoting an integrated complex which would produce pig iron, phosphoric acid and rare earth products.

In addition to the large reserves in Elliot Lake uranium ores, rare earths are also associated with uranium deposits at Agnew Lake, 65 kilometres east of Elliot Lake, where the REO content is about twice that of Elliot Lake ores; and in the Bancroft area of Ontario.

Table 2. Canadian shipments of rare earth concentrates

	Y_2O_3 Concentrates	Values
	(kilograms)	($)
1977	30 400	. .
1976[1]	26 308	. .
1975[1]	34 927	. .
1974	39 366	. .
1973	. .	. .
1972	—	—
1971	. .	. .
1970	33 112	657 000
1969	38 756	671 500
1968	51 406	936 067
1967	78 268	1 594 298
1966	9 400	130 223

[1]Taken from Annual Reports, Denison Mines Limited.
. . Not available; — Nil.

In 1977 Kerr Addison Mines Limited completed development of its 90 per cent owned Agnew Lake uranium mine in Ontario. The recovery method for uranium is underground leaching of broken ore. Production was below expectations because of problems related to its in situ recovery process, but at year end steps were being taken to correct the situation, including an increase in the amount of broken ore at the mine. The leach solution contains, in addition to uranium, substantial amounts of thorium, lanthanum, yttrium, cerium, gladolinium, dysprosium, erbium, ytterbium; but none of the Agnew Lake rare earths are presently being recovered.

Phosphorite formations in western Canada contain small quantities of rare earths, as do Florida phosphates imported into Canada for the production of phosphoric acid. Other potential sources include apatite rich carbonatites.

Shipments of rare earth concentrates since 1966 are summarized in Table 2. Statistics for 1971 and 1973 have been withheld to avoid disclosing individual company confidential data.

Denison Mines Limited, the only Canadian producer of rare earth metals in 1977 delivered 30 400 kg of yttrium oxide during the year, compared with 26 308 kg in 1976.

World industry

The minerals monazite and bastnaesite are the main source of the cerium group of rare earths. These are processed to recover mixed rare earths for low-value products such as mischmetal or further processed at much higher cost to separate individual rare earth metals.

Monazite recovery is a byproduct of mining beach sands for rutile, zircon and ilmenite. Australia, India, Brazil, Malaysia, the United States and South Africa, are the principal producers. In the United States, monazite is recovered from beach sands in Georgia and Florida.

The Molycorp mine at Mountain Pass, California is the main source of concentrates for cerium-group rare earths; and, unlike monazite, bastnaesite concentrates from this unusual carbonatite deposit do not contain thorium. The ore, mined in a small, low-cost open pit, grades 8 to 10 per cent rare earth oxides. The rare earth distribution, in per cent oxide, is: cerium, 50.0; lanthanum, 33.0; neodymium, 12.0; praseodymium, 4.0; samarium, 0.5; gadolinium, 0.2; europium, 0.1; and yttrium group, 0.2. The adjacent mill produces a flotation concentrate grading 60 per cent rare earth oxide, a leached concentrate grading 70 per cent, a calcine grading 90 per cent and seven modified concentrates. A chemical and solvent extraction plant makes intermediate rare earth products and separates a number of rare earths, including europium. Further processing is carried out at Louviers, Colorado; York, Pennsylvania; and Washington, Pennsylvania.

Production from the Mountain Pass mine in 1977 amounted to 15 400 tonnes* of REO, compared with 13 200 tonnes in 1976. The Mountain Pass mill can now produce approximately 27 200 tonnes of REO annually, and the chemical plant can process 13 600 tonnes.

A former Australian rare earth metals producer resumed production in 1976 and continued to operate in 1977. The mine, operated by Mary Kathleen Uranium Limited, produced uranium and a rare earth concentrate until 1963. In 1976 total reserves at the mine, including tailings, contain some 363 000 tonnes of REO. At a planned annual mining rate of 816 000 tonnes of ore, the mine could recover about 4 500 tonnes a year of REO contained in concentrate.

Mitsubishi Chemical Industries Ltd. of Japan and Beh Minerals Sendirian Berhad of Ipoh, Perak State, Malaysia have set up a joint company, Malaysian Rare Earth Corp. (MAREC), to produce rare earths oxides containing a minimum of 50 per cent yttrium oxide from Malaysian xenotime. The plant was officially opened in April 1977 and has a design capacity of 120 tonnes of 50 per cent yttrium concentrate a year.

Japanese demand for REO has increased greatly in recent years. Molycorp has made an agreement with Mitsubishi International, Inc. whereby the latter company will act as sales agent for Molycorp's REO sales in Japan.

A/S Megon Co. (Megon) is participating in a joint venture with Malaysian interests to construct and operate a concentrator near Kuala Lumpur in Malaysia. The plant has a design capacity of 27 tonnes a year of 60 per cent Y_2O_3 concentrate.

Ocean bed nodules, occurring over wide areas of the Pacific Ocean contain high concentrations of rare earth elements. It has not yet been determined if recovery of rare earths from this source is economically feasible. The concentration of nodules on the seafloor as well as the concentration of rare earth elements in the nodules varies considerably.

The mineral xenotime, valuable for its yttrium content, is recovered from heavy mineral rejects of the Malaysian tin industry and from retreatment of Western Australian monazite concentrate, itself a byproduct.

Some uranium ores contain the rare earth elements and are an important source for the yttrium group. Solution liquors, following uranium and thorium extraction, are treated to recover the rare earth elements. Canadian production, and potential production in Australia from the Mary Kathleen Uranium Limited and Field Metals and Chemicals Pty. Limited deposits, are of this type. The rare earth minerals euxinite, samarskite and fergusonite are another source of the yttrium group, but they are difficult to treat.

Promethium isotopes have half-lives ranging from seconds to 18 years and, therefore, are rare in nature. The commercial source of promethium 147 is from waste fission products in atomic reactors. Its radioactive properties are attractive as a power source in space research as well as in luminescent paints.

Consumption and uses

World consumption of rare earth metals increased substantially in 1977. Shipments in the United States are reported to have increased by 47 per cent relative to 1976. In the United States, leading applications of rare earth materials were in catalysts used in petroleum refining, as additives in steel and nodular iron, and in carbon arc electrodes, ceramics, glass, lighter flints and colour television phosphors. Use of rare earth metals in permanent magnets increased further in 1977.

Mischmetal is a suitable nodulizing alloy that promotes ductility in cast iron by neutralizing the harmful effects of trace elements which inhibit the formation of nodular graphite. The ductile iron industry has realized significant cost savings through the substitution of mischmetal for more expensive additives.

Mischmetal, the primary commercial form of mixed rare earth metals, is prepared by the electrolysis of fused rare earth chloride mixtures. Mischmetal contains 94 to 99 per cent rare earth metals plus traces of calcium, carbon, aluminum, silicon and iron. A typical composition is 52 per cent cerium, 18 per cent neodymium, 5 per cent praseodymium, 1 per cent samarium, 24 per cent others, including lanthanum. Some grades are nearly free of cerium. Ferrocerium is an alloy of mischmetal and iron.

In recent years the practice of adding some 1.5 kg of mischmetal or rare earth silicides to each tonne of high-strength low-alloy (HSLA) steels has become general to counter the deleterious effects of sulphur. The conventional method of treating undesirable sulphur is to combine it with magnesium; but magnesium

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

sulphide elongates when rolled, and the resulting steel is weaker in the transverse direction. The addition of rare earths results in a HSLA steel that is nearly equally strong in the transverse and longitudinal directions. HSLA steels are being used increasingly in gas and oil pipelines, automobiles, trucks, trains, ships and construction equipment. Mischmetal has a stable market in lighter flints. However, the lighter flint market is becoming a less important outlet as mischmetal applications grow in the iron and steel metallurgical fields.

The other major use of the rare earth group is for catalysts in the cracking operation of petroleum refining. Although naturally mixed elements were originally used in catalysts, the trend has been to chloride mixtures of lanthanum, neodymium and praseodymium. Relative consumption in this field has been declining in recent years. Palladium is a substitute for the rare earth elements in petroleum-refining catalysts.

The third most important market for rare earth metals, in terms of volume, is the glass polishing industry. Commercial-grade cerium and mixed rare earth oxides are used extensively in optical, mirror and plate glass polishing. Plate glass polishing has been reduced since the introduction of the Pilkington float glass process, but there is no comparable substitute for rare earth oxide compounds in high-quality optical polishing.

The glass industry employs rare earth additives for their many unique characteristics. Cerium oxide, in small quantities, is an effective glass decolourizer. Due to their ability to absorb ultraviolet light, cerium and neodymium oxides are used in transparent bottles to inhibit food spoilage, and in welders' goggles, sunglasses and optical filters. For glass colouring, praseodymium imparts a yellow-green colour, neodymium a lilac, europium an orange-red, and erbium a pink colour. Lanthanum is a major component of optical glass, and cerium glass is used for windows in atomic reactors.

Rare earth oxides and fluorides are used in significant quantities in carbon-arc lamps where a high-intensity white light is desirable.

A new type of fluorescent lamp that emphasizes three narrow spectral bands — around the blue-violet, green and orange-red wavelengths to produce a synthesized white light — is now on the market. This new light has a greater "perceived brightness" than even natural sunlight and permits a reduction in the number of lighting units in buildings. The new light uses two rare earth phosphors containing europium.

A high-value application is in the electronics field where rare earth oxides are used as phosphors in colour television tubes, temperature-compensating capacitors and associated circuit components. Although the volume of europium and yttrium oxides used in colour television phosphors is comparatively small, the value is disproportionately large because of the high degree of purity required in this application. Minor quantities of the rare earth group are used in laser materials, atomic fire extinguishers, nuclear reactor absorption and shielding materials, magnesium and aluminum alloys, brazing alloys, low-corrosion alloys, gemstones, self-cleaning oven catalysts, ceramic and porcelain stains and microwave controls.

An important and growing market is rare earth-cobalt permanent magnets (RE magnets). Samarium-cobalt permanent magnets that have many times the strength of any conventional permanent magnet are now in use. These magnets are usually fabricated by powder metallurgical methods, which facilitate the procedure for inducing a high magnetic flux. High-strength permanent magnets are used in special applications, such as aerospace equipment, where the greater cost can be justified in terms of better performance. Recent research has led to the development of less-expensive RE magnets. Part of this cost improvement has resulted from better manufacturing techniques, but a more significant development is the substitutions of mischmetal for the more-expensive samarium. Considering all the developments that have occurred within the few years since RE magnets were first discovered, the trend indicates a strong growth rate in use of these magnets for the next several years in electric motors, generators, meters, speakers and frictionless bearings. United States automobile manufacturers are seriously studying the application of mischmetal-cobalt magnets, in a range of sizes, for use in starter motors, fuel gauges, electronic ignition systems, windshield wipers, window and seat drives, and in new developments such as continuous monitoring of tire pressures. Full realization of these potential uses will depend upon further cost and weight reduction, assured availability of cobalt and utilization of rare earth metals other than samarium.

Rare earth metals catalysts have been identified as possible inexpensive alternatives to platinoid catalysts in automobile exhaust converters. The rare earth-based converters have shown promise in reducing carbon monoxide and nitrogen oxide emissions, but more research is necessary. Initially, the automotive industry opted for platinum-based systems to meet emission control standards set for United States vehicles in 1975.

Research on rare earth metals uses has taken many directions, and some very promising developments have resulted. "Hydrogen sponge" alloys that consist of nickel, and in some cases manganese, in combination with rare earth metals have been developed. These alloys can absorb up to 400 times their own volume of hydrogen gas. One cubic foot of these alloys can hold enough hydrogen to generate over 4 kilowatt-hours of heat energy. The ease with which the absorption process can be reversed by a relatively small change in temperature or pressure, the selectivity of the process to hydrogen gas, and the convenient temperature and pressure ranges over which it can occur are keys to its usefulness. Potential applications are in solar heating, nonpolluting engines, heat sinks, gas purification and compression, and auxiliary power generation.

The development of memory films for use in "magnetic-bubble-memory" for data storage and processing promises to become a major new application for rare earth materials. Gadolinium-gallium garnet (GGG) has been found to be suitable for the production of precision wafers for these memory films. This new storage medium permits faster information handling, with fewer moving parts, lower energy use and greater storage capacity. It also decreases vulnerability to the effects of power loss. GGG bubble-memory storage capacity is claimed to be competitive already in terms of cost-per-bit of information with other storage media presently in use.

Yttrium is receiving attention from researchers for use in refractory ceramics for use in gas turbines, combustion chambers, nuclear reactors and heat exchangers.

Prices

The December issue of *Industrial Minerals* (London) quotes 70 per cent leach bastnaesite concentrates, per pound REO at 58-80 cents; Australian monazite, minimum 55 per cent REO, a long ton fob Australia, $Australian185-200. Malayan xenotime concentrate, minimum 25 per cent Y_2O_3 a pound cif $U.S. 2-3.

The prices per pound in U.S. dollars according to *American Metal Market,* December 1, 1977, of pure rare earth metals of the lanthanide group as used in permanent magnets, were as follows: lanthanum, $27.50; cerium $18.00; samarium, $75.00; mischmetal, 99.8%, $3.90.

Rare earth oxide prices, in U.S. dollars per pound, as quoted in American Metal Market, December 1, 1977 issue were as follows: europium 99.99%, $650; lanthanum 99.9%, $6.00; cerium 99.9%, $6.00; neodymium 99.9%, $30; praesodymium 99%, $30; yttrium 99.99%, $36; gladolimium 99.9%, $55; samarium, 99.9%, $35.

Rhenium

J.J. HOGAN

Rhenium is a relatively new metal which was first isolated in 1925. It occurs principally in low-grade porphyry copper ores containing molybdenum and is recovered as a byproduct from the treatment of molybdenum concentrates. The rhenium content in porphyry copper ore is only a few parts per million (ppm) whereas the molybdenite concentrates produced from these ores have a rhenium content varying from 300 to 2 000 ppm. Rhenium has been identified in some molybdenum, manganese and uranium ores, but in concentrations too low to be of economic significance under present technology and price structure.

Canadian rhenium production comes from the copper-molybdenum ore of Utah Mines Ltd. (Island Copper mine) at Port Hardy, Vancouver Island, British Columbia. The ore occurs mainly in altered volcanics and, in this respect, differs from the porphyry copper deposits which have been the major source of rhenium in the United States and Chile. The metal has also been identified in the porphyry copper ores of Lornex Mining Corporation Ltd. and Brenda Mines Ltd., near Kamloops, British Columbia.

The United States, the largest producer of rhenium metal and salts in the non-communist world, recovered rhenium mainly from porphyry copper ores in the western states. The producers of rhenium in the United States in 1977 were S.W. Shattuck Chemical Co., of Denver, Colorado, a division of Engelhard Minerals & Chemicals Corporation; M & R Refractory Metals, Inc. of Winslow, New Jersey, and Molycorp Inc. of Washington, Pennsylvania. Kennecott Copper Corporation did not operate its rhenium recovery facilities at Garfield, Utah.

Chile recovered rhenium from molybdenite concentrates produced as a byproduct from its large porphyry copper ore deposits. According to data published by the United States Bureau of Mines, the United States, during 1977, imported into bonded warehouses substantial quantities of ammonium perrhenate (NH_4ReO_4) from Chile. In 1974 Chile began exporting ammonium perrhenate to the United States. It is generally used in this form by industry but can be further processed to rhenium powder. Prior to 1974, rhenium exported to the United States from Chile was contained in molybdenite concentrates shipped there for treatment.

Other countries which have metallurgical plants to recover rhenium are the U.S.S.R., Sweden, Belgium, and West Germany. With the exception of the U.S.S.R., these countries recover rhenium from molybdenite concentrates imported from Chile, Peru, Canada and Zaire.

Production

Rhenium is a recent addition to metals produced in Canada, with production first being recorded in 1972. Utah Mines reported that the rhenium contained in the molybdenite concentrates produced in 1977 at its Island Copper mine varied between 900 and 1 350 ppm and averaged about 1 117 ppm. This compares with an average of about 1 172 ppm in 1976. In 1977 shipments of molybdenite concentrates by Utah Mines to refineries in the United States totalled approximately 2 283 tonnes* compared with shipments of approximately 2 145 tonnes in 1976. The rhenium contained in the concentrates shipped was treated on a toll basis at the smelter and the recovered rhenium was returned to the company as perrhenic acid for subsequent sale. Under present technology the recovery of rhenium contained in molybdenite concentrates is in the range of 60 per cent. Based on the above shipments and estimated grade and recovery, the rhenium recovered from Canadian ores in 1977 was about 1 240 kilograms (kg).

Statistical data on world output and total value of rhenium are not available. Rhenium production in the United States in 1977 was estimated at 1 814 kg by the U.S. Bureau of Mines compared with 1 996 kg in 1976. The value of the United States production in 1977 was estimated at $1.8 million. The U.S. Bureau of Mines estimated output of rhenium by Chile in 1977 at 1 361

*The term "tonne" refers to metric ton of 2 204.62 pounds avoirdupois.

kg. The U.S.S.R., also a large producer of the metal, recovers rhenium from molybdenite concentrates obtained from its porphyry copper deposits, and its production in 1977 was estimated at 907 kg by the U.S. Bureau of Mines.

Rhenium is recovered from flue gases emitted from the roasting of byproduct molybdenite concentrates. Under properly controlled temperature conditions, rhenium volatilizes as rhenium heptoxide (Re_2O_7), a compound which is readily soluble in an aqueous solution and which is recovered by subjecting the flue gas to wet scrubbing. The rhenium is recovered from this solution as ammonium perrhenate (NH_4ReO_4) by a series of chemical steps including ion exchange treatment. Perrhenic acid ($HReO_4$), a major commercial compound of rhenium, is obtained by the reaction of rhenium heptoxide with water. Rhenium metal powder (99.99 per cent pure) is produced by the reduction of ammonium perrhenate with hydrogen. The metal powder is pressed and sintered into bars which are cold-rolled to form different shapes. The cost of producing rhenium metal and compounds is high. Recent research has been directed towards the development of processes whereby molybdenum and rhenium can be recovered economically from molybdenite concentrates by hydrometallurgy.

Properties and uses

Rhenium has become an important industrial metal because of its special properties. The metal is highly refractory, having a melting point of 3100°C, second to that of tungsten and maintains strength and ductility at high temperatures. Its density is 21 grams per cubic centimetre, exceeded only by that of the platinum group metals. Rhenium has good corrosion resistance to halogen acids. Alloyed with tungsten or molybdenum, rhenium improves the ductility and tensile strength of these metals. Stable oxide film on rhenium does not appreciably increase electrical resistance and this property, plus good resistance to wear and arc corrosion, makes the metal ideally suited for electrical contacts.

The major use of rhenium is in bimetallic platinum-rhenium catalysts used in petroleum reforming units to produce a high-octane gasoline of low-lead or no-lead content. Over 90 per cent of rhenium consumed is used for this purpose. Other applications include high-temperature thermocouples, temperature controls, heating elements, electronic devices, flashbulb filaments, metallic coatings and research and development. It is also used to produce ductile, high temperature, tungsten-based alloys used in the electronic field.

The United States is the world's largest consumer of rhenium and rhenium salts, and according to the U.S. Bureau of Mines used an estimated 2 268 kg in 1977 compared with 3 765 kg in 1976. About 93 per cent was used in bimetallic platinum-rhenium catalysts for petroleum reforming units.

Outlook

The development of rhenium as an industrial metal has taken place recently and has not shown any clearly-defined growth pattern. The potential supply of the metal is limited to that available from the treatment of byproduct molybdenite concentrates obtained from low-grade porphyry copper ores. The recovery of rhenium from molybdenite concentrates is relatively low, about 60 per cent, and research into processes to improve recovery could add to the supply of the metal. Also, the recovery of molybdenite from the processing of porphyry copper ores is generally low, varying from 20 to 80 per cent, and any success in research on methods to improve this recovery rate would increase the supply of available rhenium.

Some of the molybdic oxide producers do not recover the rhenium content of the molybdenite concentrates they process because of the costs involved in installing the required equipment. These molybdic oxide operations could be an added source of rhenium.

In the short term, the major demand for rhenium will be created by its application as a bimetallic platinum-rhenium catalyst in the petroleum-refining industry. Demand in this application has not been as large as expected because of a reduction in the rate of expansion of new refining capacity and the development of less-expensive catalysts not requiring rhenium. Low potential rhenium reserves, however, could be an important factor in limiting the development of new industrial uses for the metal. Rhenium metal and salts now available to the market are greater than the demand, and stocks are expected to continue to grow. The U.S. Bureau of Mines estimated stocks in the hands of United States consumers, producers and dealers at the end of 1977 at 11 790 kg compared with 9 620 kg at the end of 1976.

Prices

According to *Metals Week*, the quoted United States prices at the beginning of the year for the rhenium content in perrhenic acid and for rhenium powder were $515 per pound ($1 135 per kg) and $540 per pound ($1 190 per kg) respectively. Because of reduced demand for these products the prices were adjusted downward during the year to a quoted price of $350 per pound ($772 per kg) and $375 per pound ($827 per kg), respectively, on December 22, 1977.

Salt

D.H. STONEHOUSE

Although many mineral commodities are important to man's development, few can be classed as essential to his very existence as can common salt, a compound of sodium and chlorine. Sodium chloride, halite in mineralogic terms, is widely distributed in the world, a fact that has influenced history and the location of industry. Salt occurs in solution in seawater, in some spring and lake waters, in many subsurface waters, and in solid form in surface and underground deposits. Although seawaters contain the largest reserve of salt and contribute substantial quantities of solar evaporated salt to the world's annual output, underground bedded and dome deposits supply the largest part of the world's salt requirements.

Summary

In Canada, underground salt deposits have been found in all provinces except British Columbia. They have also been found in the District of Mackenzie, Northwest Territories, and in some of the Arctic islands. Bedded rock salt deposits in southwestern Ontario, Saskatchewan and Alberta, and dome deposits in Nova Scotia are the sources of most of Canada's salt output. In past years salt has been recovered from brine springs and natural subsurface brines in Nova Scotia, New Brunswick, Ontario, Manitoba, Saskatchewan and Alberta. Salt springs are also common to certain parts of British Columbia.

Canadian production of rock salt — from three underground mines — increased by 2.5 per cent in 1977 to over 4.3 million tonnes*. Fine salt, produced by multi-stage vacuum pan evaporation at six plants, totalled over 680 000 tonnes, while the production of salt in brine, generally for caustic soda, chlorine and sodium carbonate production, at six plants, was increased by 7.4 per cent to more than 1 million tonnes. At two locations, byproduct salt from potash refining operations is used, in one instance for fine salt production, and in the other for highway salt.

Imports of salt and salt in brine were down by 23 per cent in 1977 to 1.24 million tonnes, with British Columbia, Ontario and Quebec in that order being the main importers; while exports, principally to the United States, were down by 24 per cent to 1.3 million tonnes.

During 1977 Potash Company of America (PCA) and International Minerals & Chemicals Corporation (Canada) Limited (IMCC) continued to investigate potash and salt deposits in New Brunswick, and the Quebec government, through Seleine Inc., a subsidiary of Quebec Mining Exploration Company (SOQUEM), continued its mine development program on Grosse Ile in the Magdalen Islands.

Recovery methods

Canadian producers employ three different techniques in the recovery of salt and/or brine from depth, the method employed depending upon the nature of the deposit and the type of salt in demand. Conventional underground mining methods are used to mine good-quality rock salt deposits that are relatively shallow and located in areas near large markets that do not specify a high-purity product, or located close to inexpensive, large-volume, bulk transporting facilities.

Brining methods, too, are used to recover salt from subsurface deposits, usually from depths greater than acceptable mining depths. Brine can be evaporated to produce high-purity, fine, vacuum salt, or it can be used directly in the manufacture of chemicals. Salt is similarly recovered from natural subsurface brines.

The third technique is to recover salt as a coproduct of potash mining, a practice quite common in Europe. In Canada the only commercial application of this technique is at a solution-type potash mine, where production methods permit the recovery of a good-quality salt brine. The other potash producers generally regard the waste salt as unmarketable, although some shipments have been made for use in snow and ice control.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

A fourth method (not used in Canada) is solar evaporation of sea or salty lake waters, a process commonly used in warm, arid climates.

Rock salt mining

Access to rock salt deposits for conventional mining is through vertical shafts, normally about 5 metres in diameter, serving the mining zone at depths of 200 to 600 metres. Mining is normally by the room-and-pillar method, the dimensions depending on the depth and thickness of the salt deposit. Rooms vary from 9 metres to 15 metres in width and from 5.5 to 15 metres

Table 1. Canada, salt production and trade, 1976-77

	1976		1977^p	
	(tonnes)	($)	(tonnes)	($)
Production				
By type				
Mined rock salt	4 719 989	. .	4 344 122	. .
Fine vacuum salt	714 487	. .	669 674	. .
Salt content of brines used or shipped	963 144	. .	1 034 711	. .
Total	6 397 620	. .	6 048 507	. .
Shipments				
By type				
Mined rock salt	4 354 684	51 081 000	4 320 304	. .
Fine vacuum salt	676 191	29 146 000	683 664	. .
Salt content of brines used or shipped	963 144	3 852 000	1 034 711	. .
Total	5 994 019	84 079 000	6 038 679	90 165 000^e
By province				
Ontario	4 489 108	52 492 835	4 586 491	56 506 000
Nova Scotia	902 494	17 631 099	854 252	18 383 000
Saskatchewan	278 523	7 547 079	252 502	8 338 000
Alberta	296 970	6 245 096	318 158	6 764 000
Manitoba	26 924	163 240	27 276	174 000
Total	5 994 019	84 079 349	6 038 679	90 165 000^e
Imports				
Salt and brine				
United States	1 160 692	10 581 000	801 205	8 634 000
Mexico	310 302	2 090 000	294 082	2 144 000
Spain	17 798	174 000	24 698	236 000
West Germany	182	15 000	1 325	46 000
Bahamas	34 151	240 000	4 231	40 000
Other countries	220	19 000	612	62 000
Total	1 523 345	13 119 000	1 126 153	11 162 000
Salt and brine by province of landing				
Newfoundland	36 554	398 000	34 923	363 000
Nova Scotia	220	16 000	230	14 000
New Brunswick	157	20 000	333	22 000
Quebec	667 554	5 755 000	305 387	3 279 000
Ontario	331 514	2 743 000	342 782	3 182 000
Manitoba	–	–	222	18 000
Saskatchewan	286	28 000	1	. . .
Alberta	935	22 000	480	17 000
British Columbia	486 125	4 137 000	441 795	4 267 000
Total	1 523 345	13 119 000	1 126 153	11 162 000

Table 1 (concl'd)

	1976		1977^p	
	(tonnes)	($)	(tonnes)	($)
Exports				
Salt and brine				
United States	1 421 674	9 479 000	1 158 202	8 666 000
Guyana	10	1 000	2 442	300 000
St. Pierre-Miquelon	1 407	40 000	963	48 000
Leeward and Windward Islands	127	6 000	637	33 000
Barbados	—	—	401	23 000
Jamaica	105	7 000	77	14 000
Other countries	524	25 000	434	39 000
Total	1 423 847	9 558 000	1 163 156	9 123 000

Source: Statistics Canada.
^{p}Preliminary; . . Not available, — Nil; ^{e}Estimated; . . . Less than $500.

Table 2. Canada, salt shipments, 1960, 1965, 1970, 1975-77

	Producers' Shipments					
	Mined Rock	Fine Vacuum	In Brine and recovered in chemical operations	Total	Imports	Exports
			(tonnes)			($)
1960	1 200 075	393 299	1 413 871	3 007 245	174 125	3 461 366
1965	2 177 170	506 523	1 474 929	4 158 622	400 614	4 996 509
1970	3 272 520	552 704	1 036 285	4 861 509	560 659	7 430 000
1975	3 626 123	578 649	917 801	5 122 573	1 183 144	5 185 000
1976	4 354 684	676 191	963 144	5 994 019	1 523 345	9 558 000
1977^p	4 320 304	683 664	1 034 711	6 038 679	1 126 153	9 123 000

Source: Statistics Canada.
^{p}Preliminary.

in height, and pillars vary from about 20 to 60 metres square. Extraction ranges from 40 to 60 per cent. The mining operations consist of undercutting, drilling, blasting, loading and primary crushing. Underground haulage is generally by trucks and conveyor belts. Milling involves crushing, screening and sizing; at one mine the milling is done underground. The products, ranging in size from about one centimetre to a fine powder, normally have a purity of 96 per cent or better. Most of the gypsum, anhydrite and limestone impurities are removed during crushing and screening. Small amounts of the coarser salt fractions are further beneficiated by use of electronic sorters.

Most of the rock salt mined in Canada is shipped in bulk by water, rail and road, much of it being used for snow and ice control.

Brining and vacuum-pan evaporation

Underground brining is accomplished by injecting water into a salt deposit to dissolve the salt, then pumping the resulting saturated salt solution to the surface. Water injection and brine recovery can be done through a single borehole with casing and tubing, or through a series of two or more cased wells. A brine field normally has from 2 to 20 wells, depending on the quantity of brine needed for the surface operation. Depths of the brine fields in Canada range from 335 to 1 980 metres. Saturated salt brine contains 26 per cent NaCl, which equates to about three pounds of salt per gallon of fluid. At the surface the brine is either evaporated to produce fine vacuum salt, or used directly in the manufacture of chemicals.

Canadian producers use a vacuum-pan process to evaporate the brine and produce fine salt. The brine is purified to remove gypsum and other impurities and fed into a series of three or four large cylindrical steel vessels under vacuum for triple or quadruple-effect evaporation. The salt crystallizes and is removed as a slurry, washed, filtered and dried. Product purity is generally 99.5 per cent or better.

Final processing involves screening, the introduction of additives, compression into blocks, briquettes or tablets; or compaction, recrushing and packaging to prepare as many as 100 different salt products. In some cases, quantities are melted at a temperature of about 815°C and allowed to cool. This produces a fused salt, which is particularly suitable for use in water softeners.

Production and developments in Canada

Atlantic region. Salt deposits occur in isolated subbasins of a large sedimentary basin that underlies the northern mainland of Nova Scotia and extends westward under the bordering areas of New Brunswick, northeastward under Cape Breton Island, Prince Edward Island, the Magdalen Islands and southwestern Newfoundland. The salt beds occur within the Mississippian Windsor Group and are generally folded and faulted. The deposits appear to be steeply dipping tabular bodies, domes and brecciated structures of rock salt.

The only salt production in the Atlantic provinces in 1977 was from a rock salt mine and associated evaporator plant at Pugwash, Nova Scotia and a brining operation near Amherst, Nova Scotia. The mine, operated by The Canadian Salt Company Limited, recently completed a major development program to obtain production from the 830 level through a newly furnished second shaft, enabling hoisting capacity to be increased to 3 000 tonnes an 8-hour shift.

Salt domes in both Richmond and Inverness counties in Nova Scotia have been explored by Domtar Chemicals Limited and The Dow Chemical Company for gas storage purposes, and early in 1978 Home Oil Company Limited began work on the first of two test holes in the McIntyre Lake region near the Strait of Canso to determine oil storage capability. Home Oil, in partnership with Murphy Oil Company Ltd. and North Canadian Oils Limited applied for a contract in September 1977 with the U.S. Government to store 100 million barrels of crude oil as part of that country's long-term strategic storage program. If the area is suitable it could serve as a base for transshipment of crude oil to all of eastern North America.

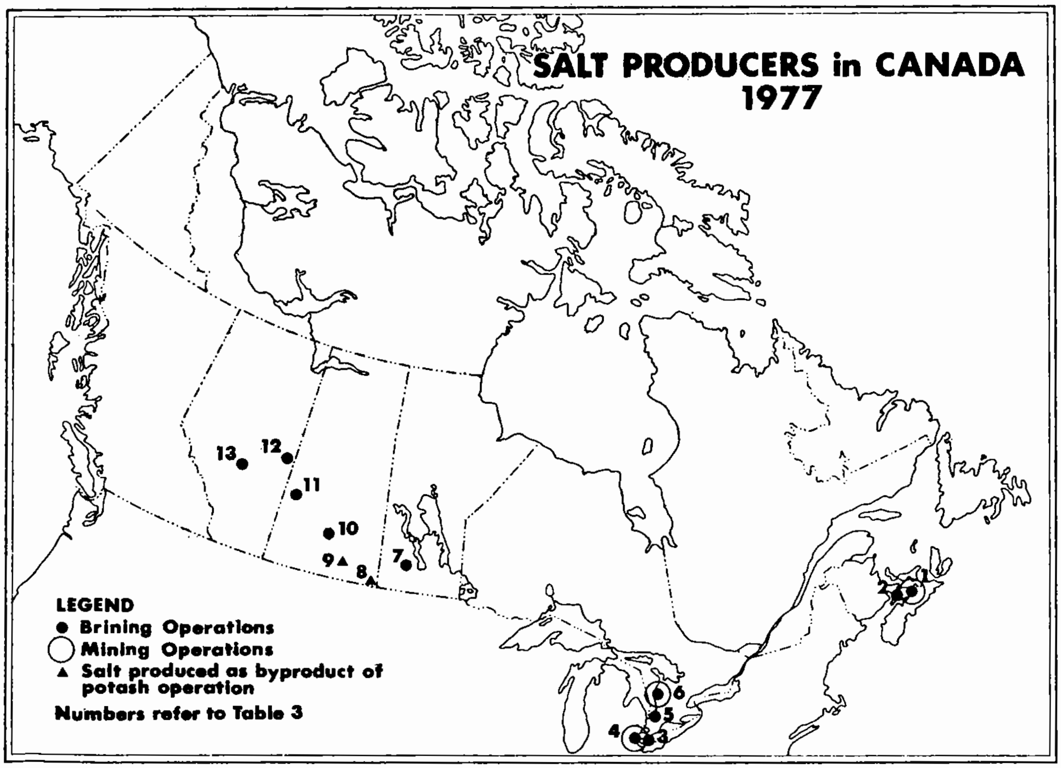


Table 3. Canada, summary of salt producing and brining operations, 1977

Company	Location	Initial Production	Remarks
Nova Scotia			
1. The Canadian Salt Company Limited	Pugwash	1959	Rock salt mining at a depth of 630 feet.
	Pugwash	1962	Dissolving rock salt fines for vacuum pan evaporation.
2. Domtar Chemicals Limited	Amherst	1947	Brining for vacuum pan evaporation.
Ontario			
3. Allied Chemical Canada, Ltd.	Amherstburg	1919	Brining to produce soda ash.
4. The Canadian Salt Company Limited	Ojibway	1955	Rock salt mining at a depth of 980 feet.
	Windsor	1892	Brining, vacuum pan evaporation and fusion.
5. Dow Chemical of Canada, Limited	Sarnia	1950	Brining to produce caustic soda and chlorine.
6. Domtar Chemicals Limited	Goderich	1959	Rock salt mining at a depth of 1 760 feet.
	Goderich	1880	Brining for vacuum pan evaporation.
Prairie Provinces			
7. Hooker Chemical Canada Ltd.	Brandon, Man.	1968	Pumping natural brines to produce caustic soda and chlorine. Operation purchased from Dryden Chemicals Limited in 1974.
8. International Minerals & Chemical Corporation (Canada) Limited	Esterhazy, Sask.	1962	Byproduct salt from potash mine for use in snow and ice control.
9. The Canadian Salt Company Limited	Belle Plaine, Sask.	1969	Producing fine salt from byproduct brine from potash mine.
10. Northern Industrial Chemicals Ltd.	Saskatoon, Sask.	1968	Brining to produce caustic soda and chlorine.
11. Domtar Chemicals Limited	Unity, Sask.	1949	Brining, vacuum pan evaporation and fusion.

Table 3. (concl'd)

Company	Location	Initial Production	Remarks
12. The Canadian Salt Company Limited	Lindbergh, Alta.	1968	Brining, vacuum pan evaporation and fusion.
13. Dow Chemical of Canada, Limited	Fort Saskatchewan, Alta.	1968	Brining to produce caustic soda and chlorine.

In New Brunswick, Potash Company of America (PCA) completed a feasibility study for a mining proposal on its property 60 kilometres (km) east of Saint John and formally signed a development agreement with the New Brunswick government. The company will commence construction of a mine and refining plant capable of processing 900 000 tonnes of potash (KCl) a year when at peak performance. Initial production is scheduled for 1981. International Minerals & Chemicals (Canada) Limited (IMCC) signed an agreement with the provincial government early in 1978 but plans two more years of exploration before commencing mine development on its property 19 km southwest of Sussex. The actual quantities of byproduct sodium chloride expected from these operations and the use to which it will be put are not determined as yet.

Quebec. Quebec Mining Exploration Company (SOQUEM) continued its rock salt mine development program on Grosse-Ile in the Magdalen Islands during 1977. Surface installations were completed towards the end of the year to permit shaft sinking. A contract was awarded to Patrick Harrison for a 4.3-metre-diameter, concrete-lined, vertical shaft to 203 metres. At that elevation about 900 metres of horizontal drifting is planned, together with some 6 100 metres of diamond core drilling to determine structure, extent and quality of the salt deposit. Mine design will depend on the results of the underground investigation.

During SOQUEM's initial drilling program to outline the Magdalen Island salt deposit, several potash intersections were encountered at or near the 366-metre horizon in the Grosse-Ile area. These were of poor quality — less than 10 per cent K_2O. In the Havre-Aubert area, however, 8.5 metres of potash ore at 305 metres analyzed 28 per cent K_2O. During 1977 further drilling was done but the program was stopped because of poor core recovery, yielding inconclusive results.

Rock salt markets in Canada are currently only about 70 per cent of the industry's capacity to produce. Concern has been registered for established producers, should SOQUEM's rock salt mine come on stream. However, the competitiveness of mining costs and the product quality of the Grosse-Ile deposit have yet to be determined. SOQUEM expects a conditional contract to be signed early in 1978 with the Quebec Transport Department for supplying 80 per cent of the department's rock salt needs over the next 10 years.

The Quebec government announced in January 1978 that it would study the possibility of establishing a multi-million dollar chemical plant to produce about 770 000 tonnes a year of soda ash (sodium carbonate) in the Gaspé region of Quebec. Surveyor, Nenninger and Chenevert Inc. of Montreal was awarded a contract ($290 000) by the Quebec industry department for a feasibility study. The proposal would use salt from the planned salt mine on Grosse-Ile in the Magdalen Islands, limestone from the Gaspé and coal from Nova Scotia. Cost estimates are in the $200 million range. The only soda ash producer in Canada liable to be affected is Allied Chemical Canada Ltd. at Amherstburg, Ontario where brine and limestone are obtained locally. Production is about 400 000 tonnes a year. Soda ash is also produced from natural ore — trona — in Wyoming. Principal markets for soda ash are the glass manufacturing industry and the paper industry.

In July 1977, Canadian Industries Limited announced plans to double the productive capacity of

Table 4. World salt production, 1975-77

	1975	1976[p]	1977[e]
		(000 tonnes)	
United States	37 246	40 114	38 949
People's Republic of China	29 937[e]	30 000[e]	30 028
U.S.S.R.	13 700[e]	14 000[e]	14 243
United Kingdom	7 775	7 900[e]	8 074
West Germany	9 316	7 495	7 620
France	5 537	6 416	6 532
Canada	4 835	6 398	6 049
Poland	5 106	5 470	5 624
Australia	5 057	5 350	5 443
Mexico	5 354	4 591	4 717
India	3 331	4 480	4 536
Italy	4 412	4 012	4 082
Other countries	29 944	31 199	31 842
Total	161 550	167 425	167 739

Sources: U.S. Bureau of Mines, Minerals Yearbook Preprint 1976 and U.S. Bureau of Mines, Mineral Commodity Summaries, January 1978; for Canada, Statistics Canada.
[p] Preliminary; [e] Estimated.

its Bécancour caustic soda-chlorine plant from its present capability of about 140 000 tonnes of chlorine and about 136 000 tonnes of caustic a year. By 1980 the plant will require 500 000 tonnes of salt a year.

Ontario. Thick salt beds underlie much of southwestern Ontario, extending from Amherstburg northeastward to London and Kincardine, bordering on what is known geologically as the Michigan Basin. As many as six salt beds, occurring in the Upper Silurian Salina Formation at depths from 275 to 825 metres, can be identified and traced from drilling records. Maximum bed thickness is 90 metres, with aggregate thickness reaching as much as 215 metres. The beds are relatively flat-lying and undisturbed, permitting easy mining.

During 1977 these beds were worked through two rock salt mines, one at Goderich and one at Ojibway, and through brining operations at Goderich, Sarnia, Windsor and Amherstburg.

Prairie provinces. Salt beds underlie a broad belt of the Prairie Provinces extending from the extreme southwestern corner of Manitoba northwestward across Saskatchewan and into the north-central part of Alberta. Most of the salt deposits occur within the Prairie Evaporite Formation, which constitutes the upper part of the Middle Devonian, Elk Point Group, with thinner beds of salt occurring in Upper Devonian rocks. Depths range from 180 metres at Fort McMurray, Alberta, to 900 metres in eastern Alberta, central Saskatchewan and southwestern Manitoba, and to 1 830 metres around Edmonton, Alberta, and in southern Saskatchewan. Cumulative thicknesses reach a maximum of 400 metres in east-central Alberta. The beds lie relatively flat and undisturbed. The same rock sequence contains a number of potash beds, currently being exploited in Saskatchewan.

Brine for vacuum-pan evaporation was produced from these formations at two locations — Lindbergh, Alberta and Unity, Saskatchewan — while brine for the production of caustic soda and chlorine was obtained at Brandon, Manitoba; Saskatoon, Saskatchewan and Fort Saskatchewan, Alberta. In addition, byproduct brine from a potash solution mine at Belle Plaine, Saskatchewan was used in the production of fine vacuum-pan salt by The Canadian Salt Company Limited, and at Esterhazy, Saskatchewan, International

Table 5. Canada, available data on salt consumption, 1974-77

	1974	1975	1976[p]	1977[e]
		(tonnes)		
Snow and ice control[1]	2 218 661	2 301 541	2 224 234	2 600 838
Industrial chemicals	1 400 725[r]	531 323[r]	1 964 406	1 456 300
Fishing industry	87 100[e]	96 700[e]	97 400	. .
Food processing				
Fruit and vegetable preparation	19 832	31 406	19 859	25 100
Bakeries	17 536	15 011	13 639	16 800
Fish products	15 689	17 080	22 108	21 000
Dairy factories and process cheese	8 431	8 973	8 732	8 400
Biscuits	1 766	1 702	3 104	2 500
Poultry processors	163	168	74	200
Miscellaneous food preparation	19 279	21 191	22 810	21 000
Grain mills[2]	55 329	50 473	47 012	58 700
Slaughtering and meat packing	34 338	40 106	37 904	41 900
Pulp and paper mills	31 639	31 322	37 691	46 100
Leather tanneries	10 734	9 074	11 416	12 600
Soap and cleaning compounds	2 527	2 525	3 181	3 800
Textile dyeing and finishing	1 442	2 742	2 656	2 900
Breweries	421	370	550	800

Sources: Statistics Canada; Salt Institute.
[1]Fiscal year ending June 30. [2]Includes feed and farm stock salt in block and loose forms.
[e]Estimated by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa; [p]Preliminary; [r]Revised; . . Not available.

Minerals & Chemical Corporation (Canada) Limited (IMCC) supplied a significant quantity of waste salt from potash mining for snow and ice control on highways.

British Columbia. Solar salt from Mexico supplies the British Columbia caustic soda-chlorine manufacturing industry. Early in 1977 the three producers of caustic soda and chlorine in B.C. were struck by members of the Oil, Chemical and Atomic Workers International Union. Settlements were reached in February at the Erco Industries Limited plant in North Vancouver and at the Squamish plant of FMC Canada Limited, and in early March with Hooker Chemical Canada Ltd. at North Vancouver.

Canadian consumption and trade

Salt is marketed in at least 100 different forms, packages and containers and its direct and indirect uses number in the thousands. The largest single market for salt in Canada is for snow and ice control on highways and city streets. By comparison with other uses, this market is new, having expanded in Canada from less than 100 000 tonnes in 1954 to an estimated 2.6 million tonnes in 1977.

The next-largest consumer of salt is the industrial chemical industry, particularly for the manufacture of caustic soda (sodium hydroxide) and chlorine. Salt for four caustic soda and chlorine plants is obtained from on-site brining and natural brines; others use mined rock salt or imported solar salt. Other industrial chemicals that require significant quantities of salt in the manufacturing process include sodium carbonate (soda ash), sodium chlorate, sodium bicarbonate, sodium chlorite and sodium hypochlorite.

The pattern of Canada's salt trade has changed considerably in the past few years. Because of its low unit value and availability in most key market areas, salt is seldom hauled long distances, except in the case of seaborne and intercoastal shipments where greater mileage entails little additional cost.

Canadian imports, principally from the United States and Mexico, amounted to 1.12 million tonnes in 1977, down from 1.52 million tonnes in 1976. Exports in 1977 were 1.28 million tonnes, mainly from Ontario to the United States.

Outlook

Regardless of the increased demand for road salt, despite protests against its use; and for salt for the chemicals industry, the salt industry in Canada can expect slow growth over the long term. Development of a new mine in Quebec will eventually reduce imports of rock salt from the United States, but may also necessitate cutbacks at Canadian mines presently supplying the Quebec market. The British Columbia market will continue to be supplied by Mexico despite the long water haul.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
92501-1	Common salt (including rock salt)	free	free	5¢/100 lb.	free
92501-2	Salt for use of the sea or gulf fisheries	free	free	free	free
92501-3	Table salt made by the admixture of other ingredients when containing not less than 90 per cent of pure salt	5%	5%	15%	3%
92501-4	Salt liquors and sea water	free	free	free	free

United States

Item No.		
420.92	Salt in brine	5% ad valorem
420.94	Salt in bulk	0.8¢ per 100 lb
420.96	Salt, other	free

Sources: For Canada, The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa, Canada. For United States, Tariff Schedules of the United States Annotated (1978) TC Publication 843.

Sand and Gravel

D.H. STONEHOUSE

Unconsolidated granular mineral material produced by the natural disintegration of rock under weathering and erosion processes is termed either "sand" or "gravel". The terms relate to grain size rather than to composition. Sand is defined very generally as passing a 9.51 mm sieve, almost all passing a No. 4 (4.76 mm) sieve, and almost all remaining on a No. 200 (74 micron) sieve. Gravel is that granular material remaining on a No. 4 sieve — the cut-off between commercial sand and gravel. Material finer than 200-mesh is referred to as silt or clay, depending on the particle size.

Commercial sand and gravel deposits are generally classified into one of four categories according to origin or method of deposition. Deposits composed of sand and gravel that had been carried by rivers and streams are referred to as fluvial deposits. They exhibit limited size gradation, and the distribution of size ranges and shapes can vary greatly, depending on whether the streams had been meandering, fast-flowing, narrow or shallow. Glacial deposits were distributed from massive ice sheets over large areas of Canada and the United States as well as other countries. They consist of rock particles of various types, shapes and sizes and display little sorting or gradation. Marine and lake deposits are usually of hard, tough material, well-segregated and well-worn to rounded shapes. Unstratified mixtures of sand and gravel, covering the complete size range and occurring on top of the parent rock, are termed residual deposits. These are not usually of commercial importance because of the large amount of softer clays associated with the mass.

The Canadian industry

Activity in the construction industry in Canada, particularly the heavy or engineering construction segment, determines to a great extent the amount of aggregate produced and used. The construction industry is often the first to be influenced by changes in the economic climate and, as suppliers of raw materials to such a volatile industry, the producers of sand and gravel and other aggregates must be capable of adjusting to periods of high and low activity thus created, as well as to surges in demand caused by regional and seasonal construction programs.

Sand and gravel deposits are widespread throughout Canada, and large producers have established "permanent" plants as close to major consuming centres as possible. Urban expansion has greatly increased demand for sand and gravel in support of major construction. Paradoxically, urban spread has not only tended to overrun operating pits and quarries, but has extended at times to areas containing mineral deposits, thereby precluding the use of these resources. Further complications have arisen in recent years as society has become increasingly aware of environmental problems and the need for planned land utilization. Municipal and regional zoning must be designed to determine and regulate the optimum utilization of land, but must not be designed to provide less than optimum resource utilization. Industry must locate its plants so as to minimize any adverse effects on the environment from their operations. Also, provision must be made for rehabilitation of pit and quarry sites in order to ensure the best sequential land use. The frequency with which small quarries and pits materialize to supply short-lived, local demands, leaving unsightly properties, has prompted action by municipal and provincial governments to control or to prohibit such activity.

Ideally, the exploitation of sand, gravel and stone deposits should be done as part of the total land-use planning package, such that excavations are designed to conform with a master plan of development and even to create new land forms. Ontario seems to be leading other provinces in enacting legislation to control pit and quarry licensing, operation and rehabilitation, and its new laws are typical of what can be expected in other provinces. The urgency associated with the aggregate situation in Ontario, being greater than in other provinces, was a major reason for the formation of a Mineral Aggregate Working Party by the Ontario Government in December, 1975. The Working Party brought together representatives of the Ministry of Natural Resources, the Ministry of Housing, the Ministry of the Environment, the Ministry of Treasury, Economic and Intergovernmental Affairs, the Ministry of Transport and Communications, municipal governments, the Niagara Escarpment Commission and the Conservation Council of Ontario; and through a series of public meetings entertained proposals from all interested persons relative to all aspects of aggregate identification, production and utilization. The working party's report contains a number of recommendations which should lead to the development of a policy for mineral aggregate resource management in Ontario. Ontario's current regulations apply to operations in designated areas of the province and to rehabilitation of depleted sites.

Table 1. Canada, construction spending by provinces, 1976-78

	1976[1]	1977[2]	1978[3]
	($ 000)		
Newfoundland	733 028	593 306	668 901
Prince Edward Island	100 512	123 797	139 577
Nova Scotia	874 040	908 002	983 665
New Brunswick	892 979	883 679	936 572
Quebec	7 903 180	8 676 518	9 058 669
Ontario	10 065 954	10 475 509	11 060 677
Manitoba	1 287 615	1 385 974	1 465 635
Saskatchewan	1 421 590	1 557 384	1 674 357
Alberta	5 197 440	6 195 413	6 528 512
British Columbia, Yukon and Northwest Territories	4 654 861	4 953 619	5 348 886
Canada	33 131 199	35 753 201	37 865 451

Source: Statistics Canada.
[1]Actual; [2]Preliminary; [3]Forecast.

Inventories indicating the potential available reserves of sand, gravel and stone should be prerequisite to legislation regulating land use. Surveys to locate such resources are being carried out in many provinces in order to optimize their use and to choose the best possible distribution routes to consuming centres. It should be observed that controls and zoning can reduce reserves of these resources significantly.

In addition to large aggregate operations usually associated with some other phase of the construction industry such as a ready-mix plant or an asphalt plant, there are many smaller, privately owned producers serving small, localized markets. These are often operated on a seasonal or part-time basis. Many larger operations are short-term, intermittently serving as a supply arm of a heavy construction company, and providing material for a given project. Provincial departments of highways operate regional or divisional quarries to supply roadbed material for new and repair work. Exploitation by such a large number of widely diversified groups not only makes control difficult, it also provides great obstacles to the collection of accurate data concerning both production and consumption of sand, gravel and stone.

Although producers' shipments, as recorded by Statistics Canada (Catalogue 26-215), reflect the total amounts of sand and gravel recovered by all producers regardless of statistical classification, only about 150 "establishments" are listed, showing a total employment of less than 2 000 persons. More detailed data from individual provincial government departments such as highways, municipal affairs, natural resources, lands and forests are required to reveal the total number of active pit and quarry operations.

Substitutes

Materials competitive with sand and gravel include crushed stone, slag and the lightweight aggregates,

Table 2. Canada, production (shipments) of sand and gravel by provinces, 1975-77

	1975		1976		1977[p]	
	(000 tonnes)	($000)	(000 tonnes)	($000)	(000 tonnes)	($000)
Newfoundland	6 237	9 587	4 964	8 687	4 627	8 600
Prince Edward Island	929	1 787	789	1 684	816	1 800
Nova Scotia	8 906	14 043	8 408	15 727	7 620	15 100
New Brunswick	3 834	4 239	5 672	5 403	4 990	5 200
Quebec	82 039	70 488	77 156	68 852	75 568	69 900
Ontario	69 705	95 579	68 802	106 093	70 307	112 400
Manitoba	16 417	22 934	16 126	25 395	15 331	25 200
Saskatchewan	8 313	10 672	8 619	11 142	8 346	11 900
Alberta	20 453	33 952	24 520	43 659	25 129	48 500
British Columbia	30 322	41 900	34 103	47 772	31 116	45 300
Canada	247 155	305 181	249 159	334 414	243 850	343 900

Source: Statistics Canada.
[p]Preliminary.

Table 3. Production (shipments) of sand and gravel by uses and by areas, 1975 and 1976

		Atlantic Provinces	Quebec	Ontario	Western Provinces	Canada
				(000 tonnes)		
Roads	1975	15 493	52 868	35 633	39 898	143 892
	1976	14 848	54 013	34 369	47 793	151 023
Concrete aggregate	1975	1 623	10 520	14 491	12 486	39 120
	1976	11 541	5 516	15 841	10 733	33 631
Asphalt aggregate	1975	1 892	5 934	4 717	6 025	18 568
	1976	2 356	4 048	5 072	6 334	17 810
Railroad ballast	1975	179	521	202	3 224	4 126
	1976	192	226	195	2 338	2 951
Mortar sand	1975	53	438	2 037	604	3 132
	1976	59	414	1 271	502	2 246
Backfill for mines	1975	112	226	1 508	137	1 983
	1976	107	7	928	24	1 066
Other fill	1975	544	6 584	9 963	11 440	28 531
	1976	577	5 650	9 530	12 198	27 955
Other uses	1975	9	4 948	1 154	1 692	7 803
	1976	153	7 282	1 596	3 446	12 477
Total sand and gravel	1975	19 905	82 039	69 705	75 506	247 155
	1976	19 833	77 156	68 802	83 368	249 159

Source: Statistics Canada, with breakdown by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.

Table 4. Canada, exports and imports of sand and gravel, 1975-77

	1975		1976		1977p	
	(tonnes)	($)	(tonnes)	($)	(tonnes)	($)
Exports						
Sand and gravel						
United States	138 399	352 000	377 599	551 000	273 598	431 000
France	9	1 000	18	2 000	126	11 000
Japan	—	—	—	—	19	3 000
Other countries	44	12 000	36	5 000	—	—
Total	138 452	365 000	377 653	588 000	273 743	445 000
Imports						
Sand and gravel, not elsewhere stated						
United States	1 909 319	3 530 000	2 087 565	3 813 000	1 645 328	4 643 000
West Germany	575	10 000	1 959	5 000	327	1 000
Hong Kong	—	—	26	. . .	—	—
Total	1 909 894	3 540 000	2 089 550	3 818 000	1 645 655	4 644 000

Source: Statistics Canada.
— Nil; . . . Less than $500; pPreliminary.

Table 5. Sand and gravel, comparison of costs by provinces, 1976

	$/ton at point of loading	Average rates for truck haul ($/ton)				
		1 mile	10 miles	20 miles	25 miles	50 miles
Newfoundland	1.59	0.38	1.32	2.36	2.78	4.08
Nova Scotia	1.70	0.41	1.39	2.48	2.87	4.09
Prince Edward Island	1.94	0.43	1.45	2.58	2.99	4.26
New Brunswick	0.86	0.35	1.19	1.94	2.29	4.04
Quebec[1]	0.81	0.40	1.30	2.30	2.63	4.23
Ontario[2]	1.40	0.48	1.10	1.45	1.78	3.40
Manitoba[3]	1.43	0.32	1.04	1.79	2.14	3.89
Saskatchewan	1.17	0.49	1.02	2.25	2.82	5.64
Alberta[4]	1.62	0.52	1.46	2.50	3.02	5.62
British Columbia[5]	1.27	—	—	—	—	—

[1]A zoned rate structure in Montreal from 1 to 22 miles ranges from 10¢ to 20¢ a ton. Hourly rates for trucks range from $15.00 to $27.00. [2]Hourly rates for trucks range from $18.00 to $22.00. [3]Hourly rates for trucks in Winnipeg range from $10.00 to $27.45. [4]Hourly rates for trucks range from $15.00 to $18.00. [5]No standard schedule. A zoned rate structure in Vancouver ranges from $1.00 to $3.90 a ton.
Source: *The Canadian Mineral Aggregate Industry*, Canadian Transport Commission, 1978.

depending on the application considered. It has been estimated that total aggregate consumption in some Canadian urban centres could reach 18 tonnes* per capita by 1980. Estimates have indicated that available sand and gravel supplies in some regions will be depleted by the 1990s. This could make outlying deposits not only attractive but necessary, and could also encourage development of underwater deposits. Marine aggregates now account for about 12 per cent of total sand and gravel production in the United Kingdom, the world's largest producer from such resources. It is not completely impossible that areas of concentrated population such as the eastern seaboard of the United States where reserves of aggregate are already becoming depleted, will have to import their requirements, perhaps from offshore by boat or barge. Large tonnages of crushed limestone are exported annually from Canada's west coast quarries, particularly from Texada and Aristazabal islands, for cement, lime and aggregate use in Oregon and Washington while as much as 3 million tonnes of similar material is imported into Ontario from quarries in the Rogers City region of Michigan each year.

Uses

The main uses for sand and gravel are: as fill, granular base and finish course material for highway construction, coarse and fine aggregates in concrete manufacture, coarse aggregate in asphalt production, and fine aggregate in mortar and concrete blocks. Specifications vary greatly, depending on the intended use, and many tests are required to determine the acceptability of aggregates for certain applications. Particle size distribution of aggregates, as assessed by grading tests or sieve analysis, affects the uniformity and workability of a concrete mix as well as the strength of the concrete, the density and strength of an asphalt mix, and the durability, strength and stability of the compacted mass when aggregates are used as fill or base-course material. Of importance also are tests to determine the presence of organic impurities or other deleterious material, the resistance of the aggregate to abrasion and to freeze-thaw cycles, the effects of thermal expansion, absorption, porosity, reactivity with associated materials and surface texture.

The use of sand and gravel as backfill in mines continues, along with increasing use of cement and mill tailings for this purpose. Abrasive sands, glass sand, foundry sands and filter sands are also produced.

Even the common products such as sand and gravel require a sales and distribution effort which depends upon forecast data supplied by monitoring relevant indicators. One such indicator is the number of regional housing starts which, in turn, can be projected to determine future needs for roads, driveways, shopping centres and schools. Heavy construction awards can be used to provide an estimate of the quantity of aggregate required for given projects over given periods of time.

Prices

There is no standard price for sand and gravel (Table 5). Prices are determined regionally, or even locally, by

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

production and transportation costs, by the degree of processing required for a given end use and by the quantity of material required for a particular project. Increased land values, reduction of reserves and added rehabilitation expenditures should result in higher prices.

Table 6. Canada, production (shipments) of sand and gravel by uses, 1975 and 1976

	1975	1976
	(000 tonnes)	
Roads — construction, maintenance, ice control	143 892	151 023
Concrete aggregate	39 120	33 631
Asphalt aggregate	18 568	17 810
Railroad ballast	4 126	2 951
Mortar sand	3 132	2 246
Backfill for mines	1 983	1 066
Other fill	28 531	27 955
Other uses	7 803	12 477
Total sand and gravel	247 155	249 159
$000	305 181	334 414

Source: Statistics Canada, with breakdown by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.

Sand and gravel must be quarried, screened, washed, stockpiled and transported in large volume to compensate for the relatively low unit value received. Transportation and handling often double the plant cost, making it necessary to utilize close-in reserves and influencing the scope of exploration for new deposits. The need for an inventory of aggregate materials surrounding regions of large population growth cannot be emphasized too strongly. To illustrate the importance of resource management in the case of aggregates, the Ministry of Natural Resources, Ontario has calculated that had the total aggregates used in Ontario in 1975 been transported one additional mile, truck travel would have increased by 5.5 million miles, an extra 1.25 million gallons of fuel would have been used, and the total cost to the consumer would have increased by over $8 million.

Unit trains, or more precisely, "hook and haul" trains, have been used to transport aggregate into the Toronto area in minimum loads of 4 000 tonnes at negotiated freight rates. The wide physical distribution of consumers within the area being served causes difficulties with such a system, as further handling and transporting is required.

Outlook

On average, total aggregate consumption will rise in line with population increases, housing requirements and construction in general. Sand and gravel consumption will continue in competition with crushed stone and, in some applications, with lightweight aggregates. New reserves must be located, assessed and made part of any community development planning or regional zoning, with optimum land and resource utilization in mind. In the search for new sources of sand and gravel some countries are turning to their sea beds. The use of huge pumps and specially equipped ships to draw gravel from the sea floor and deposit it in attendant barges is already common practice in Britain. Such methods of obtaining aggregates can have far-reaching environmental effects.

Table 7. Canada, sand and gravel production (shipments) and trade, 1960, 1965, 1970, 1975-77

	Production	Imports	Exports
		(tonnes)	
1960	174 247 054	803 406	189 758
1965	186 208 979	517 982	624 090
1970	183 846 431	456 077	1 125 083
1975	247 155 421	1 909 894	138 452
1976	249 158 891	2 089 550	377 653
1977[p]	243 850 000	1 645 655	273 743

Source: Statistics Canada.
[p] Preliminary.

Prices for graded, washed and crushed gravel and sand will show slow but steady increase, based on greater property costs, more sophisticated operating techniques and equipment, pollution and environmental considerations, and higher labour and transportation costs.

Selenium and Tellurium

G.E. WOOD

Selenium is a non-metallic element which is widely dispersed in low concentrations throughout the earth's crust, where it is the 69th element in order of abundance. The chemistry of selenium is similar to that of sulphur. It has some of the properties of a metal and is sometimes referred to as a metal. Selenium was first discovered in 1817 by the Swedish chemist Berzelius. Selenium occurs in minerals associated with copper, lead and iron sulphides. Commercial production is from electrolytic copper refinery slimes and from flue dusts from copper and lead smelters. Therefore, the quantity of selenium produced in any particular year is dependent upon the level of production in the world primary copper-refining industry. Countries producing selenium include the United States, Canada, Japan, the U.S.S.R., Belgium and Luxembourg, Sweden, Mexico, Yugoslavia, Finland, Peru, Australia and Zambia. A significant amount of selenium is also produced each year from secondary sources.

Production of selenium in all forms, from Canadian copper refineries plus refined selenium from domestic primary materials, was 207 000 kilograms (kg) in 1977[p] compared with 109 649 kg in 1976. Canada was the second-largest producer of selenium in the non-communist world in 1977, after Japan. The United States was the third.

Domestic consumption of selenium in 1976 was reported to be 11 212 kg. The corresponding figure for 1977 has been withheld to avoid disclosing confidential company information. The major user of selenium in Canada has been the glass industry, which consumed 75 per cent of the total in 1976.

Table 1 gives details of Canadian selenium production, exports and consumption in 1977 and 1976. Increased production of selenium is reported from each of the producing provinces in 1977. Production had been unusually low in 1976 due to the curtailment of production from the Canadian Copper Refiners Limited plant for environmental reasons.

As shown in Tables 1 and 2, the bulk of Canada's production of selenium is exported. The quantity of selenium exported each year varies in a wide range and often differs from refined production. The United States is Canada's major market, followed by the United Kingdom. These two countries purchased 92 per cent of Canada's exports in 1977.

Canadian Copper Refiners Limited at Montreal East, Quebec, operates Canada's largest selenium recovery plant. The company's refinery treats anode copper from the Noranda smelter at Noranda Mines Limited, the Murdochville smelter of Gaspé Copper Mines, Limited, both in Quebec; and blister and anode copper from the smelter of Hudson Bay Mining and Smelting Co., Limited at Flin Flon, Manitoba. The selenium plant can produce a commercial-grade product (99.5 per cent Se), a high-purity product (99.99 per cent Se) and a variety of selenium compounds. Annual capacity is 186 600 kg of selenium in elemental form and in salts. This capacity is dictated by selenium content of copper processed rather than by other factors. Production was interrupted by an 18-day strike in April 1977.

The 67 200-kg-a-year selenium recovery plant of Inco Limited at Copper Cliff, Ontario, treats tankhouse slimes from the company's Copper Cliff copper refinery and its Port Colborne, Ontario, nickel refinery. The marketable product is minus 200 mesh selenium powder (99.5 per cent Se).

Non-communist world production of selenium in 1977 was 1 186 700 kg, compared with 1 023 182 kg in 1976. The biggest increases were in the United States and in Canada.

In the United States, Canada's most important market, total primary production was estimated at 249 500 kg, 37 per cent above 1976 production of 181 890 kg. This increase was achieved in spite of an industry-wide copper strike which forced the shutdown of one selenium plant for the full third quarter and two other selenium plants for three weeks and two months,

[p] Preliminary.

Table 1. Canada, selenium production, exports and consumption 1976-77

	1976		1977^p	
	(kilograms)	($)	(kilograms)	($)
Production				
All forms[1]				
Quebec	36 265	1 419 130	91 000	3 630 000
Ontario	49 169	1 924 100	56 000	2 223 000
Manitoba	15 765	616 901	45 000	1 815 000
Saskatchewan	8 450	330 647	15 000	599 000
Total	109 649	4 290 778	207 000	8 267 000
Refined[2]	226 419	. .	410 552	. .
Exports				
United States	139 480	6 701 000	106 000	5 259 000
United Kingdom	87 044	3 441 000	76 000	3 270 000
Japan	10 478	560 000	10 000	558 000
South Africa	998	39 000	4 000	163 000
Argentina	1 270	58 000	1 000	46 000
Puerto Rico	862	40 000	1 000	44 000
Other countries	816	31 000	. . .	11 000
Total	240 948	10 870 000	198 000	9 351 000
Consumption[3]	11 212	. .	. .	. .

Source: Statistics Canada.
[1]Recoverable selenium content of blister copper treated at domestic refineries, plus refined selenium from domestic primary materials. [2]Refinery output from all sources, including imported materials and secondary sources. [3]Consumption (selenium content), as reported by consumers.
^{p}Preliminary; . . Not available; . . . Negligible.

respectively. United States consumption grew less rapidly than production in 1977. Producer stocks at the end of 1977 were 146 900 kg, compared with 80 200 kg a year earlier. Prices weakened as a result and producer prices were lowered for the first time since May 1974.

In October 1977, selenium production began at the Ndola copper refinery in Zambia.

Consumption and uses

Selenium is used in the manufacture of glass, steel, electronic components, explosives, animal and poultry feeds, fungicides and pigments, and in xerography.

Elemental selenium is marketed in two grades; commercial, with a minimum content of 99.5 per cent Se; and high purity, with a minimum content of 99.99 per cent Se. Other forms in which selenium is available include ferroselenium, nickel selenium, selenium dioxide, barium selenite, sodium selenate, sodium selenite and zinc selenite. Consumption by industrial sectors in the United States in 1977 was estimated by the United States Bureau of Mines (USBM) to have been: electronic and photocopier components, 42 per cent; ceramics and glass, 32 per cent; chemicals and pigments, 16 per cent and other uses, 10 per cent.

An important but declining use of selenium is in the electrical field, where it is used in the manufacturing of rectifiers used in electroplating, welding, battery charging and other similar applications. Selenium is used in specialty transformers varying in size from a fraction of a watt to 500 kilowatts. Xerography (electrostatic printing), a dry photocopying or photographing process, uses a large quantity of selenium. In semiconductors selenium has largely been replaced by silicon.

The glassmaking industry is one of the major consumers of selenium. Small quantities added to the glass batch neutralize the greenish tinge imparted to glass by iron impurities in the sand. Selenium is meeting with some competition from cerium in this application. The brilliant ruby-red glass used in traffic and other signal lenses, automotive taillights, marine equipment, infrared equipment and decorative tableware is produced by adding larger quantities of selenium to the glass batch. An increasing amount of selenium is used in tinted "black" glass which is used as the outer facing of many high-rise office buildings.

Selenium has wide application in the chemical industry, the most important being the manufacture of the orange-red-maroon cadmium sulphoselenide pigments. They have considerable light stability, maintain their brilliance and are resistant to heat and chemical action. Their most important application is in the expanding high-temperature, cured-plastic industry,

Table 2. Canada, selenium production, exports and consumption, 1960, 1965, 1970, 1975-77

	Production			
	All forms[1]	Refined[2]	Exports[3]	Consumption[4]
	(kilograms)			
1960	236 611	237 981	183 437	6 559
1965	232 274	233 416	204 660	7 206
1970	300 884	387 572	311 209	7 135
1975	182 385	684 784	217 996	9 933
1976	109 649	226 419	240 948	11 212
1977^p	207 000	410 552	198 000	. .

Source: Statistics Canada.
[1]Recoverable selenium content of blister copper treated at domestic refineries, plus refined selenium from domestic primary materials. [2]Refinery output from all sources, including imported materials and secondary sources. [3]Exports of selenium, selenium powder, shot, etc. [4]Consumption (selenium content), as reported by consumers.
^{p}Preliminary; . . Not available.

Table 3. Non-communist world production of selenium 1975-77

	1975	1976	1977^e
	(kilograms)		
Japan	417 346	460 396	453 600
United States	162 386	181 890	249 500
Canada	182 385	109 649	207 000
Belgium and Luxembourg	65 000	81 647	81 600
Mexico	58 000	58 059	59 000
Other countries	115 304	131 541	136 000
Total	1 000 421	1 023 182	1 186 700

Sources: For Canada, Statistics Canada. For other countries, U.S. Bureau of Mines Commodity Data Summaries, January 1977 and 1978 and Mineral Trade Notes, October 1977.
^{e}Estimated.

but they are also used to colour ceramics, paints, enamels and inks.

In proportions ranging from 0.2 to 0.35 per cent, selenium imparts improved machinability to stainless steel without affecting its corrosion-resistance properties, and in lesser amounts improves the forging characteristics of steel. Small quantities of iron selenide, from 0.01 to 0.05 per cent, are used as an additive in steel casting to prevent pinhole porosity.

Finely ground elemental selenium and selenium diethyldithio-carbamate (selenac) are used in natural and synthetic rubber to increase the rate of vulcanization and to improve the aging and mechanical properties of sulphurless and low-sulphur rubber. Selenac is used as an accelerator in butyl rubber.

Table 4. Canada, industrial use of selenium 1975-77

	1975	1976	1977^p
	(kilograms of contained selenium)		
By end use			
Glass	7 420	8 448	8 371
Other[1]	2 514	2 764	4 105
Total	9 934	11 212	12 476

Source: Statistics Canada.
[1]Steel, pharmaceuticals.
^{p}Preliminary; . . Not available.

Selenium is used in the organic chemical and pharmaceutical industries, in the manufacture of cortisone and nicotine acids, in the preparation of various proprietary medicines and shampoos for the control of dermatitis in human beings and animals, and in the control of certain diseases in animals and poultry. It is known that selenium is an essential element for normal physical development and prevents white muscle disease in livestock and poultry. Growing attention within this field could result in a large new market for selenium as a feed supplement. In the United States, the Food and Drug Administration has proposed that selenium be added to poultry and swine feed. However, selenium is highly toxic to both livestock and human beings if consumed in excessive quantities.

A small amount of selenium is used in the manufacture of delay-action blasting caps.

Interest has been revived in the use of selenium in the photogalvanic cell, which converts light energy to electrical energy. An increased demand for selenium-tinted windows, which have a lower heat conductivity than conventional glass is expected.

Outlook

Selenium production is primarily a byproduct of copper refining, but the relationship is trending towards a lower proportion of selenium output as existing selenium-rich copper reserves are exhausted. An increasing amount of copper production is being derived from selenium-poor ores.

It is likely that Canadian production of selenium will gradually decline in the medium term for the reason mentioned above. Production in 1978 should be somewhat lower than in 1977 due to lower copper production.

Prices

According to *Metals Week*, 1977 selenium producer prices, in United States currency, were as follows:

	($U.S./lb)
Commercial grade	
January 1 to September 14	18.00
September 15 to September 19	15.00-18.00
September 20 to December 31	15.00

High-purity grade	$U.S./lb
January 1 to September 19	21.00-22.00
September 20 to December 31	18.00

Dealer prices in the United States rose during the first four months to a peak of $U.S. 16.50-17.50 a pound in April. At the end of 1977 dealer prices declined to $U.S. 10.75-11.25 a pound.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
92804-4	Selenium	5%	10%	15%	5%

United States

Item No.		
420.50	Selenium dioxide	free
420.52	Selenium salts	free
420.54	Other selenium compounds	5%
632.40	Selenium metal, unwrought, other than alloys, waste and scrap	free
632.84	Selenium metal alloys, unwrought	9%
633.00	Selenium metals, wrought	9%

European Communities

Item No.		Conventional Rate of Duty
28.04 C.11	Selenium	free

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division; Tariff Schedules of the United States Annotated 1978, T.C. Publication 843; Official Journal of the European Communities, November 14, 1977.

TELLURIUM

Like selenium, tellurium is recovered in Canada from the tankhouse slimes of the two electrolytic copper refineries and the Port Colborne nickel refinery. It is refined by the same two companies: Canadian Copper Refiners Limited at Montreal East, Quebec, and Inco Limited at Copper Cliff, Ontario. Tellurium is more metallic than selenium but resembles selenium and sulphur in chemical properties. Like selenium, tellurium is a semiconductor. It was discovered by Muller in 1782 in Transylvanian gold ore.

Porduction of tellurium in all forms from Canadian ores in 1977 amounted to 36 000 kg valued at $922 000, compared with 48 698 kilograms valued at $1 093 988 in 1976. Tellurium is related to selenium output because tellurium is a coproduct of selenium recovery. Refined output from all sources, including imported material, for the years 1977 and 1976 was 37 021 kg and 53 141 kg respectively.

Canadian Copper Refiners Limited (CCR) has an annual capacity to produce 27 200 kg of tellurium in the form of powder, stick, lump and dioxide. The Copper Cliff refinery has capacity to produce 8 200 kg of tellurium a year in the form of dioxide.

Consumption and uses

Tellurium is recovered mainly as a byproduct of copper refining and the supply is, therefore, related to copper production. Under present technological practices a low ratio of recovery is obtained, but it is adequate to meet demand. Tellurium and many of its compounds are highly toxic and great care is required in handling these materials.

Table 5. Canada, tellurium production and consumption, 1976-77

	1976		1977^p	
	(kilograms)	($)	(kilograms)	($)
Production				
All forms[1]				
Quebec	36 312	815 750	23 000	581 000
Ontario	7 031	157 945	8 000	205 000
Manitoba	3 486	78 310	4 000	102 000
Saskatchewan	1 869	41 983	1 000	34 000
Total	48 698	1 093 988	36 000	922 000
Refined[2]	53 141	. .	37 021	. .
Consumption[3]	589	. .	. .	. .

Source: Statistics Canada.
[1]Recoverable tellurium content of blister copper treated, plus refined tellurium from domestic primary material. [2]Refinery output from all sources, including imported materials and secondary sources. [3]Consumption (tellurium content), as reported by consumers.
^{p}Preliminary; . . Not available.

Most of the commercial-grade tellurium sold by the primary producers is in the form of slab, stick, lump, tablet and powder. It is also sold as copper and iron alloys.

In the United States consumption by major uses in 1976 was estimated to be: iron and steel, 77 per cent; nonferrous metal products, 14 per cent; chemicals, 5 per cent and others, 4 per cent.

The primary metal industries are by far the largest consumers of tellurium. When it is added to copper and low-carbon and alloy steels, the machinability of these metals is greatly improved. In stainless steel castings it reduces or prevents pinhole porosity. A very small quantity of tellurium added to molten iron controls the chill depth of grey-iron castings. An alloy containing 99.5 per cent copper and 0.5 per cent tellurium is used in the manufacture of welding tips and communications equipment because it can be hot- or cold-worked, and the thermal and electrical conductivity is only slightly less than that of copper. Up to 0.1 per cent tellurium in lead forms an alloy that has better resistance to wear, vibration breakdown and corrosion, and, because of these properties, the alloy is used to sheathe marine cables and to line tanks subject to chemical corrosion.

Tellurium, as a component of alloys containing gallium, bismuth and lead, is used in thermoelectric devices for the direct conversion of heat into electricity, and for cooling as a result of its Peltier effect. A thermonuclear heart pacemaker that employs the thermoelectric principle is under development. In the device, nuclear power provides heat and a tellurium alloy converts the heat to electrical energy. The minimum life of this experimental pacemaker is reported to be ten years.

Tellurium is used as a secondary vulcanizing agent in natural and synthetic rubber in which it increases toughness and resistance to abrasion and heat. These characteristics made possible its application for the jacketing of portable electric cable used in mining, dredging, and welding and for specialized conveyor belting. Tellurium is employed to eliminate porosity in thick rubber sections and as an accelerator for butyl applications.

Table 6. Canada, production and consumption of tellurium, 1960, 1965, 1970 and 1975-77

	Production		Consumption
	All forms[1]	Refined[2]	Refined[3]
	(kilograms)		
1960	20 267	18 940	1 922
1965	31 658	32 536	848
1970	26 459	29 317	399^r
1975	19 854	42 253^r	614
1976	48 698	53 141	589
1977^p	36 000	37 021	. .

Source: Statistics Canada.
[1]Includes recoverable tellurium content of blister copper treated, plus refined tellurium from domestic primary metal. [2]Refinery production from all sources, including imported material and secondary sources. [3]Consumption (tellurium content), as reported by consumers.
^{p}Preliminary; . . Not available; ^{r}Revised.

Table 7. Non-communist world production of tellurium, 1975-77

	1975	1976	1977[e]
	(kilograms)		
United States[1]	59 350	. .	. .
Canada	19 854	48 698	36 000
Peru	21 209	12 331	27 200
Japan	21 000	28 500	27 200
Total	121 413	89 529	90 400

Sources: For Canada, Statistics Canada. For other countries, U.S. Bureau of Mines-Commodity Data Summaries, January 1977 and 1978 and Mineral Trade Notes, October 1977.
[1]In 1975, the United States accounted for 42 per cent of world output.
[e] Estimated; . . Not available.

Some tellurium is consumed in glass and ceramic production to develop blue-to-brown coloration, in the preparation of insecticides and germicides and in the manufacture of delay-electric blasting caps and pigments.

Outlook

Supply is largely limited to that which is available from copper output and, as in the case of selenium, new copper production is increasingly derived from tellurium-poor ores. In the short- to medium-term a slow growth in demand is expected, in the range of zero to 2 per cent, and supply will be adequate to meet requirements. The drop in inventories of tellurium is not expected to continue in 1978 and prices are expected to stabilize around the levels reached at the end of 1977.

Prices

According to *Metals Week*, the 1977 tellurium prices for slab in 150-pound lots, in United States Currency, were as follows:

	($U.S./lb)
January 1 to January 12	12.00-15.00
January 13 to May 31	15.00
June 1 to June 12	15.00-18.00
June 13 to September 15	18.00
September 16 to December 31	20.00

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
92804-5	Tellurium metal	5%	10%	15%	5%

United States

Item No.		
421.90	Tellurium compounds	5%
427.12	Tellurium salts	5%
632.48	Tellurium metals, unwrought, other than alloys, and waste and scrap (duty on waste and scrap suspended to June 30, 1978)	4%
632.84	Tellurium metal alloys, unwrought	9%
633.00	Tellurium metal, wrought	9%

European Communities

Item No.		Conventional Rate of Duty
28.04 C.111	Tellurium metal	2.4%

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division; Tariff Schedule of the United States Annotated, 1978, T.C. Publication 843; Official Journal of the European Communities, November 14, 1977.

Silica

G.H.K. PEARSE

Silica (SiO_2) occurs as the mineral, quartz, in a variety of rocks and unconsolidated sediments. Although it is one of the most abundant minerals, making up an estimated 12 per cent of the earth's crust, commercial sources of silica are presently restricted to uncommonly pure sands, sandstones, quartzites and vein quartz. Further, because of its low unit value, an economically viable deposit should normally be mineable by low-cost, open-pit methods and, ideally, be located close to consuming areas in order to minimize transportation costs.

The principal uses for silica are: as the chief constituent in glass, as metallurgical flux, in the manufacture of silicon carbide, as an ore of silicon and ferrosilicon, as foundry sand for metal castings, in sand blasting, and as filler materials in tile, asbestos cement pipe, concrete and bricks.

Production of silica in Canada in 1977 was 2.36 million tonnes*, down 6 per cent from 1976. The record 2.94 million tonnes shipped in 1970 remains unsurpassed.

About 60 per cent of silica produced in Canada is low-value lump and sand consumed as metallurgical flux. High-quality silica sand suitable for the manufacture of glass is produced by two companies in Canada. Indusmin Limited, the largest, operates beneficiation plants in southern Ontario and Quebec. Steel Brothers Canada Ltd. quarries high-grade silica sandstone on Black Island in Lake Winnipeg and processes the material at the company's plant at Selkirk, Manitoba.

Canada imports high-grade silica sand for use in glass manufacturing and sand suitable for foundry castings, silex and crystallized quartz and silica brick. In 1977, imports, nearly all from the United States, totalled 1.10 million tonnes, 18 per cent less than in 1976.

Principal producers and developments

Newfoundland. Newfoundland Enterprises Limited, a subsidiary of Armand Sicotte & Sons Limited, produces silica from a quarry at Villa Marie on the Avalon Peninsula. The silica is hauled by truck 19 kilometres (km) to Long Harbour where it is used as a flux in the manufacture of elemental phosphorus by Erco Industries Limited. This plant, which requires about 100 000 tonnes of silica annually, was not active during 1977.

Quebec. Indusmin Limited produces a wide variety of silica products at its mill near Saint-Canut, Quebec. In addition to quarrying Potsdam sandstone adjacent to the Saint-Canut mill, the company quarries a friable Precambrian quartzite from a deposit near Saint-Donat. Material from the Saint-Donat quarry is trucked about 80 km to the Saint-Canut mill for processing. Products produced at Saint-Canut include silica sand suitable for glass and silicon carbide manufacture, foundry sand, and silica flour for use as a filler in tiles, asbestos cement pipe, concrete blocks and bricks. Production at Indusmin's operation in Quebec was 432 000 tonnes in 1977, up 11 per cent from 1976 despite severe operating conditions during part of the winter. Ore reserves at the two deposits are reported to be 15.4 million tonnes combined (annual report — 1977). The silica sand suitable for glass manufacture is marketed in Quebec, while much of the product suitable for use in the construction industry is sold in Ontario. The balance of Quebec's silica sand requirement for glass manufacture is imported from the United States.

Union Carbide Canada Mining Ltd. quarries quartzitic sandstone at Melocheville, Beauharnois County, for use in ferrosilicon manufacture at Beauharnois. Fines from this operation are used in foundry work, cement manufacture and as a metallurgical flux. Silice L.M. Ltée at Lac Bouchette, Roberval produces about 15 000 tonnes from vein quartz for Union Carbide's silicon plant at Chicoutimi.

During 1975 Baskatong Quartz Products Ltd. closed its plant which had produced lump silica and crushed quartz from a deposit on the southwest shore of Lake Baskatong. The lump silica was used in the

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Canada, silica production and trade, 1976-77

	1976		1977p	
	(tonnes)	($)	(tonnes)	($)
Production, quartz and silica sand				
By province				
Quebec	676 517	7 279 941	641 000	8 240 000
Ontario	1 126 909	5 203 268	1 002 000	5 940 000
Manitoba	449 490	1 573 611	414 000	1 782 000
Alberta	. .	1 084 692	. .	1 500 000
Nova Scotia	. .	199 965	. .	386 000
Saskatchewan	119 541	195 021	181 000	316 000
British Columbia	23 491	252 425	25 000	280 000
Newfoundland	. .	218 000	—	—
Total	2 520 476	16 006 923	2 362 000	18 444 000
By use				
Glass and fiberglass	442 492	6 182 059	. .	. .
Flux	1 328 677	2 612 264	. .	. .
Ferrosilicon	338 665	1 807 181	. .	. .
Other uses[1]	410 642	5 405 419	. .	. .
Total	2 520 476	16 006 923	. .	. .
Imports				
Silica sand				
United States	1 334 404	9 698 000r	1 094 904	9 476 000
Belgium-Luxembourg	2 734	13 000	6 198	39 000
France	—	—	24	9 000
United Kingdom	—	—	54	3 000
Total	1 337 138	9 711 000r	1 101 180	9 527 000
Silex and crystallized quarts				
United States	862	220 000	1 187	230 000
France	—	—	30	12 000
Brazil	—	—	1	3 000
Mexico	—	—	1	1 000
United Kingdom	1	2 000	—	—
Total	863	222 000	1 219	246 000
Firebrick and similar shapes, silica				
United States	5 454	1 756 000	8 548	2 180 000
Japan	78	12 000	377	271 000
West Germany	5 087	1 775 000	414	174 000
Austria	—	—	247	159 000
Other countries	231	128 000	443	265 000
Total	10 850	3 671 000	10 029	3 049 000
Exports				
Quartzite				
United States	47 944	249 000	56 296	246 000
Barbados	—	—	1	. . .
Total	47 944	249 000	56 297	246 000

Source: Statistics Canada.
[1]Includes foundry use, sand blasting, silica brick, concrete products, chemical manufacture, building products and silicon carbide.
p Preliminary; — Nil; . . Not available; . . . Less than $500; r Revised.

manufacture of silicon metal and to a lesser extent as grinding pebble. The crushed quartz was sold for use as exposed aggregate in decorative concrete. A new 52 000-tonne-a-year ferrosilicon plant came on stream at Bécancour, Quebec in 1976. The company, S.K.W. Electro-Metallurgy Canada Ltd., obtains its raw material from a high-purity silica deposit 40 km north of Baie St. Paul near La Galette in Charlevoix County, operated by Baskatong Quartz Products. The silica is shipped by truck via Baie St. Paul to Bécancour. Production commenced in the fall of 1975.

Armand Sicotte & Sons Limited produces about 80 000 tonnes of silica for flux in phosphorus-making at Erco Industries Limited's plant at Varennes.

A new company, Montreal Silica Mines Ltd., began production during the summer from unconsolidated Pleistocene sands near Ormstown, 50 km southwest of Montreal. The 50 000-tonne-a-year washing, screening and drying plant produces 50-, 55- and 65-mesh foundry sand, 24- and 40-mesh sandblasting sand and a 70-mesh product for glass fibre manufacture. Much of the impurities are in the finer sizes, and screening results in a product purity of 93 to 96 per cent SiO_2.

Ontario. Indusmin Limited quarries a high-grade silica deposit on Badgeley Island in Georgian Bay. The deposit, containing reported reserves of 13 million tonnes, consists of very pure Precambrian Lorraine quartzite. A primary crushing plant at the deposit, some 190 km north of Midland across Georgian Bay, and a grinding and processing plant at Midland, came on stream during the first half of 1970. The Badgeley Island operation has a capacity of approximately 1 million tonnes a year of washed lump silica and fine material. The Midland plant capacity is about 500 000 tonnes a year of refined silica products. Primary products from the crushing plant on Badgeley Island are shipped directly to manufacturers of ferrosilicon and silicon metal, and to the Midland grinding plant for further processing. Products from the Midland plant go to glass, ceramic, chemical and other industries in Ontario.

A 25 per cent decrease in lump silica shipments was largely attributable to slackness in the United States ferrosilicon market. This loss was partially offset by an 8.5 per cent increase in sales from the Midland plant. A new product, 325-mesh flour, will be marketed in 1978. In 1977, production was 436 000 tonnes (exclusive of metallurgical flux). Inco Limited and Falconbridge Nickel Mines Limited together use about 745 000 tonnes of silica for smelter flux.

Manitoba. Steel Brothers Canada Ltd. quarries friable sandstone of the Winnipeg Formation at Black Island in Lake Winnipeg. The sandstone is then barged to the company's processing plant at Selkirk where it is washed, sized and packaged for sale. The company provides silica sand for a large portion of the western Canadian market. Silica sand suitable for the manufacture of glass containers is shipped to Alberta. The majority of the remaining production is consumed in the Manitoba market, largely as foundry sand. The company formerly quarried quartzite and sand for Inco's smelter at Thompson, Manitoba, for use as metallurgical flux. Inco now manages these facilities. Manitoba's output declined almost 8 per cent to 414 000 tonnes in 1977 as a result of slack demand in most sectors.

Saskatchewan. Hudson Bay Mining and Smelting Co., Limited obtains silica for smelter flux from Pleistocene glacial sand deposits in Saskatchewan adjacent to its operations at Flin Flon, Manitoba. Production in 1977 was 181 000 tonnes.

Alberta. Sil Silica Ltd. quarries Pleistocene dune sands at Bruderheim, 65 km northeast of Edmonton. A washing and flotation plant upgrades material running 93 per cent silica, 3 per cent alumina, 1 per cent clay and 0.75 per cent iron oxide, to products suitable for fibreglass manufacture, sand blasting and foundry use. Since operations started in 1971, capacity has tripled to more than 60 000 tonnes a year. Reserves are adequate for many years.

British Columbia. In August 1968 Pacific Silica Limited ceased production of silica for ferrosilicon and silicon carbide at its deposits near Oliver, British Columbia. Stucco dash and roof chips are being produced from existing stockpiles. Production in 1977 was 25 000 tonnes.

Uses and specifications

The principal uses of lump silica, silica sand and crushed quartzite, together with specifications by consuming industry, are as follows:

Lump silica. *Silica flux.* Massive quartz, quartzite, sandstone and unconsolidated sands are used for flux in smelting base-metal ores where iron and basic oxides are slagged as silicates. Because free silica is the active slagging agent, the free silica content should be as high as possible. Minor amounts of impurities such as iron and alumina are tolerable. Lump silica used as a flux is usually minus one-plus 5/16 inch in size.

Silicon and silicon alloys. Lump quartz, quartzite and well-cemented sandstones are used in the manufacture of silicon, ferrosilicon and other silicon alloys. Lump silica ¾ to 5 inches in size, obtained by crushing quartzite or indurated sandstone, is used in the manufacture of ferrosilicon. Chemical specifications are: silica, 98.0 per cent, alumina (Al_2O_3), less than 1.0 per cent; iron (Fe_2O_3) plus alumina, not over 1.5 per cent; lime and magnesia, each less than 0.2 per cent. Phosphorus and arsenic should be absent.

Silica brick. Quartz and quartzite crushed to minus 8 mesh are used in the manufacture of silica brick for high-temperature refractory furnaces. Chemical specifications for this use are: silica, 96 to 98 per cent;

Table 2. Canada, silica production and trade, 1960, 1965, 1970, 1975-77

	Production	Imports		Exports	Consumption
Year	Quartz and Silica Sand	Silica Sand	Silex or Crystallized Quartz	Quartzite	Quartz and Silica Sand
			(tonnes)		
1960	2 050 932	653 922	9 544	11 845	2 458 170
1965	2 207 802	757 300	4 630	101 181	2 863 498
1970	2 937 498	1 176 199	186	58 917	3 979 305
1975	2 491 715	1 044 160	1 550	39 977	3 510 818
1976	2 520 476	1 337 138	863	47 944	. .
1977^p	2 362 000	1 101 180	1 219	56 297	. .

Source: Statistics Canada.
^{p} Preliminary; . . Not available.

alumina, less than 0.1 per cent; combined iron and alumina, less than 1.5 per cent. Other impurities such as lime and magnesia should be low.

Aggregate. Crushed and sized quartz and quartzite are used as exposed aggregate in precast concrete panels for buildings, slabs, sidewalks and for other decorative landscape purposes.

Other uses. Lump quartz and quartzite are used as lining material in ball and tube mills and as lining and packing for acid towers. In some instances, naturally occurring quartzitic pebbles are used as grinding media in the crushing of various non-metallic ores.

Silica sand. *Glass.* High-purity, natural-occurring sand or material produced by crushing quartzite or sandstone is used in the manufacture of glass. Minor amounts of certain elements are particularly objectionable because they act as powerful colourants. For example, chromium should not exceed six parts per million and cobalt not over two parts per million. Glass fibre optics technology, developing over the last few years, promises to become important in communications and could displace copper cable in several applications.

Silicon carbide. Silica sand used in the manufacture of silicon carbide should have a silica content of at least 99 per cent. Iron and alumina should be less than 0.1 per cent each; lime, magnesia and phosphorus should be absent. Sand should be plus 100 mesh, with the bulk of it plus 35 mesh.

Hydraulic fracturing. Sand is used in the hydraulic fracturing of oil-bearing strata to increase open-pore spaces, thus increasing the productivity of the oil well. Sand utilized for this purpose should be clean and dry, have a high compressive strength, be free of acid-consuming constituents and have a grain size between 20 and 35 mesh. Grains should be well-rounded to facilitate placement in the formation in order to provide maximum permeability.

Foundry sand. Naturally occurring sand or material produced by crushing friable sandstone is used in the foundry industry for moulding. For foundry purposes, the chemical composition of the sand is not as important as its physical properties. For the end-use, a highly refractory sand, having rounded grains with frosted or pitted surfaces, is preferred. Grain sizes vary between 20 and 200 mesh. Rounded grains are preferable to angular fragments because they allow maximum permeability of the mould and maximum escape of gas during casting.

Sodium silicate. Sand for the manufacture of sodium silicate should contain more than 99 per cent silica, less than 0.25 per cent alumina, less than 0.05 per cent lime and magnesia combined, and less than 0.03 per cent iron (Fe_2O_3). All sand should be between 20 and 100 mesh.

Other minor uses. Coarsely ground, closely sized quartz, quartzite, sandstone and sand are used as abrasive grit in sandblasting and in the manufacture of sandpaper. Various grades of sand are used as filtering media in water-treatment plants; silica is also required in portland cement manufacture if there is insufficient silica in the limestone or in other raw material used in the process.

Silica flour. Silica flour, produced by fine-grinding quartzite, sandstone and lump quartz, is used in the ceramics industry for enamel frits and pottery flint. For use in enamels, the silica flour must be over 97.5 per cent silica, with alumina (Al_2O_3) less than 0.5 per cent and iron (Fe_2O_3) less than 0.2 per cent. Silica flour is also used as an inert filler in rubber and asbestos cement products, as an extender in paints and as an abrasive agent in soaps and scouring pads. It is used

Table 3. Canada, available data on consumption of silica, by industries, 1975-76

	1975	1976
	(tonnes)	
Smelter flux[1]	1 496 195	1 328 677
Glass manufacture (incl. glass fibre)	684 210	740 427
Foundry sand	677 886	577 455[e]
Refractory brick	239 352	280 090[e]
Artificial abrasives	137 632	143 895[e]
Fertilizer stock, poultry feed	14 939	54 351[e]
Chemicals	16 977	19 966
Concrete products	11 168	12 064
Gypsum products	8 659	8 932
Other[2]	223 800	209 019
Total	3 510 818	3 373 876

Source: Statistics Canada for source data. Compiled by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
[1]Producers' shipments of quartz and silica for flux purposes. [2]Includes asbestos products, ceramic products, soaps, frits and enamels, paper and paper products, roofing, silica brick and other minor uses.
[e]Estimated.

increasingly in autoclave-cured concrete products such as building blocks and panels, approximately 45 pounds of silica flour being used for each 100 pounds of portland cement consumed.

Quartz crystal. Quartz crystal with desirable piezoelectric properties is used in radio-frequency control, radar and other electronic devices. Natural crystal for this purpose must be perfectly transparent and free from all impurities and flaws. The individual crystals should weigh 100 grams or more and measure at least two inches in length and one inch or more in diameter. Much of the world's crystal requirement has been met in the past by natural crystal from Brazil; however, natural crystal is rapidly being replaced by excellent-quality, synthetic crystal grown in the laboratory from quartz "seed". Artificial quartz crystals are oriented for the cutter prior to delivery. The high degree of purity permits product yields at least four times that of natural quartz crystal.

There is no production of quartz crystal in Canada, and only a small demand exists. Domestic requirements are met mainly by imports, chiefly from the United States, with minor amounts from Brazil. Quartz Crystals Mines Limited, Toronto produced minor amounts from an occurrence near Lyndhurst, Ontario, several years ago.

A quartz-crystal stockpile of 165.8 tonnes was sold by the Canadian Government during 1974.

Outlook

Silica output and consumption in Canada has been stagnant for seven years, reflecting declines in base metals production and hence silica flux requirement, a decline in silicon and ferrosilicon production, and, periodically, such constraints as strikes in consuming industries and technical problems at silica plants. However, glass requirements, especially more recently glass fibre for thermal insulation, and other higher-value silica end-uses have advanced strongly. Because metallurgical flux constitutes more than half of silica production, a recovery in the base metal industries would be necessary to boost silica tonnages significantly, but it should be noted that silica flux is valued at less than $2.00 a tonne.

Compared with 1970, total Canadian silica production is down 20 per cent in tonnage but has almost tripled in value by virtue of the change in product mix. Imports of high-quality grades during this period have declined slightly.

The outlook is for a continuation of the growth in output of higher quality silica products through increases in domestic and United States demand and erosion of imports. Montreal Silica Mines Ltd.'s new facility, and expanded capacity under study at Indusmin's operations, are the most immediate developments that will give effect to this outlook. Recovery in the nonferrous smelting industry and other elements of the economy will provide growth over the medium term, and in the long term the new fibre optics technology is likely to become an important consumer of silica, although significant improvements in mineral processing technology would be required for any of the current Canadian operations to meet the stringent raw material specifications.

Tariffs

Canada

Item No.		(¢ per ton)
29500-1	Ganister and sand	free
29700-1	Silex or crystallized quartz, ground or unground	free

United States

Item No.		
513.11	Sand containing 95% or more silica, and not more than 0.6% of oxide of iron	25
513.14	Sand, other	free
514.91	Quartzite, whether or not manufactured	free
523.11	Silica, not specially provided for	free

Sources: For Canada, The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1978), T.C. Publication 843.

Silicon, Ferrosilicon, Silicon Carbide and Fused Alumina

A. BOUCHARD

Throughout the world, silicon reserves are almost inexhaustible, since silicon, which usually occurs as oxide, constitutes nearly 25 per cent of the earth's crust. Silica deposits (SiO_2) are the main commercial sources of silicon. Silica is reduced by coke in electric furnaces to give silicon metal, and with addition of iron scrap, ferrosilicon. Energy is the most important cost factor in the production of silicon metal, silicon alloys and silicon carbide. For this reason, plants producing silicon metal or its alloys are most frequently situated in regions where electrical energy is plentiful and available at a competitive price. The second important factor in the location of these industries is the proximity to markets. The ideal location would be a region with cheap and plentiful electricity where a well-developed iron and steel industry already exists or is within easy access via large commercial routes.

Canada

For reasons given in the preceding paragraph, i.e., a good supply of electricity at competitive prices and proximity to markets either local or foreign by large commercial routes, Canada, and in particular, Quebec, is an important producer and exporter of silicon metal and ferrosilicon. Canada has three ferrosilicon producers amongst which two also produce silicon metal. Union Carbide Canada Limited produces ferrosilicon at Chicoutimi and ferrosilicon as well as silicon metal at Beauharnois. S.K.W. Electro-Metallurgy Canada Ltd. produces ferrosilicon and silicon metal at Bécancour, and Chromasco Ltd. produces ferrosilicon at Beauharnois. There are other ferrosilicon producers, but their product has a lower silicon content (less than 20 per cent) and is a byproduct of fused alumina.

In 1977 the Union Carbide Canada Limited plant at Chicoutimi operated at full capacity, while at Beauharnois only one of the four furnaces was in operation for the major part of the year, thus reducing production to less than 60 per cent of the total capacity of the company. This low rate of production would be due to market conditions, to the appearance of a new Canadian producer and to repairs carried out at the Beauharnois plant. In the course of the year, in addition to installing an anti-pollution system and bringing it on stream, Chromasco increased its production capacity to about 27 000 tonnes* of ferrosilicon through addition of a new electric furnace. Towards the end of 1977 the Ferroalloys Association of the United States announced its intention to submit a petition to the U.S. Treasury accusing the new Canadian producer, S.K.W. Electro-Metallurgy Canada Ltd. of dumping silicon metal and ferrosilicon on the American market. This action, if carried through, will take place during 1978. In 1977, Chromasco and SKW-Canada operated at full capacity.

Availability of energy is also the reason for Canada being an important bulk producer and exporter of synthetic abrasives; silicon carbide (SiC) and fused alumina (Al_2O_3). Producers of these abrasives are located in Quebec and Ontario. The Quebec-based companies are: Canadian Carborundum Company Limited (SiC), Shawinigan; Norton Company (SiC) and Electro Refractories & Abrasives Canada Ltd. (SiC) of Cap-de-la-Madeleine, and Unicorn Abrasives of Canada Ltd. (Al_2O_3) of Arvida. The Ontario-based companies are Canadian Carborundum Company, Limited (Al_2O_3), Norton Company (Al_2O_3 and SiC) and Usigena (Canada) Limited (Al_2O_3 and SiC), all of Niagara Falls, and The Exolon Company of Canada, Ltd. (Al_2O_3 and SiC) of Thorold. All Canadian production of synthetic abrasives is exported; principally to the United States where the bulk material is crushed, screened and classified. A small part of the refined material is reimported for production of bonded abrasives such as abrasive wheels and for production of coated abrasives such as sandpaper. For 1976, the most recent year for which statistics are available, Canadian deliveries of crude silicon carbide amounted to 99 195 tonnes for a value of $32 116 000 or about $324 a tonne and crude fused alumina amounted to 141 695 tonnes for a value of $39 966 000 or about $282 a tonne. In the

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

same year, Canadian consumption of refined silicon carbide used in the manufacture of abrasive products was 1 061 tonnes for a value of $897 000, or about $845 a tonne, and that of refined fused alumina was 6 219 tonnes for a value of $2 703 000, or about $435 a tonne. The 1976 value of Canadian deliveries of abrasive wheels, cloths, paper and other abrasive products are respectively, $17 929 000, $9 957 000, $16 871 000 and $6 577 000.

World developments

A number of events relating to the silicon industry took place during 1977. In the United States, Tennessee Alloys, a division of International Minerals and Chemical Corporation opened a new plant at Bridgeport, Alabama. Allegheny Ludlum Steel Corp., which holds a 25 per cent interest in this plant, will consume a portion of the production equivalent to the

Table 1. Canadian exports and imports of ferrosilicon, silicon carbide and other ferroalloys[1], 1976 and 1977

	1976		1977^p	
	(tonnes)	(000 $)	(tonnes)	(000 $)
Exports				
Ferrosilicon				
United States	30 009	9 794	31 895	11 337
United Kingdom	3 406	1 239	2 605	730
West Germany	—	—	8 795	3 961
Dominican Republic	89	52	190	117
Jamaica	62	46	62	47
Angola	188	40	266	67
Japan	207	40	1 207	711
France	—	—	181	140
Other countries	259	113	290	115
Total	34 220	11 324	45 491	17 225
Silicon carbide, crude and grains				
United States	83 848	22 857	80 474	26 362
United Kingdom	1 872	587	453	146
Brazil	292	131	—	—
Japan	255	101	4 876	1 920
Greece	148	54	214	83
Total	86 415	23 730	86 017	28 511
Ferroalloys, nes				
United States	1 012	1 836	1 363	1 598
Argentina	80	318	53	460
Japan	51	227	23	4
India	34	203	—	—
Netherlands	36	179	—	—
United Kingdom	357	106	308	47
Peru	—	—	31	8
New Zealand	—	—	18	2
Belgium and Luxembourg	—	—	3	2
Other countries	161	26	—	—
Total	1 731	2 895	1 799	2 121
Imports				
Ferrosilicon				
United States	7 992	5 533	7 768	4 583
South Africa	—	—	230	186
Norway	615	473	418	302
France	276	225	425	285
Sweden	209	164	192	162
Chili	37	12	50	16
Italy	—	—	23	17
Other countries	1 257	714	. .	1
Total	10 386	7 121	9 106	5 552

Table 1. (concl'd)

	1976		1977^p	
	(tonnes)	(000 $)	(tonnes)	(000 $)
Silicomanganese, including silico-spiegel				
United States	4 950	2 583	2 691	1 569
Norway	3 588	2 013	1 139	431
Yugoslavia	—	—	1 000	348
Chili	41	18	3	9
Other countries	3 443	1 636	—	—
Total	12 022	6 250	4 833	2 357
Ferroalloys, nes				
Dominican Republic	12 578	19 305	637	1 082
Greece	4 491	6 066	9 237	11 449
United States	3 229	3 788	3 108	3 582
Brazil	361	1 863	1 797	3 721
South Africa	3 210	1 477	961	477
France	884	952	1 199	1 395
Peru	—	—	75	364
Netherlands	—	—	5	43
Other countries	222	260	96	44
Total	24 972	33 711	17 115	22 157

Source: Statistics Canada.
[1]Other important ferroalloys are discussed in their respective sections.
nes Not elsewhere specified; — Nil; ^{p}Preliminary; . . Not available.

Table 2. Ferrosilicon production and trade, 1975

	Production	Imports	Exports
	(tonnes, gross weight)		
Austria	. .	10 969	. .
Belgium and Luxembourg	. .	27 134	. .
Canada	. .	26 352	28 813
France	. .	. .	47 709
West Germany	. .	116 066	15 935
India	33 459	. .	996
Italy	. .	34 329	. .
Japan	. .	33 905	26 163
Norway	. .	. .	222 187
Spain	. .	. .	4 625
Sweden	52 102	20 176	29 300
United Kingdom	. .	116 610	1 199
United States	475 806	89 171	34 883
U.S.S.R.	. .	. .	154 492
Yugoslavia	. .	. .	32 741

Sources: *Metal Bulletin,* Handbook 1977; for Canada, Statistics Canada; for United States, Bureau of Mines, *Minerals Yearbook,* 1976 Preprint.
. . Not available.

percentage of its interests. This new plant, with a capacity of 68 000 tonnes of 50 per cent ferrosilicon, will replace the old Tennessee Alloys plant at Bridgeport. Toward the end of the year, Ohio Ferro-Alloys Corp. announced that its ferrosilicon plant at Brilliant, Ohio, where operations had stopped for several months, would definitely close its doors because of strong competition from imports. The most important producer of silicon carbide in Western Europe, Elektroschmelzwerk Kempten GmbH of West Germany, a subsidiary of another West German company, the Wacker-Chemie GmbH, will construct a plant with a capacity of 22 700 tonnes a year of silicon carbide at Hennepin, Illinois. This plant will be operated by the Wacker Chemical Company of New York, the American subsidiary of Wacker-Chemie GmbH. Production is expected to commence during the first part of 1979. The Carborundum Company has commenced an important expansion project at its plant at Niagara Falls, N.Y. The first stage, which was carried out during 1977, consisted of increasing the annual production capacity of 14 500 tonnes of silicon carbide. The total expansion will probably be two to three times that already available. Carborundum has also announced its intention to construct a new plant for production of silicon carbide at Ottawa, Illinois.

Table 3. Canadian ferrosilicon production[1], 1967-76

	Ferrous Industry[2]	Other Industries[3]	Total
		(tonnes)	
1967	38 453	11 439	49 892
1968	71 175	9 428	80 603
1969	70 386	11 430	81 816
1970	78 338	8 087	86 425
1971	65 303	13 068	78 371
1972	69 878	12 065	81 943
1973	68 172	21 048	89 220
1974	66 940	28 163	95 103
1975	41 443	15 922	57 365
1976	70 755	14 813	85 568

Source: Statistics Canada.
[1]Producers shipments; [2]Estimated by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa; [3]Principally abrasives industry.

Uses

Silicon metal is used principally in the aluminium industry where it serves to increase fluidity, corrosion resistance, thermal and electrical conductivity, and reduces specific density and thermal expansion. These alloys are used to make aluminium castings and consume most of the silicon metal since they contain on the average, around 6 per cent silicon. More than half of the cast aluminium tonnage is used in the transport industry. The second important use of silicon metal is in the fabrication of silicones, which are used in oil production, synthetic rubber, resin, electric motor insulation, etc. More than 200 varieties of products based on silicone are presently being made. Silicon metal is also used in silicon bronze, in aluminium alloy which serves as a coating for steel sheets, in semiconductor electronic devices and in silicon nitride (Si_3N_4), but these are of secondary importance.

The iron and steel industry is, in fact, the only important user of ferrosilicons and other alloys of silicon such as silicocalcium, silicochrome and silicomanganese. Ferrosilicon is used principally as a deoxidant in the fabrication of steel. It is also used as a graphite promoter in carbon steels, to improve the electrical properties of electric steels and as a reducing agent in other alloys. In terms of silicon content, pig iron, which contains between 15 and 25 kilograms (kg) of silicon a tonne of pig iron, consumes about one-half of the ferrosilicon produced. Carbon steel contains on the average 0.755 kg of silicon a tonne of steel and consumes about one-third of the ferrosilicon production. Stainless steels and electric steels, which contain an average of 10 and 20 kg of silicon respectively per tonne of steel, share the remainder of the ferrosilicon consumption with the other types of steel. Ferrosilicon is also used in the production of other metals by the silicothermic process, but this represents only small tonnages.

Table 4. Canadian consumption, exports and imports of ferrosilicon, 1968-77

	Consumption	Exports		Imports	
	(tonnes)	(tonnes)	($)	(tonnes)	($)
1968	46 674	42 833	5 424 665	8 905	2 615 000
1969	46 028	43 998	5 257 000	8 210	2 010 000
1970	50 556	45 345	8 284 000	9 477	2 386 000
1971	39 571	48 217	8 699 000	9 417	2 679 000
1972	42 270	48 349	7 188 000	8 676	2 663 000
1973	55 811	46 574	6 836 000	12 920	4 135 000
1974	59 661	46 002	9 316 000	10 560	5 293 000
1975	54 904	28 813	8 024 000	26 353	15 665 000
1976	61 734	34 219	11 324 000	10 384	7 120 000
1977[p]	. .	45 491	17 225 000	9 106	5 552 000

Source: Statistics Canada.
[p]Preliminary; . . Not available.

Table 5. Canadian manufacturers' shipments of crude silicon carbide, 1967-76

	(tonnes)	($)
1967	87 283	13 564 000
1968	99 042	16 192 000
1969	98 156	15 815 000
1970	104 113	17 653 000
1971	93 879	15 798 000
1972	104 152	17 880 000
1973	107 303	18 985 000
1974	102 299	21 908 000
1975	89 346	24 597 000
1976	99 195	32 116 000

Source: Statistics Canada.

Table 6. Canadian exports of silicon carbide, 1967-77

	(tonnes)	($)
1967	79 076	11 461 930
1968	93 372	14 690 146
1969	93 895	14 974 000
1970	96 159	15 976 000
1971	85 148	13 593 000
1972	94 700	15 051 000
1973	92 984	15 666 000
1974	91 819	15 887 000
1975	78 611^r	17 440 000^r
1976	86 395	23 724 000
1977^p	86 017	28 511 000

Source: Statistics Canada.
^{p}Preliminary; ^{r}Revised.

Silicon carbide and fused alumina are used principally in the fabrication of abrasive products such as abrasive wheels, cloths, papers, stones and abrasive powders. Silicon carbide can be used as a deoxidant in the fabrication of pig iron. These materials (but especially silicon carbide) are also used in refractory products.

Outlook

The future consumption of silicon metal is estimated at about 60 per cent by the aluminum industry and about 35 per cent by the chemical industry (silicone). The demand for silicon metal is thus very closely related to that of aluminum and silicones. At the present time, aluminum demand in the transport industry (main consumer of aluminum-silicon alloys) is very strong, and the future appears very promising. The silicone industry has developed very rapidly over the last 10 years, and this will probably continue in coming years.

The demand for different ferrosilicons and silicon alloys depends directly on the iron and steel industry, and thus follows the demand profile of this industry.

The demand for synthetic abrasives, which includes silicon carbide and fused alumina, follows that of industry in general, since these products are used by most of them.

Table 7. Canadian manufacturers' shipments of crude fused alumina, 1967-76

	(tonnes)	($)
1967	137 268	17 620 000
1968	128 078	17 337 000
1969	149 071	19 993 000
1970	131 364	18 088 000
1971	112 935	16 159 000
1972	140 540	21 198 000
1973	155 342	25 986 000
1974	174 108	34 679 000
1975	110 736	26 162 000
1976	141 695	39 966 000

Source: Statistics Canada.

Table 8. Canadian exports of crude fused alumina, 1968-77

	(tonnes)	($)
1968	143 896	19 385 395
1969	167 791	24 508 870
1970	152 572	23 234 285
1971	122 652	19 096 000
1972	160 147	24 967 000
1973	171 324	29 923 000
1974	184 182	33 839 000
1975	127 658^r	26 650 000^r
1976	154 002	38 844 000
1977^p	154 293	43 087 000

Source: Statistics Canada.
^{p}Preliminary; ^{r}Revised.

Prices

Prices published by "Metals Week" in December 1976 and 1977

		1976	1977
		(U.S.¢)	(U.S.¢)
Ferrosilicon, per pound silicon content, fob shipping point, freight equalized to nearest main producer, carload lots, lump bulk			
High-purity	(%Si) 75	37.0	37.0
Regular	50	34.5	33.5
Silicon metal, per pound of silicon content, fob shipping point, freight equalized to nearest main producer, carload lots, lump bulk			
(% max. Fe)	(% max. Ca)		
0.35	0.07	46.4-49.4	46.4
0.50	0.07	44.7-47.7	44.7
1.00	0.07	42.5-45.5	42.5

Prices published by "American Metal Market" in December 1976 and 1977

	1976	1977
	(U.S.¢)	(U.S.¢)
SMZ alloy: 60-65% Si, 5-7% Mn and 5-6% Zr, 15 tonne lots, per pound of alloy	35.5	35.5
Calcium-silicon and Calsibar alloy, fob producer, 15-tonne lots, per pound	57.0	57.0
	1976	1977
	($U.S.)	($U.S.)
Electric furnaces silvery pig iron, fob Keobuck, Iowa		
16% Si, per tonne	190.00	190.00
22% Si, per gross tonne	212.00	212.00

Prices published by "Industrial Minerals" in December 1976 and 1977

(long tons fob main European ports)

	1976	1977
	(£)	(£)
Aluminium oxide, 8-220 mesh, fob		
Brown, min. 94% Al_2O_3	250-260	250-260
White, min. 99.5% Al_2O_3	300-320	300-320
Silicon carbide 8-220 mesh, fob		
Black, about 99% SiC	450-460	450-460
Green, over 99.5% SiC	570-580	570-580

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
		(¢)	(¢)	(¢)	(¢)
37502-1	Silicomanganese — alloys of manganese and iron containing more than 1%, by weight, of silicon per pound or fraction thereof, on the manganese contained therein	free	0.75	1.75	free
37503-1	Ferrosilicon being an alloy of iron and silicon containing 8% or more, by weight, of silicon and less than 60%, per pound or fraction thereof, on the silicon contained therein	free	free	1.75	free
37504-1	Ferrosilicon being an alloy of iron and silicon containing 60% or more, by weight, of silicon and less than 90%, per pound or fraction thereof, on the silicon contained therein	free	0.75	2.75	free
37505-1	Ferrosilicon being an alloy of iron and silicon containing 90% or more, by weight, of silicon per pound or fraction thereof, on the silicon contained therein	free	2.50	5.50	free
92804-1	Silicon metal	10%	15%	25%	10%
92815-4	Silicon sulphide	10%	15%	25%	10%

United States

Item No.		General
		(¢)
519.21	Crude silicon carbide	free
519.37	Silicon carbide in grains, ground, pulverized or refined, per pound	0.40
607.50	Ferrosilicon, per pound Si content, containing over 8% but not over 60% by weight of silicon	free
607.51	Ferrosilicon, per pound Si content, containing over 60% but not over 80% by weight of silicon	0.50
607.52	Ferrosilicon, per pound Si content, containing over 80% but not over 90% by weight of silicon	1.00
607.53	Ferrosilicon, per pound Si content, containing over 90% by weight of silicon	2.00
607.55	Ferrosilicon chromium	10%
607.57	Ferrosilicon manganese, per pound Mn content	0.46 +3.5%

Japan

Item No.		General	G.A.T.T.	Preferential
		(%)	(%)	(%)
28-04	Silicon — single crystal	16	12	free
	— other	12	6	free
28-56	Silicon carbide	12	6	free
68-06	Abrasive paper	12	-	free
73-02	Ferrosilicon	8	4	free
	Silicochrome	-	4	-

European Economic Community

Item No.		Autonomous	Conventional
		(%)	(%)
28.13	Silicon dioxide	10	6.4
73.02	Ferrosilicon	10	10 (limit 20 000 tonnes)
	Ferrosilicomanganese	6	5.5 (limit 50 000 tonnes)
	Ferrosilicochrome	7	7

Sources: For Canada, the Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States, Annotated (1978), TC Publication 843. For Japan, Customs Tariff Schedules of Japan, 1977, Japanese Tariff Association. For E.E.C. Official Journal of European Communities, Vol. 20, No. L289, 1977.

Silver

J.G. GEORGE

Canada's primary production* of silver in 1977, estimated at 1 329 922 kilograms (kg), was 48 485 kg more than in 1976. The increase was mainly attributable to greater byproduct output by several base-metal mines, particularly the Sturgeon Lake Joint Venture property of Falconbridge Copper Limited in northwestern Ontario and Cyprus Anvil Mining Corporation at Faro in the Yukon Territory. Greater output by the silver-cobalt mines in the Cobalt area of northern Ontario also contributed to the higher Canadian production. Declines in output in New Brunswick, Quebec and Newfoundland were more than offset by increases in the other silver-producing provinces and the territories. Ontario was again, by far, the leading silver-producing province, primarily because of the substantial byproduct silver produced at the Kidd Creek base-metal mine of Texasgulf Canada Ltd. The Value of Canadian silver production was $210.2 million, or $33.1 million more than in 1976 because of greater output and higher prices.

Canada's exports of silver in ores and concentrates and as refined metal totalled 1 618 663 kg in 1977, or 235 460 kg more than in 1976. The United States continued to be the major market, accounting for over 87 per cent of Canada's total exports. Canadian imports of refined silver declined from 59 136 kg in 1976 to 33 005 kg in 1977. Most of the imports came from the United States, with minor quantities from the United Kingdom and West Germany.

Canadian consumption of silver for both industrial and coinage uses in 1977 was estimated at 298 724 kg, compared with 551 212 kg in 1976. These figures are published by Statistics Canada, but are incomplete. Completion in 1976 of the minting of Olympic silver coins was the main reason for the decrease.

*As reported by Statistics Canada and defined in Footnote 1 of Table 1.

Domestic production

Mine production. The principal source of silver was again base-metal ores, and byproduct silver derived from this source accounted for about 80 per cent of total production. About 19 per cent was derived from mines whose primary product is silver. The remaining one per cent came from silver-cobalt ores mined in the Cobalt district of northern Ontario or as byproduct recovery from lode and placer gold ores. The principal mine producers of silver in Canada are listed in Table 5, while the map, "Silver Producers in Canada 1977", on page 23 shows their approximate locations. The four largest mine producers in declining order of output were: Texasgulf Canada Ltd. in Ontario, Brunswick Mining and Smelting Corporation Limited in New Brunswick, Mattabi Mines Limited in northwestern Ontario, and Cominco Ltd. (Sullivan mine) in south-eastern British Columbia. Base-metal ores mined by these four producers in 1977 accounted for almost 42 per cent of total Canadian silver production. The largest producer in the Cobalt area of northern Ontario was Teck Corporation Limited, Silverfields Division, with output of 27 366 kg of silver contained in ores and concentrates produced.

Metal production. Production of refined silver in 1977 at the six Canadian primary silver refineries was as follows:

	Production[1] Refined Silver	Annual Rated Capacity[2]
	(kilograms)	
Brunswick Mining and Smelting Corporation Limited, Smelting Division, Belledune, New Brunswick	107 556[3]	108 900

	Production[1] Refined Silver	Annual Rated Capacity[2]
	(kilograms)	
Canadian Copper Refiners Limited, Montreal East, Quebec	683 841	777 600
Royal Canadian Mint, Ottawa, Ontario	5 545[4]	217 705[5]
Canadian Smelting & Refining (1974) Limited, Cobalt, Ontario	36 422	186 600[7]
Inco Metals Company, Copper Cliff, Ontario	66 872[6]	. .
Cominco Ltd., Trail, British Columbia	292 248	373 200
Total	1 192 484	1 664 005

Sources: Reports of companies and of the Royal Canadian Mint.

[1]Production of refined silver includes silver produced or derived from domestic and imported ores and concentrates as well as secondary materials. The largest portion of such refined silver was, however, derived from domestic ores and concentrates. [2]As of December 31, 1977. [3]Some 99 531 kg of the refined silver bullion produced by Brunswick Mining and Smelting Corporation Limited was shipped to Canadian Copper Refiners Limited (CCR) at Montreal East, Quebec, for further refining; and the 683 841 kg of silver reported as production for CCR includes all of that silver bullion produced by Brunswick and refined by CCR in 1977. [4]Silver derived from refining gold bullion. [5]Total capacity for producing refined gold and silver, of which about 10 per cent is silver. [6]Silver delivered to markets. [7]Up to this amount, depending on nature of materials processed.
. . Not available.

Canadian Copper Refiners Limited at Montreal East, Quebec, was again Canada's largest producer of refined silver, recovering it mainly from the treatment of anode and blister copper and the further refining of lower-grade silver bullion. The silver refinery of Cominco Ltd. at Trail, British Columbia, was the second-largest producer, recovering byproduct silver in the processing of its own, as well as custom, lead and zinc ores and concentrates. Other producers of refined silver were Inco Metals Company at Copper Cliff, Ontario (from nickel-copper concentrates); and the Royal Canadian Mint at Ottawa, Ontario (from gold bullion). At Cobalt, Ontario, Canadian Smelting & Refining (1974) Limited recovered silver in processing silver-cobalt ores and concentrates produced in that area of northern Ontario. At Belledune, New Brunswick, Brunswick Mining and Smelting Corporation Limited, Smelting Division, recovered byproduct silver from lead concentrates treated in a blast furnance.

At its electronic materials plants at Trail, B.C., Cominco Ltd. also produced high-purity silver metal

Table 1. Canada, silver production, trade and consumption, 1976 and 1977

	1976		1977^p	
	(kilograms)	($)	(kilograms)	($)
Production[1]				
By province and territories				
Ontario	507 521	70 131 231	513 207	81 113 000
British Columbia	239 538	33 100 313	247 055	39 046 000
New Brunswick	192 336	26 577 757	173 184	27 370 000
Yukon Territory	92 698	12 809 321	132 283	20 908 000
Northwest Territories	103 795	14 342 774	129 173	20 414 000
Quebec	91 554	12 651 369	81 802	12 928 000
Manitoba	25 599	3 537 387	28 615	4 521 000
Newfoundland	17 994	2 486 483	14 650	2 316 000
Saskatchewan	10 401	1 437 213	9 953	1 573 000
Alberta	1	64	—	—
Total	1 281 437	177 073 912	1 329 922	210 189 000

Table 1. (concl'd)

	1976		1977p	
	(kilograms)	($)	(kilograms)	($)
By source[2]				
Base-metal ores	1 247 910	172 436 222	1 288 329	208 341 000
Gold ores	10 736	1 483 463	6 500	1 026 000
Silver-cobalt ores	22 678	3 138 631	35 000	807 000
Placer gold ores	113	15 596	93	15 000
Total	1 281 437	177 073 912	1 329 922	210 189 000
Refined silver[3]	1 023 928	. .	987 510	. .
Exports				
In ores and concentrates				
United States	272 358	32 594 000	318 487	43 260 000
Japan	96 839	12 683 000	102 929	13 703 000
West Germany	28 066	2 103 000	21 162	1 786 000
Belgium and Luxembourg	24 701	1 794 000	17 418	1 139 000
United Kingdom	2 205	178 000	9 750	759 000
South Korea	—	—	1 491	182 000
Others	11 621	695 000	5 568	481 000
Total	435 790	50 047 000	476 805	61 310 000
Refined metal				
United States	939 192	129 060 000	1 092 579	169 374 000
United Kingdom	1 158	119 000	43 813	6 903 000
Trinidad-Tobago	3 160	441 000	2 752	434 000
Jamaica	2 512	368 000	2 179	364 000
Dominican Republic	550	34 000	300	22 000
Others	841	114 000	235	39 000
Total	947 413	130 136 000	1 141 858	177 136 000
Imports				
Refined metal				
United States	49 300	6 862 000	31 748	4 664 000
United Kingdom	2 726	415 000	894	156 000
West Germany	57	13 000	153	27 000
Others	7 053	757 000	209	16 000
Total	59 136	8 047 000	33 004	4 863 000
Consumption, by use				
Sterling	51 840	. .	55 824	. .
Silver alloys	79 494	. .	75 951	. .
Wire rod	2 489	. .	3 354	. .
Others[4]	417 389	. .	163 595e	. .
Total	551 212	. .	298 724e	. .

Sources: Statistics Canada; Royal Canadian Mint Annual Report, 1976.
[1]Includes recoverable silver in: ores, concentrates and matte shipped for export; crude gold bullion produced; blister and anode copper produced at Canadian smelters; and base and other bullion produced from domestic ores. [2]Estimated by Energy, Mines and Resources. [3]From all sources, domestic and imported materials of both primary and secondary origin. [4]Includes sheet, partial coinage and miscellaneous uses.
pPreliminary; — Nil; . . Not available; eEstimated.

Table 2. Canada, silver production, trade and consumption, 1968-77

	Production		Exports			Imports, Refined Silver	Consumption[3], Refined Silver
	All Forms[1]	Refined[2] Silver	In Ores and Concentrates	Refined Silver	Total		
			(kilograms)				
1968	1 400 054	1 076 533	668 788	874 150	1 542 938	437 335	422 956
1969	1 353 964	1 203 036	680 638	1 078 013	1 758 651	596 216	178 754
1970	1 376 354	955 668	678 676	752 689	1 431 365	134 347	187 679
1971	1 431 493	638 996	795 085	566 126	1 361 211	22 482	219 309
1972	1 393 193	714 361	688 749	616 641	1 305 390	37 874	262 025
1973	1 477 029	802 751	814 975	712 422	1 527 397	272 304	529 090
1974	1 331 531	852 755	602 892	663 709	1 266 601	909 655	598 114
1975	1 234 642	931 540[r]	471 410	713 566	1 184 976	420 078	642 089
1976	1 281 437	1 023 928	435 790	947 413	1 383 203	59 136	551 212
1977[p]	1 329 922	987 510	476 805	1 141 858	1 618 663	33 004	298 724[e]

Sources: Statistics Canada; Royal Canadian Mint Annual Report, 1976.
[1]Includes recoverable silver in: ores, concentrates and matte shipped for export; crude gold bullion produced; blister and anode copper produced at Canadian smelters; base and other bullion produced from domestic ores. [2]From all sources, domestic and imported materials of both primary and secondary origin. [3]In some cases includes only partial consumption for coinage.
[p]Preliminary; [e]Estimated; [r]Revised.

with metallic impurities totalling one part per million or less. This specialty metal product was manufactured mainly for applications in the electronics industry such as solder preforms, brazing preforms and lead wire.

World production, consumption and economic factors

New production of silver in the non-communist world in 1977, as estimated by Handy & Harman*, was 7 713.66 tonnes**, or 40.43 tonnes more than in 1976. In 1977 non-communist world consumption for both industrial and coinage uses was 12 783.53 tonnes, compared with 13 349.61 tonnes in 1976. The gap between new production and consumption was 5 069.87 tonnes, or considerably less than in 1976.

Consumption of silver for coinage in the non-communist world in 1977 was 684.28 tonnes, or about 248.83 tonnes less than in 1976.

Based on preliminary figures, Canada was the world's third largest mine producer of silver in 1977 being surpassed by Mexico and the U.S.S.R.

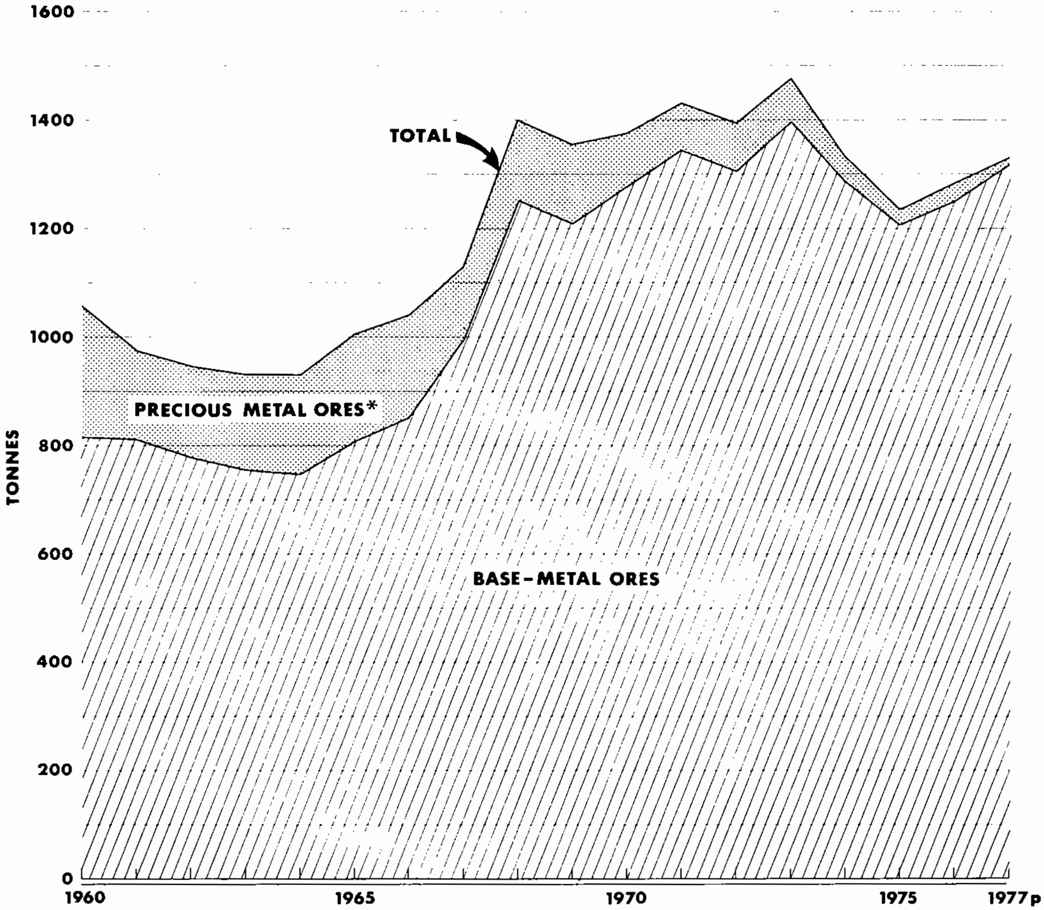
According to the United States Bureau of Mines, new production of silver in the United States increased somewhat, from 1 067.7 tonnes in 1976 to 1 173.6 tonnes in 1977. In the United States, the world's largest silver consumer, consumption for industrial uses and coinage was 4 785.1 tonnes and 2.7 tonnes, respectively, in 1977. The large deficit in requirements was again met by imports, demonetized coinage, secondary silver derived from discarded jewellery, silverware and films; liquidation of speculative holdings, and withdrawals from industrial and United States Treasury stocks. Most of the requirements for United States coinage were again obtained from Treasury stocks (balance in Bureau of the Mint only) which, in the form of bullion, coin bars and coinage metal fund silver, declined slightly during 1977 from 1 235.0 to 1 224.2 tonnes. The General Services Administration (GSA) did not sell any silver from the nation's strategic and critical materials stockpile. The new goal of zero established late in 1976 by the U.S. Federal Preparedness Agency (FPA) remained unchanged at year end 1977, when the stockpile contained 4 338.9 tonnes, all of which is surplus to the goal. None of this surplus silver, however, may be disposed of without congressional approval. A number of bills have been introduced in Congress since the beginning of 1977 to dispose of silver.

Public Law PL-93-127, enacted October 18, 1973, authorized the Secretary of the United States Treasury to mint 45 million silver-clad alloy coins commemorating the Bicentennial of the American Revolution in 1976. The coins contain 40 per cent silver and were minted in 25c, 50c and $1.00 denominations. Although the U.S. Bureau of the Mint struck the last of these Bicentennial coins late in 1976, it issued a total of 658

*_The Silver Market 1977_, compiled by Handy & Harman, a leading United States refiner and fabricator of precious metals and a large consumer of silver.

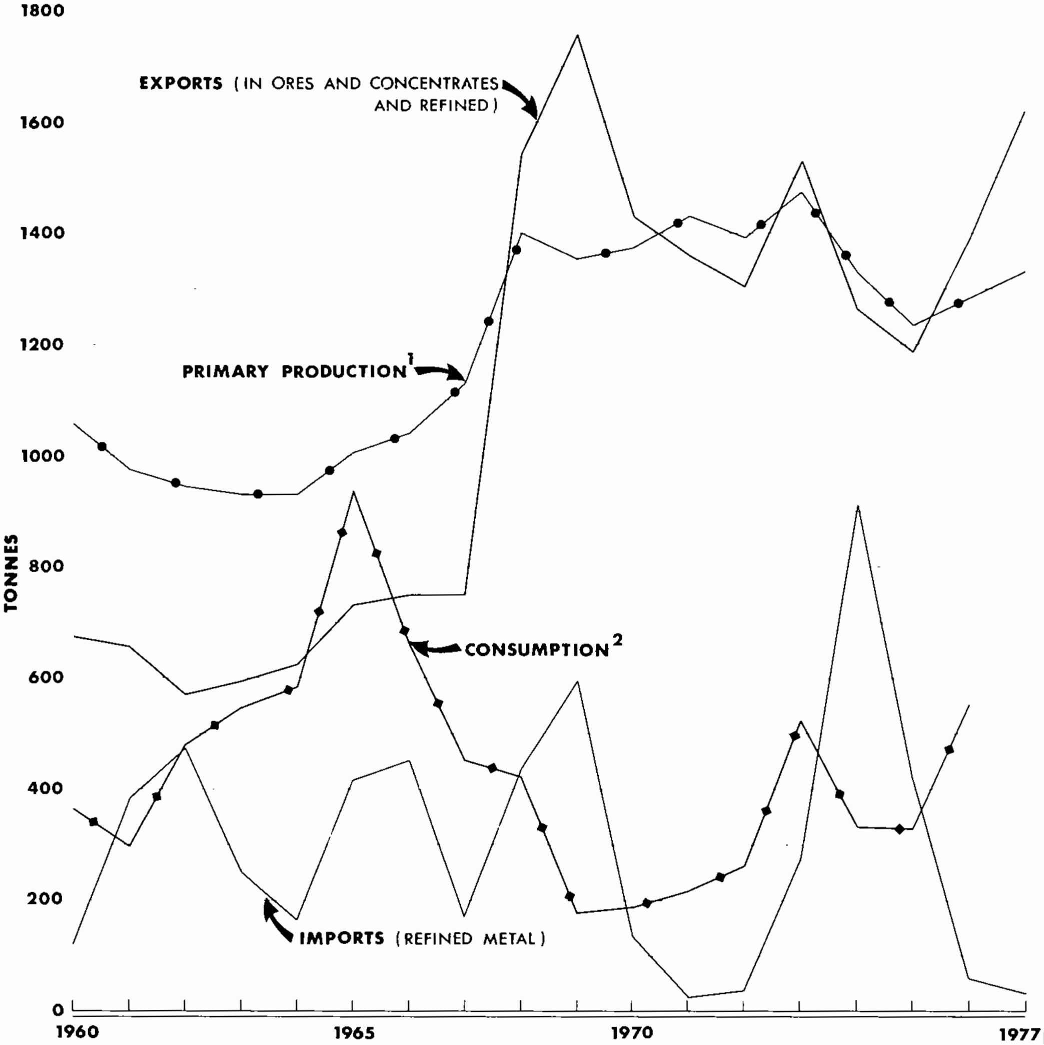
**The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

PRIMARY SILVER PRODUCTION in CANADA by SOURCE



* Mostly from Silver-cobalt ores; some from Gold ores.
p Preliminary

SILVER IN CANADA*



* As reported by Statistics Canada
1 As defined in Footnote 1 to Table 1.
2 Statistics for years 1960 to 1973 inclusive include consumption for coinage; 1974 to 1976 statistics include only partial consumption for coinage.
p Preliminary

Table 3. World mine production of silver, 1976 and 1977

	1976[1,p]		1977[2,p]	
	(troy ounces)	(kilograms)	(troy ounces)	(kilograms)
Mexico	42 640 000	1 326 000	47 000 000	1 461 900
U.S.S.R.	44 000 000[e,3]	1 368 600[e,3]	45 000 000	1 399 700
Canada	41 199 000	1 281 400	42 800 000	1 331 200
United States	34 328 000	1 067 700	38 200 000	1 188 200
Peru	35 579 000	1 106 600	38 100 000	1 185 000
Australia	25 097 000	780 600	25 200 000	783 800
Poland	8 000 000[e]	248 800[e]	9 700 000	301 700
Japan	9 299 000	289 200	9 600 000	298 600
Chile	7 287 000	226 700	6 400 000	199 100
Bolivia	5 091 000	158 300	5 900 000	183 500
Sweden	4 700 000[e]	146 200[e]	5 100 000	158 600
Yugoslavia	4 631 000	144 000	4 700 000	146 200
Republic of South Africa	2 821 000	87 800	3 100 000	96 400
France	2 806 000	87 300	2 900 000	90 200
Honduras	2 964 000	92 200	2 800 000	87 100
Zaire	2 472 000	76 900	2 700 000	84 000
Morocco	2 300 000[e]	71 500[e]	2 100 000	65 300
South Korea	1 838 000	57 200	2 100 000	65 300
Argentina	1 750 000	54 400	1 800 000	56 000
Spain	3 107 000	96 600	1 600 000	49 800
Philippines	1 481 000	46 100	1 600 000	49 800
North Korea	1 600 000[e]	49 800[e]	1 600 000	49 800
East Germany (German Democratic Republic)	1 600 000[e]	49 800[e]	1 500 000	46 700
Dominican Republic	907 000	28 200	1 400 000	43 500
Romania	1 300 000[e]	40 400[e]	1 300 000	40 400
Czechoslovakia	1 300 000[e]	40 400[e]	1 300 000	40 400
South-West Africa	1 400 000[e,4]	43 500[e,4]	1 300 000	40 400
Italy	1 543 000[3]	48 000[3]	1 300 000	40 400
Greece	477 000[3]	14 800[3]	1 200 000	37 300
Papua and New Guinea	1 841 000	57 300	1 200 000	37 300
West Germany	1 060 000[e]	33 000[e]	1 100 000	34 200
Bulgaria	1 000 000[e]	31 100[e]	1 000 000	31 100
Other countries	7 793 000	242 400	6 840 000	212 800
Total	305 211 000	9 493 100	319 440 000	9 935 700

Sources: Statistics Canada for 1976 and 1977 Canadian figures; United States Department of the Interior, Preprint from the 1976 Bureau of Mines *Minerals Yearbook* for all other 1976 statistics; and The Silver Institute of Washington, D.C., U.S.A. for all other 1977 statistics.

[1]Recoverable content of ores and concentrates produced unless otherwise noted. [2]Figures represent mine production of silver reported on an accountable basis. [3]Smelter and/or refinery production. [4]Data include estimate of silver production from Klein Aub Koper Maatskappy Ltd. copper mines.

[p]Preliminary; [e]Estimated.

206 of the coins in 1977. The total of 45 million coins required 251.0 tonnes (8.07 million ounces*) of silver.

Mexico and Peru held informal discussions about mid 1974 and again in the early part of 1975 concerning the establishment of the "Association of Silver Exporting Countries" to help maintain "equitable" price levels for the metal in world markets. Mexico and Peru together accounted for almost 27 per cent of world mine production of silver in 1977 and are significant exporters. Up to late 1977 no firm action had been taken on the proposed association.

Industrial consumption of silver in West Germany in 1977 amounted to about 1 008 tonnes which represents a decline of some 17 per cent from 1976. Apparently no German silver-containing coins were melted down in 1977 compared to approximately 871 tonnes of silver derived from the demonitization of retired 5-Deutschemark coins in 1976.

In Japan, exploration was most active in the famed "Kuroko" sulphide district in Akita Prefecture. In 1977 the Ezuri deposit of Dowa Mining Co. Ltd. was proven to contain 3 000 000 tonnes assaying 0.8 per cent copper, 3.3 per cent lead, 10.1 per cent zinc, and 205.71 grams (g) of silver and 0.69g of gold a tonne. Japan's industrial consumption of silver continued to expand and was about 1 950 tonnes in 1977, making this country the non-communist world's second largest user of silver. All major categories appear to have registered increases. No silver was used in coinage.

Since August 26, 1976 all sales abroad of Indian silver have been handled by the country's State Trading Corporation (STC). About mid July 1977 the Indian government announced that it had abolished its latest fixed floor price of $U.S. 4.60 an ounce applicable to exports. In its place STC set up a flexible floor price linked to international silver price fluctuations. In 1977 Indian exports of silver were about 840 to 900 tonnes, down considerably from the 1 400 to 1 550 tonnes exported in 1976. There is virtually no mine production of silver in India and whatever silver is exported comes from above-ground supplies accumulated over the centuries. Varying estimates have placed these Indian stocks at between 30 000 and 150 000 tonnes. Although very large, the Indian holdings are extremely widespread. Given sufficient price inducement, India will continue to be an important source of silver.

In the United States the new Coeur mine near Wallace, in northern Idaho, completed its first full year of operations in 1977 and produced concentrates containing 8 per cent more silver than its projected capacity of 68 400 kg a year. Development work at the Coeur mine added a significant tonnage to existing ore reserves. ASARCO Incorporated leases the Coeur mine from Coeur d'Alene Mines Corporation and operates it as a joint venture with Callahan Mining Corporation and Day Mines, Inc. It is the fourth-largest silver mine in the United States.

The DeLamar silver-gold property near DeLamar, Idaho began operations early in April 1977. The mine is an open-pit operation and the concentrator's designed capacity is 1 550 tonnes of ore a day. The mine is expected to produce about 78 tonnes (2.5 million ounces) of silver and 0.5 tonne (16 500 ounces) of gold a year and has an economic life estimated to be at least 20 years. Average grade of two of the property's mining areas is 144.0 g of silver a tonne (4.2 ounces a short ton*) and 1.58 g of gold a tonne (0.046 ounce a short ton). Based on these grades, total reserves are estimated at some 11 000 000 tonnes. The property is a joint venture in which Earth Resources Company of Dallas, Texas has a 52½ per cent interest, with the remaining interest held by Superior Oil Company and Canadian Superior Mining Company Limited. The property is managed by Earth Resources.

The largest silver mine in the United States resumed operations March 14, 1977 after being strike-bound since March 11, 1976. The Sunshine mine is at Kellogg, Idaho, in the Coeur d'Alene district of Idaho and in 1977 produced 117 873 kg of silver compared with 34 141 kg in 1976. Historically the mine has provided about 18 per cent of total U.S. mine production of silver. It had been jointly owned by Sunshine Mining Company (57.14 per cent), Hecla Mining Company (33.25 per cent), and Silver Dollar Mining Company, Limited (9.61 per cent). However, by late 1977 Great Western United Corporation (GWU) had acquired controlling interest in and management of the Sunshine mine. GWU is controlled by the Hunt brothers, W. Herbert and N. Bunker, heirs of the late Texas oil magnate, H.L. Hunt. The Hunt brothers are believed by many to be the largest private holders of silver in the world. By April 1979 it is expected that the Sunshine property will be reorganized with GWU's successor, Hunt International Resources Corporation of Dallas, Texas.

The new Amarillo copper refinery of ASARCO Incorporated, at Amarillo, Texas, completed its first full year of operations in 1977. Included in this facility is a precious-metals plant which has a silver refinery with an annual capacity of 1 866.2 tonnes (60 million ounces) of refined silver. Interruptions at the Amarillo copper plant and other ASARCO copper and lead plants, because of a 10-week strike, adversely affected silver output at Amarillo in 1977 when it totalled only 1 041.4 tonnes. The Amarillo silver refinery is one of the world's largest and most modern silver refineries, and ASARCO is the world's largest silver refining company.

The El Mochita Mine in the Republic of Honduras, 100 per cent owned by Rosario Resources Corporation

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*In this review the term "ounce" refers to the troy ounce, and the conversion factor used for converting ounces to grams (g) is 1 troy ounce = 31.1034 g.

*2 000 pounds avoirdupois.

(a United States company with headquarters in New York City), produced 325 900 tonnes of ore in 1977, from which were derived lead and zinc concentrates and dore bullion, all of which contained a total of 87 665.6 kg of silver. An expansion program is under way at the Mochita mine and concentrator to produce and process lower grade silver — base-metal ore on a larger scale to help overcome the effects of high treatment charges involved in smelting the lead and zinc concentrates.

Mexico, which has some lead-zinc mines that operate primarily for the extraction of silver, increased its mine output of the metal by 136 900 kg in 1977 but expects a somewhat smaller increase in 1978. Mexico surpassed the U.S.S.R. as the world's leading mine producer of silver in 1977 and is expected to continue its expansion of silver mining during the 1978-81 period, thus widening the gap between itself and other major producing countries. In the four-year period 1977-81, Mexican output is expected to expand by 35.5 per cent, reaching 1 980 tonnes of silver in 1981. The U.S.S.R., which will still be the world's second largest producer of silver in 1981, will only see its output grow by 31 tonnes a year to 1 524 tonnes in 1981.

In 1977 the Las Torres mining complex, consisting of four silver-gold underground mines at Guanajuato in central Mexico, completed its first full year of operations. Ore produced at the four mines is fed to a centrally located 2 000-tonne-a-day concentrator. In 1977 the concentrator processed 474 654 tonnes of ore from which were derived concentrates containing 151 481.5 kg (4 870 243 ounces) of silver and 1 045.0 kg (33 598 ounces) of gold. When full production is reached by all four mines, up to 248 800 kg (8 000 000 ounces) of silver and 1 555 kg(50 000 ounces) of gold could be produced annually. The Las Torres mining complex is now one of the world's largest silver-gold producers. Exploration for new ore in the Guanajuato area is continuing in order to maintain reserves and extend the life of the Las Torres mines. The company operating the project is Compania Minera Las Torres, S.A., which is owned 30 per cent by Lacana Mining Corporation, 37 per cent by Compania Fresnillo, S.A., and 33 per cent by Industrias Penoles, S.A. Penoles is one of Mexico's largest private mining enterprises. Lacana Mining Corporation is a Canadian company with headquarters in Toronto.

In 1977 the Mexican government completed the minting of a new short-run issue of 100-peso silver coins which sold out quickly. The issue comprised about 3 million pieces. With each coin containing 20 g of silver, the total content approximated 60 tonnes. The new coin was part of an effort to stem inflation and force Mexicans to save more and buy less. The Mexican government could strike another issue of silver coins in 1978.

The zinc-lead-copper-silver property at Woodlawn in New South Wales, Australia, will begin production in the second half of 1978 at a rate of 2 725 tonnes of ore a day. Ore reserves are estimated at 9 million tonnes grading 9.1 per cent zinc, 3.5 per cent lead, 1.8 per cent copper and 62.72 g of silver a tonne. The $U.S. 88 million mine-mill facility is a three-way joint venture among St. Joe Minerals Corporation, Phelps Dodge Corporation and Australian Mining & Smelting Ltd., each having a one-third interest.

Exploration work continued at the McArthur River lead-zinc-silver deposit in the Northern Territory of Australia. Construction of an adit into the deposit was completed in 1976 and a supplemental drilling program is now under way. Operation of a 50-tonne-a-day concentrator pilot plant began in June 1977 as part of the overall feasibility study to determine the economic viability of the project. This sizeable well-bedded stratiform deposit is reported to contain 200 million tonnes grading 9.5 per cent zinc, 4.1 per cent lead and 40.43g of silver a tonne. The property is owned by M-I-M Holdings Ltd. in which ASARCO Incorporated holds a 48.9 per cent interest.

Silver prices in 1977 were characterized by less violent fluctuations than those experienced during the previous five years. The 66¢ spread between the 1977 high and low New York silver prices of $4.96 and $4.30 an ounce was the smallest since 1971. Again, the fluctuations were mainly in response to speculative activity which in turn was fostered by economic uncertainties, monetary disturbances and inflationary pressures. Average prices for 1977 were significantly lower than those for 1976 and no new highs were established. A generally rising trend prevailed in the first quarter, but from April through August the trend was downward. The third phase from September through December 1977 was characterized by a recovery and strengthening of prices. The pattern of silver price behavior in 1977 must be attributed more to speculator reaction to the flow of events than to periodic changes in the level of commercial demand, especially since non-communist world consumption of silver declined over 4 per cent in 1977 compared with 1976. Other important factors behind silver price movements in 1977 were a decline in world visible stocks, the continuing shortfall between consumption and new production, and silver's use as a hedge against the monetary uncertainties and worldwide inflation that continued in 1977. Other factors influencing the silver price pattern were a small increase in world mine production, the deterring effect of the possible release by the United States government of a part of its strategic stockpile of 4 338.9 tonnes of silver, all of which is surplus to the zero goal.

Looking at silver's price performance since 1966, the year before the United States Treasury Department brought to an end the sale of Treasury silver at the statutory $U.S. 1.2929 an ounce, provides some insight. In the 11-year period ending 1977, the average annual New York silver price rose from about $1.29 to $4.62 (in current dollars), an increase of over 350 per cent or almost 32 per cent annually (or over 12 per cent annually compounded). Adjusting for inflation, using the U.S. Wholesale Price Index, which almost doubled from the base year 1966, the silver price, in real terms, increased an average of 16 per cent a year.

On the New York Commodity Exchange, Inc. (Comex), one of the principal futures markets for contracts in silver in the United States, the volume of trading in silver in 1977 amounted to 3 540 047 contracts of 5 000 ounces each, compared with 3 741 868 contracts of 5 000 ounces each in 1976. The volume of silver traded on the Chicago Board of Trade in 1977 amounted to 2 257 059 contracts of 5 000 ounces each, compared with 2 011 041 contracts of the same size traded in 1976. The volume of silver traded on the MidAmerica Commodity Exchange at Chicago in 1977 was 366 585 contracts of 1 000 ounces each, compared with 447 513 contracts of the same size in 1976. Silver traded on the London Metal Exchange was 459 440 000 ounces in 1977, compared with 6111 110 000 ounces in 1976.

New York Commodity Exchange, Inc. silver stocks at the end of 1977 were 69.28 million ounces compared with 54.76 million ounces at December 31, 1976. Chicago Board of Trade silver in storage, at the end of 1977 and registered for delivery against futures' contracts, was 62.22 million ounces, compared with 61.04 million ounces at December 31, 1976. Both figures for

Table 4. Non-communist world consumption of silver, 1976 and 1977

	1976		1977^{p}	
	(troy ounces)	(kilograms)	(troy ounces)	(kilograms)
Industrial uses				
United States	170 500 000	5 303 100	161 000 000	5 007 700
Japan	60 700 000	1 888 000	62 700 000	1 950 200
West Germany	40 800 000	1 269 000	33 800 000	1 051 300
United Kingdom	28 000 000	870 900	32 000 000	995 300
Italy	28 000 000	870 900	27 000 000	839 800
France	19 400 000	603 400	20 600 000	640 700
India	18 000 000	559 900	17 600 000	547 400
Canada	6 300 000	195 900	6 500 000	202 200
Mexico	6 500 000	202 200	5 600 000	174 200
Other countries	21 000 000	653 200	22 200 000	690 500
Total industrial uses	399 200 000	12 416 500	389 000 000	12 099 300
Coinage				
France	5 800 000	180 400	6 900 000	214 600
Austria	5 500 000	171 100	6 000 000	186 600
West Germany	1 800 000	56 000	2 400 000	74 700
United States	1 300 000	40 400	400 000	12 400
Canada	11 900 000	370 100	300 000	9 300
Other countries	3 700 000	115 100	6 000 000	186 600
Total coinage	30 000 000	933 100	22 000 000	684 200
Total consumption	429 200 000	13 349 600	411 000 000	12 783 500

Source: Handy & Harman, *The Silver Market 1977.*
^{p}Preliminary.

the Chicago Exchange are exclusive of some additional silver that may have been in stocks at such times, but not registered for future delivery. London Metal Exchange stocks at the end of 1977 were 19.21 million ounces compared with 28.50 million ounces at the end of 1976. United States industrial stocks* on December 31, 1977 were reported to be some 35.94 million ounces compared with about 30.63 million ounces at the end of 1976.

Outlook

Canada's primary production** of silver in 1978 is forecast to be 1 250 tonnes and is expected to range between 1 200 and 1 450 tonnes annually from 1979 to 1983.

There was a small decline in world demand for silver in 1977 resulting partly from a slowdown in economic activity in the European countries. Other contributing factors were the general decline in demand for the metal in the more direct consumer use sectors, namely: silverware, jewellery and commemoratives, even in the United States in spite of the continued economic recovery in that country. With overall business activity now picking up in the world's economy, a small increase in silver consumption is expected in 1978. Also, the long-term demand for silver for industrial uses is expected to increase significantly.

Consumption will, nevertheless, continue to exceed primary production by a wide margin as mine output of silver is largely related to the production of the major base-metal ores. About 80 per cent of the world's mine output of silver is derived as a byproduct or coproduct in the mining of such ores and, accordingly, the supply of newly-mined silver will continue to depend more on the production of base-metal ores than on the demand for or price of silver. However, a significant increase in mine output of silver is expected over the next few years in Mexico where a substantial portion of that country's silver production is derived from mines whose primary product is silver.

Because of large world stocks and a sluggish demand for the major base-metals, cutbacks in production of these metals, initiated in 1974, continued in 1977 and are still persisting in some countries in 1978. These cutbacks resulted in reduced mine output of silver from such sources. In the short- or medium-term, however, there should be no real shortage of silver for industrial requirements. Sufficient quantities of secondary silver, speculative holdings, greater Indian exports and some hoarded silver coins will continue to find their way into the market. Because of better prices and the increasing emphasis being placed on recycling by both government and industry, greater quantities of secondary silver are reaching the market. One increasing source of secondary silver results from microfilms being used to record data from some much-larger X-ray negatives, thus making possible the immediate recycling of the silver used in the original films.

Among the "bullish" factors influencing the silver market are the big perennial, and now increasing, deficiency between new production and consumption, a projected increase in industrial demand should the western economies pick up steam, and a small decline in world visible stocks of silver that occurred in 1977. "Bearish" elements include the 4 338.9 tonnes of surplus silver in the United States government's strategic stockpile and the possibility of increasing exports from India. Depressing factors, insofar as mine output of silver is concerned, are the lower base-metal prices, high inflation, rising operating costs and — according to the industry — the onerous mineral taxes that continue to plague the metal mining industry. As a result of this adverse economic climate, some base-metal mines continue to operate below capacity. Exploration and development work have been curtailed. Such measures do not augur well for the future supply of silver. The profitability, as well as the ability of the metal mining industry to explore for and develop new or alternative sources of raw materials, has been impaired; and, even worse, the industry's ability to replace existing facilities and ore reserves is being restricted.

It is expected that silver prices will be erratic again in 1978, although displaying an upward trend. Again, the price fluctuations will not be entirely governed by the law of supply and demand but will continue to be affected by the whims and actions of the speculators. An ill omen is that the economic recovery in most industrialized countries is continuing at only a sluggish pace and worldwide inflation has not been brought under control. Excepting the Middle East, the world economy is still struggling to absorb the higher energy costs. In spite of these adverse economic conditions, the outlook for silver is bright. Because inflation and the depreciating value of paper currencies, the speculative demand for silver will continue. In the mid- and long-term, silver prices should move considerably upward, especially since higher "real" prices will be required to bring out the much needed secondary supplies.

Canadian developments

Atlantic Provinces. According to Statistics Canada, silver production in the Atlantic provinces was significantly lower in 1977 than in the previous year, mainly because of lower byproduct shipments by Brunswick Mining and Smelting Corporation Limited at its silver and base-metals property near Bathurst, New Brunswick. Because of a decline in zinc prices and a worldwide oversupply of the metal, Brunswick Mining reduced its capital and operating expenditures in 1977.

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*Refiner, fabricator and dealer stocks.
**As defined in the footnote to Table 1.

Expansion of the No. 12 mine to increase its mining capacity from 8 500 to 10 000 tonnes of ore a day has been deferred and will be rescheduled when justified by market conditions. Also, it was decided to temporarily complete the No. 3 shaft only to the 1 128-metre (m) level instead of the originally planned 1 370-m level. At the No. 6 mine, mining of the open-pit ore was completed and the underground mine was developed and stoping began. Production continued to decline at the zinc-lead-copper-silver mine at Buchans, Newfoundland, because of diminishing ore reserves. Despite an active exploration program, no deposits of economic importance were found. It is likely that mineable ore will be exhausted and operations terminated within the next two years. The property is a joint venture of ASARCO Incorporated and The Price Company Limited, with ASARCO managing the mining and milling operations.

Silver output declined in 1977 at the Little River silver and base-metals property of Heath Steele Mines Limited near Newcastle, N.B., because of the lower silver grade of the ore mined. An expansion program begun several years ago to increase ore production capacity from 2 725 to 3 630 tonnes a day was completed early in 1977. Mine output in 1978 will, however, be less than the new capacity as production was curtailed 12.5 per cent beginning January 1978 because of weak copper and zinc markets. Because the limited quantity of ore reserves and their distribution were such that it was not possible to continue to operate profitably, the zinc-lead-copper-silver mine of Nigadoo River Mines Limited, near Bathurst, N.B., was closed down in August 1977.

Quebec. Silver output in Quebec, derived mostly from base-metal ores, was somewhat lower in 1977 than in 1976, partly because of the closure in 1976 of four base-metal mines.

Because of the depression in demand and prices for zinc, Orchan Mines Limited considered suspending operations, about mid-1978, at its zinc-copper-silver property in the Matagami Lake area of northwestern Quebec. However, upon receipt of financial assistance from the Department of Natural Resources of the Quebec provincial government, it was decided to continue operations at a reduced rate. At the company's nearby Norita mine, a new "A" zone was discovered early in 1978 and its drill indicated size is 1.18 million tonnes with an average uncut and undiluted grade of 5.6 per cent zinc, 2.6 per cent copper, and 37.7 g of silver and 0.69 of gold a tonne.

Exploration and development work continued at the "Detour Project" of Selco Mining Corporation Limited and Pickands Mather & Co. of Cleveland, Ohio, in Brouillan township in northwestern Quebec. Three zones, A-1, A-2 and B, of copper-zinc-silver mineralization, have been located. Completion of an access ramp and lateral exploration work were done on the A-1 zone and sinking of a 5-compartment vertical shaft to a depth of 120 m was begun on the B zone to enable underground exploration to take place. Feasibility studies on the A-1 and B zones were scheduled for completion in 1978. Diamond drilling on the A-1 zone has indicated the presence of a near-surface deposit of 32.1 million tonnes with an average diluted grade of 0.39 per cent copper, 2.30 per cent zinc, 35.7 g of silver and 0.31 g of gold a tonne. Selco (in which Selection Trust Limited of London, England has a 94 per cent interest) and Pickands Mather are equal partners in the project, with it being managed by Selco.

Ontario. Ontario was again, by far, the leading silver-producing province or territory, with its output in 1977 accounting for almost 39 per cent of Canadian production. The leading producer was Texasgulf Canada Ltd., which recovered 278 687 kg (8.96 million ounces) in copper, lead and zinc concentrates at its Kidd Creek property, the largest single mine producer of silver in Canada, and probably the world.

The silver treatment plant and refinery of Canadian Smelting & Refining (1974) Limited (CSR), at Cobalt, Ontario, completed its first full year of operations at the end of 1977. The plant, designed especially to treat the arsenic-rich ores and concentrates produced by the Cobalt area mines, is a hydrometallurgical operation using an acid-wash cyanidation process. The plant can also treat similar-type concentrates, or silver-containing precipitates, residues or secondary materials, produced elsewhere. The major product is refined silver, with the annual capacity being up to 187 000 kg (6 million ounces) of silver, depending on the nature of the materials processed. Grade of the refined silver is 99.95+ per cent silver. Byproducts produced are precipitates, residues and other materials containing cobalt, nickel, copper, lead and antimony, as well as CSR brand arsenic trioxide grading 99.0+ per cent As_2O_3. One of these byproducts is 10 to 20 tonnes monthly of a lead bullion containing 0.7 per cent silver. The silver-cobalt ores and concentrates produced by the mines in the Cobalt area are all processed at the CSR plant.

In the Cobalt area of northern Ontario silver contained in ores and concentrates produced in 1977 was almost double that of 1976 because of output from the property of Canadaka Mines Limited. Its concentrator began tune-up operations late in January 1977 and reached operating capacity of 275 tonnes of ore (or 550 tonnes of mill tailings) a day in April of the same year.

A disastrous fire swept through a 1.5-km section of the town of Cobalt, Ontario on May 23, 1977 and destroyed an estimated $4 million in real estate. However, no damage was caused to the property or buildings of either Temiskaming Testing Laboratories or the silver refinery of Canadian Smelting and Refining (1974) Limited, both of which are located in the town of Cobalt. The properties of the three silver-producing mines in the area, namely Agnico-Eagle Mines Limited, Teck Corporation Limited and Canadaka Mines Limited, were also untouched by the fire since each of them are several kilometers from the town of Cobalt.

Table 5. Principal silver (mine) producers in Canada, 1977 and (1976)

Company and Location	Mill Capacity	Grade of Ore Milled: Silver	Copper	Lead	Zinc	Ore Milled	Silver Contained in Concentrates Produced	Remarks
	(tonnes of ore/day)	(grams/ tonne)	(%)	(%)	(%)	(tonnes)	(kilograms)	
Newfoundland								
ASARCO Incorporated, Buchans	1 150 (1 150)	106.97 (105.60)	0.99 (0.96)	6.12 (6.03)	10.76 (10.69)	174 179 (188 694)	15 509.2 (17 216.7)	Known ore reserves at end of 1977 will be exhausted in about two years at present rate of production.
Consolidated Rambler Mines Limited, Baie Verte	1 100 (1 100)	23.07 (21.74)	4.25 (3.68)	– (–)	– (–)	218 201 (187 284)	3 659.0 (3 461.1)	Improvements in mill planned for early 1978 which should increase metal recoveries and concentrate grade.
New Brunswick								
Brunswick Mining and Smelting Corporation Limited, Nos. 12 and 6 mines, Bathurst[1]	8 950 (8 950)	84.75 (86.32)	0.37 (0.38)	3.12 (2.87)	7.83 (7.18)	3 134 419 (2 247 211)	173 570.0 (113 550.6)[e]	Mining in No. 6 open pit completed and underground mining begun.
Heath Steele Mines Limited, Newcastle	3 650 (3 650)	68.23 (77.83)	1.22 (0.99)	1.53 (1.85)	3.90 (4.53)	1 150 338 (1 052 567)	41 453.4 (49 746.7)	No. 5 shaft came into operation June 1977.
Nigadoo River Mines Limited, Bathurst	1 050 (1 050)	85.71[e] (93.94)	0.145[e] (0.157)	2.39[e] (2.43)	2.54[e] (2.63)	118 640[e] (198 698)	8 227.0[e] (15 100.0)[e]	Operations suspended August 26, 1977.
Quebec								
Campbell Chibougamau Mines Ltd., Henderson, Cedar Bay and Merill Pit mines, Chibougamau	3 650 (3 650)	7.51 (8.64)	1.43 (1.62)	– (–)	– (–)	264 308 (132 996)	1 171.5 (652.0)	Mine development confined to opening of existing ore reserves.

Table 5. (cont'd)

Company and Location	Mill Capacity	Grade of Ore Milled: Silver	Copper	Lead	Zinc	Ore Milled	Silver Contained in Concentrates Produced	Remarks
	(tonnes of ore/day)	(grams/ tonne)	(%)	(%)	(%)	(tonnes)	(kilograms)	
Falconbridge Copper Limited, Lake Dufault Division, Millenbach mine and Norbec stockpile ore, Noranda	1 400 (1 400)	38.73 (41.49)	3.27 (3.09)	— (—)	3.74 (3.44)	389 967 (458 447)	11 504.7[e] (15 396.2)[e]	Preproduction development work continued at Corbet mine.
Falconbridge Copper Limited, Opemiska Division, Perry, Springer and Cooke mines, Chapais	2 900 (2 900)	13.71 (12.55)	2.04 (2.01)	— (—)	— (—)	926 917 (947 053)	10 673.7 (9 786.7)	Cooke mine began production July 1977.
Gaspé Copper Mines, Limited, Needle Mountain and Copper Mountain mines, Murdochville	30 400 (30 400)	. . (. .)	0.53 (0.53)	— (—)	— (—)	11 051 406 (11 139 321)	19 533.9 (22 730.5)	Exploration reactivated to supplement inventory of probable and proven ore.
Louvem Mining Company Inc., Louvicourt	900 (. .)	41.83 (56.23)	0.12 (. .)	0.16 (. .)	5.95 (5.99)	277 837 (258 534)	11 602.6 (12 447.6)[e]	
Lemoine Mines Limited, Chibougamau	350 (350)	100.80 (96.68)	4.67 (4.35)	— (—)	10.64 (10.03)	110 677 (88 237)	8 304.6 (7 295.0)	Exploration below 326-m level in 1978 expected to outline additional ore.
Madeleine Mines Ltd., Ste-Anne-des-Monts	2 250 (2 250)	— (. .)	— (1.007)	— (—)	— (—)	— (738 398)	— (4 576.4)	Late in 1976 company suspended operations for an indefinite period.
Mattagami Lake Mines Limited, Matagami	3 500 (3 500)	30.86 (31.89)	0.52 (0.55)	. . (0.10)	6.64 (7.3)	946 342 (1 112 156)	14 434.7 (16 010.7)	Continuing major exploration project involving 2 285-m ramp and associated diamond drilling.
Noranda Mines Limited, Horne Division, Horne mine, Noranda	— (1 900)	— (. .)	— (. .)	— (—)	— (—)	— (123 745)[2]	— (992.5)	Horne mine suspended operations July 1, 1976.

Quebec (cont'd)

Orchan Mines Limited, Matagami	1 900 (1 700)	31.89 (31.89)	0.54 (0.78)	— (—)	6.35 (6.74)	507 817 (424 259)	7 872.9[e] (6 685.6)[e]	Suspension of work on P.D. Division property will continue until metal markets improve.
Patino Mines (Quebec) Limited, Chibougamau	2 725 (2 550)	10.63 (10.29)	1.74 (1.72)	— (—)	— (—)	605 102 (516 356)	4 511.5 (3 581.9)	
Sullivan Mining Group Ltd., Stratford Centre Cupra Division	1 250 (1 250)	— (. .)	— (. .)	— (. .)	— (. .)	— (. .)	— (. .)	Operations suspended January 31, 1977.
D'Estrie Mining Company Ltd.		. . (. .)	. . (. .)	. . (. .)	. . (. .)	10 368 (. .)	709.6 (. .)	Operations suspended January 31, 1977.
Ontario								
Agnico-Eagle Mines Limited, Cobalt district	350 (350)	181.37 (200.23)	. . (. .)	— (—)	— (—)	40 245 (37 607)	6 183.7 (5 999.4)	Exploration work continuing at Beaver-Temiskaming property.
Canadaka Mines Limited, Cobalt district	275 (275)	120.68 (—)	. . (—)	— (—)	— (—)	91 001 (—)	9 904.5 (—)	Further underground drifting and crosscutting.
Falconbridge Copper Limited, Sturgeon Lake Joint Venture, Sturgeon Lake	1 100 (1 100)	206.40 (183.77)	3.46 (2.15)	1.26 (1.23)	10.44 (9.57)	383 882 (377 256)	71 114.1 (36 448.4)[e]	Recovery of metals increased by selective mining, blending and improved ore beneficiation procedures.
Falconbridge Nickel Mines Limited, Ontario mines, Sudbury district	11 200 (12 700)	. . (. .)	. . (. .)	— (—)	— (—)	2 599 318 (2 920 552)	. . (. .)	Hardy Pit and Longvack South mines closed in 1977 due to exhaustion of ore reserves.
Inco Limited, Sudbury and Shebandowan, Ont., and Thompson, Man.	73 950 (77 950)	. . (. .)	. . (. .)	— (—)	— (—)	17 611 159 (17 962 258)	66 872.5[3] (37 013.1)[3]	In 1977 company began to gradually reduce ore production.
Mattabi Mines Limited, Sturgeon Lake	2 700 (2 700)	121.71 (121.03)	1.01 (1.23)	0.84 (0.76)	8.40 (8.13)	938 427 (966 797)	90 575.0 (82 245.2)[e]	Metallurgical recovery of metals improved in 1977.
Noranda Mines Limited, Geco Division, Manitouwadge	4 550 (4 550)	41.83 (44.23)	1.94 (1.69)	0.11 (0.12)	2.62 (2.55)	1 591 673 (1 529 780)	52 845.9 (52 826.7)	Capital expenditures limited to cost saving mining equipment.

Table 5. (cont'd)

Company and Location	Mill Capacity	Grade of Ore Milled: Silver	Copper	Lead	Zinc	Ore Milled	Silver Contained in Concentrates Produced	Remarks
	(tonnes of ore/day)	(grams/ tonne)	(%)	(%)	(%)	(tonnes)	(kilograms)	
Selco Mining Corporation Limited, South Bay Division, Uchi Lake area	450 (450)	76.78 (79.88)	1.68 (1.73)	. . (. .)	9.87 (10.38)	164 792 (163 482)	8 419.5 (10 036.2)[e]	Shaft deepened by 97 m.
Teck Corporation Limited, Silverfields Division, Cobalt district	250 (250)	356.57 (246.85)	0.6 (0.5)	— (—)	— (—)	76 628 (69 989)	27 365.8 (17 388.1)	Plans further surface and underground exploration work.
Texasgulf Canada Ltd., Kidd Creek mine, Timmins	8 165 (9 050)	104.0 (119.71)	1.84 (1.74)	0.22 (. .)	7.26 (8.05)	3 299 033 (3 242 278)	278 690.7[e] (323 942.7)	Open pit ceased operation and all ore now comes from underground.
Union Minière Explorations and Mining Corporation Limited, Thierry mine, Pickle Lake area	3 650 (3 650)	8.23 (7.54)	1.26 (1.14)	— (—)	— (—)	875 810 (230 608)	4 550.5 (1 177.6)	Operating below capacity because of depressed copper market.
Willroy Mines Limited, Manitouwadge Division, Manitouwadge	1 450 (1 450)	73.03 (54.51)	0.95 (0.56)	0.14 (0.17)	4.06 (3.67)	57 442 (311 430)	2 097.5 (11 948.7)	Operations suspended March 17, 1977.
Manitoba-Saskatchewan								
Hudson Bay Mining and Smelting Co., Limited, Flin Flon and Snow Lake districts	7 700 (7 700)	20.57 (20.57)	2.2 (2.3)	0.2 (0.2)	2.8 (2.7)	1 652 526 (1 417 617)	23 217.2 (21 679.4)	Began construction of new 3 450 tonne-a-day concentrator at Snow Lake.
Inco Limited, Thompson, Man.		(included with this company's listing for Ontario)						
Sherritt Gordon Mines Limited, Fox mine, Lynn Lake	2 600 (2 600)	. . (. .)	1.46 (1.560)	— (—)	1.93 (1.681)	807 687 (755 122)	5 360.2[e] (6 325.5)[e]	Pillar recovery supplied 58% of total mine output in 1977
Ruttan mine, Ruttan	9 050 (9 050)	. . (. .)	1.127 (1.083)	— (—)	1.946 (2.143)	2 051 351 (2 413 867)	12 523.0[e] (16 321.5)[e]	Plans underground development program down to 1 400 level.

British Columbia								
Bethlehem Copper Corporation,	18 150	. .	0.43	—	—	5 554 884	7 150.0	Building molybdenum circuit
Highland Valley	(18 150)	(. .)	(0.444)	(—)	(—)	(6 763 873)	(4 942.3)	which expected to be in operation by August 1978.
Brenda Mines Ltd.,	21 750	. .	0.19	—	—	9 634 483	8 018.0	
Peachland	(21 750)	(. .)	(0.167)	(—)	(—)	(10 047 615)	(7 891.5)	
Cominco Ltd., Sullivan mine,	9 075	47.6	. .	3.8	3.8	2 198 840	90 188.6[e]	Plans further mechanization of
Kimberley	(9 075)	(45.94)	(. .)	(4.0)	(3.95)	(2 124 892)	(84 701.3)	mining methods.
Dankoe Mines Ltd.,	150	353.14	. .	. .	. .	31 984	9 160.3	
Keremeos	(150)	(. .)	(. .)	(. .)	(. .)	(. .)	(7 896.0)[e]	
Dusty Mac Mines Ltd.,	ore	—	—	—	—	—	—	Operations suspended June 1976.
Keremeos	custom milled	(146.40)	(. .)	(. .)	(. .)	(53 517)	(5 824.8)	
Gibraltar Mines Ltd.,	36 300	. .	0.38	—	—	12 765 211	. .	Plans to commence development
McLeese Lake, Cariboo district	(36 300)	(. .)	(0.45)	(—)	(—)	(7 672 336)	(. .)	of Gibraltar East Stage 2.
Granby Mining Corporation, Granisle mine,								
Babine Lake	14 300	2.06	0.444	—	—	4 474 144	5 983.9	Metallurgical recovery improved.
	(12 700)	(2.06)	(0.42)	(—)	(—)	(4 008 242)	(4 880.9)	
Phoenix Copper Division,	2 600	5.08	0.386	—	—	833 829	1 767.3	Ore supplied from low grade
Greenwood	(2 600)	(6.17)	(0.50)	(—)	(—)	(965 850)	(3 261.4)	stockpiles.
Lornex Mining Corporation Ltd.,	43 550	. .	0.481	—	—	15 480 725	19 210.0	Plans limited percussion drilling.
Highland Valley	(34 450)	(. .)	(0.511)	(—)	(—)	(15 436 973)	(15 585.3)	
Newmont Mines Limited,	6 800	. .	1.31	—	—	1 333 143	10 881.0	Operations suspended June 30,
Granduc mine, Stewart	(6 800)	(. .)	(1.26)	(—)	(—)	(1 315 912)	(10 649.2)	1978.
Similkameen Division,	19 150	0.642	0.373	—	—	7 134 400	4 354.0	New pits to begin production in
Princeton	(19 150)	(. .)	(0.42)	(—)	(—)	(6 355 736)	(4 578.4)	1981.
Northair Mines Ltd.,	250	126.51	. .	1.54	2.03	92 166	10 130.7[e]	Major development program
Alta Lake	(250)	(111.77)[e]	(. .)	(0.86)[e]	(1.81)[e]	(47 553)	(3 662.4)	underway on the 853-m elevation adit level.

Table 5. (cont'd)

Company and Location	Mill Capacity	Grade of Ore Milled: Silver	Grade of Ore Milled: Copper	Grade of Ore Milled: Lead	Grade of Ore Milled: Zinc	Ore Milled	Silver Contained in Concentrates Produced	Remarks
	(tonnes of ore/day)	(grams/ tonne)	(%)	(%)	(%)	(tonnes)	(kilograms)	
British Columbia (cont'd)								
Silvana Mines Inc., Silmonac mine, Slocan district (formerly listed as Kam-Kotia Mines Limited, Silmonac mine)	100 (100)	594.0 (457.71)	. . (. .)	7.15 (5.3)	6.04 (4.86)	15 877 (16 694)	10 106.1 (7 408.8)	Major development and exploration program scheduled for 1978.
Teck Corporation Limited, Beaverdell mine, Beaverdell	100 (100)	353.14 (336.34)	. . (. .)	0.36 (0.43)	0.41 (0.54)	33 977 (34 448)	12 030.6 (11 583.6)	Operations to continue on a salvage basis.
Utah Mines Ltd., Island Copper mine, Coal Harbour, Vancouver Island	34 450 (34 450)	. . (. .)	0.42 (0.47)	— (—)	— (—)	13 110 000 (12 246 994)	9 700.0 (9 642.1)	
Wesfrob Mines Limited, Tasu Harbour, Queen Charlotte Islands	4 650 (4 650)	. . (. .)	. . (. .)	— (—)	— (—)	. . (. .)	1 546.3 (2 870.5)	Switch from open-pit to underground mining was completed in 1977.
Western Mines Limited, Buttle Lake, Vancouver Island	700 (700)	147.08 (169.37)	1.14 (1.19)	1.34 (1.42)	7.58 (7.73)	269 069 (269 294)	34 910.3 (41 972.6)[e]	Mine exploration and development work being reduced.
Yukon Territory								
Cyprus Anvil Mining Corporation, Faro	9 050 (9 050)	22.5 (16.46)	0.17 (. .)	2.7 (2.66)	4.9 (5.48)	3 116 035 (1 519 880)	49 090.6 (21 264.6)[e]	New and larger mining equipment placed into service in second quarter of 1977.
United Keno Hill Mines Limited, Elsa	450 (450)	1 216.79 (1 216.79)	. . (. .)	4.57 (4.02)	1.12 (1.17)	82 995 (68 506)	87 003.0 (74 305.9)[e]	Reactivating cyanide plant.

Yukon Territory (cont'd)

Whitehorse Copper Mines Ltd., Whitehorse	2 250 (2 250)	9.60 (. .)	1.65 (1.69)	— (—)	— (—)	817 790 (726 506)	7 765.7 (7 500.9)	Continuing limited exploration and diamond drilling.
Northwest Territories								
Echo Bay Mines Ltd., Port Radium	100 (100)	2 142.8 (. .)	0.9 (. .)	. . (. .)	. . (. .)	31 089 (35 731)	67 467.7 (57 759.2)	Plans exploration and development work on new levels.
Nanisivik Mines Ltd., Strathcona Sound, Baffin Island	1 350 (1 350)	50.0 (. .)	. . (. .)	1.98 (2.9)	13.27 (14.5)	546 000 (70 760)	27 000.0 (. .)	
Terra Mining and Exploration Limited, Silver Bear mine, Camsell River area	200 (200)	1 242.0 (1 491.41)	0.29 (. .)	. . (. .)	. . (. .)	26 334 (41 812)	32 020.0 (59 127.6)	New uranium-silver orebody discovered 300 m north of Silver Bear mine.
Norex mine, Camsell River area	ore custom milled	1 949.0 (—)	0.19 (—)	1.4 (—)	0.6 (—)	7 174 (—)	13 890.0 (—)	Mine brought into production in 1977.

Sources: Company reports and technical press.
[1]All statistical data, including mill capacity, represent combined results for No. 12 and 6 mines and mills. [2]Figure is exclusive of 382 220 tonnes of silver-containing copper slag processed in the Horne concentrator in 1976. [3]Silver delivered to markets.
[e]Estimated; — Nil; . . Not available.

Table 6. Prospective silver-producing mines in Canada

Company and Location	Year Production Expected	Planned Mill or Mine Capacity	Indicated Ore Reserves	Average Grade of Deposit				Remarks
				Silver	Copper	Lead	Zinc	
		(tonnes ore/day)	(tonnes)	(grams/ tonne)	%	%	%	
Quebec								
Noranda Mines Limited, Magusi property, northwestern Quebec	. .	1 350	1 379 000	34.29	1.0	—	4.8	Property contains copper and zinc zones which also have average gold content of 1.37 g a tonne. Higher zinc and copper prices required before development for production is considered.

Table 6 (cont'd)

Company and Location	Year Production Expected	Planned Mill or Mine Capacity	Indicated Ore Reserves	Average Grade of Deposit: Silver	Copper	Lead	Zinc	Remarks
		(tonnes ore/day)	(tonnes)	(grams/ tonne)	%	%	%	
West Macdonald mine, northwestern Quebec	1980-82	. .	2 502 000	24.00	0.15	—	4.5	Deposit also contains 1.03 g gold a tonne. Property could be reactivated when zinc markets improve.
Orchan Mines Limited, Barvue zinc-silver property, Barraute township	. .	. .	3 629 000	37.32	. .	. .	3.5	Production to begin when market conditions warrant.
P.D. Division, La Gauchetiere township, Matagami area	1980-82	725	1 402 000	17.14	0.9	—	4.5	Further development of property awaits improved metal markets.
Selco Mining Corporation Limited, Pickands Mather & Co, Detour project, Brouillan township	1982-85	1 800	32 114 000	35.66	0.39	—	2.3	A-1 zone is close to surface.
			3 084 000	39.43	4.49	—	0.8	B zone underground above 275 m. Deposit also contains 1.23 g gold a tonne.
Ontario								
Mattagami Lakes Mines Limited, Lyon Lake Division, Sturgeon Lake	. .	900	3 656 000	116.23	1.15	0.63	6.66	Development suspended and property on a care-and-maintenance basis, awaiting more favourable economic conditions. Deposit also grades 0.34 g gold a tonne.
British Columbia								
Equity Mining Corporation, Sam Goosly deposit Omineca district, near Houston	1982-85	4 200	39 473 000	95.3[1]	0.33	. .	. .	Deposit also contains 0.89 g gold a tonne. Kennco Explorations (Western) Limited holds 30% carried interest in property.
Noranda Mines Limited, Goldstream River property, Goldstream valley	1982-84	. .	3 629 000	21.26[e]	3.6	—	2.6	Environmental studies and an evaluation of power supply alternatives are continuing.

Yukon Territory								
Canex Placer Limited, Howard's Pass deposit, Summit Lake area	1985	. .	180 000 000 to 270 000 000	. .	. .	(5-10%)^e combined lead plus zinc		Major exploration work continuing. Construction of 80-kilometre (km) access road expected to be completed early 1978. U.S. Steel Corp. participating in exploration program.
Hudson Bay Mining and Smelting Co., Limited, Tom claims, MacMillan Pass, Canol Road area	. .	. .	7 843 000	94.28	—	8.19	8.4	Underground work concluded in 1972. Further development is planned. Property is opened by adit.
Kerr Addison Mines Limited Grum deposit, Vangorda Creek	1982-85	5 000	26 300 000[1]	65.14	—	4.1	6.4	Deposit to be activated when zinc markets improve. Deposit might be developed by open pit mining methods.
Northwest Territories								
Arvik Mines Ltd., Polaris deposit, Little Cornwallis Island, Arctic area	1984-85	2 000	22 700 000	34	. .	4.1	14.1	Owned 75% by Cominco Ltd. Feasibility study completed. Mine development plans deferred pending outcome discussions with federal government.

Sources: Company reports, technical press and private sources and estimates by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
[1] Tonnage figure includes contiguous mineralization of Vangorda Joint Venture.
^{e}Estimated; — Nil; . . Not available.

At the Kidd Creek property of Texasgulf Canada Ltd. near Timmins, Ontario, work continued on the $300-350 million (original estimate) expansion program begun in 1974, but at a reduced rate. Included in the program is a transition from open-pit to underground mining which was completed in April 1977 when the open pit ceased operations, and an increase in mine production from 3.3 to 4.5 million tonnes of ore a year by 1981. Late in 1977 the No. 2 underground mine shaft was bottomed at its final depth of 1 555 m and will be fully equipped and ready for hoisting late in 1978. The new fourth 3 175-tonne-a-day circuit in the concentrator was completed and began operation in May 1978. Construction of the new copper smelter and refinery is being stretched out and will be completed (in 1981) at a slower pace than originally planned. Included in the new copper refinery complex is a silver refinery. The silver refinery could come on stream as much as two years later than the copper refinery, although there is a possibility it will open simultaneously with the copper refinery. It is anticipated that the silver refinery will ultimately have an annual capacity of 311 000 to 373 000 kg (10-12 million ounces) of refined silver. This capacity should be sufficient to process the silver content of the copper concentrates at maximum planned production.

Manitoba-Saskatchewan. In 1977 much of the silver produced in Manitoba and Saskatchewan came from several base-metal mines operated by Hudson Bay Mining and Smelting Co., Limited near Flin Flon and Snow Lake, in northern Manitoba. Significant quantities were also derived from the Fox and Ruttan copper-zinc mines operated by Sherritt Gordon Mines Limited at Lynn Lake and Ruttan, Manitoba, respectively. Hudson Bay brought its Centennial mine into production in June 1977. It is 15 km southeast of Flin Flon and has a deposit of 1 270 000 tonnes indicated to a depth of 365 m. This mineralized zone grades 2.06 per cent copper, 2.60 per cent zinc and 24.00 g of silver and 1.37 g of gold a tonne, and is still open at depth. The company's Westarm mine on the west arm of Schist Lake about 15 km south of Flin Flon reached the production stage in January 1978. Diamond drilling has outlined reserves of 644 000 tonnes of copper ore to the 425-m horizon at the Westarm deposit and it is still open at depth. In July 1977, Hudson Bay began construction of a $26 million 3 450-tonne-a-day concentrator adjacent to the Stall Lake mine in the Snow Lake area. It is expected to come on stream in December 1978 and will process the ores produced by the company's mines in the Snow Lake district.

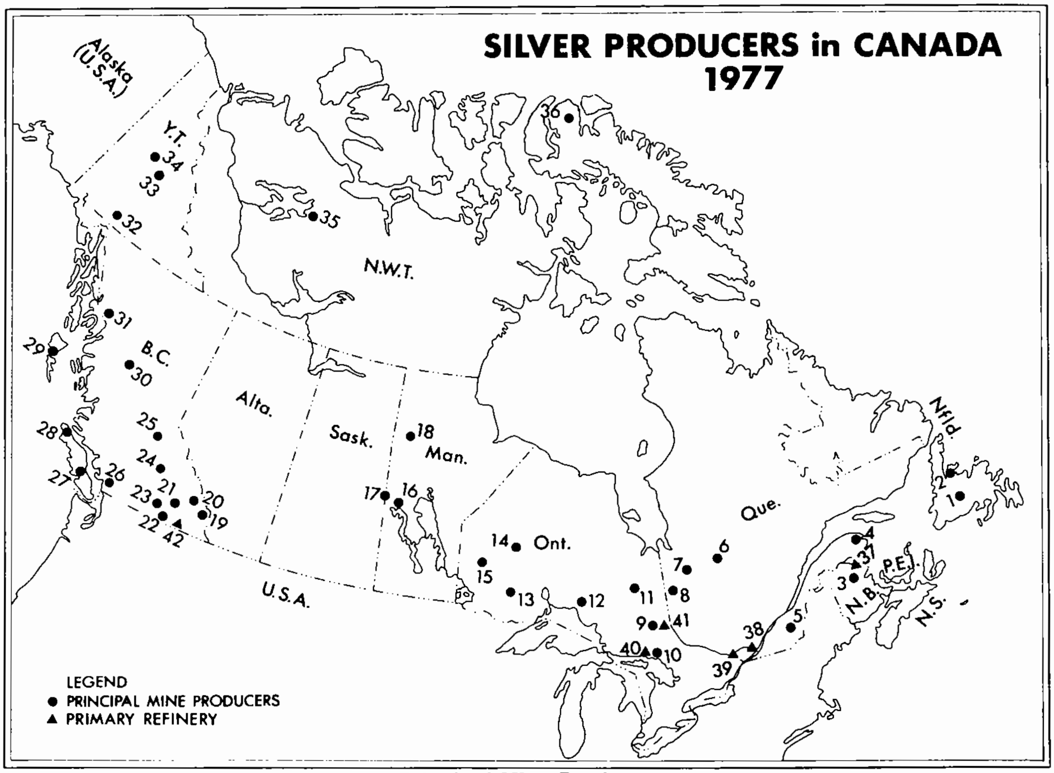
British Columbia. Base-metal ores continued to be the main source of British Columbia's mine output of silver. Cominco Ltd., the largest silver producer in the province, derived its output from the lead-zinc-silver ores of its Sullivan mine and from purchased ores and concentrates. Byproduct silver output from the Sullivan mine was higher in 1977 than in 1976 because of the higher grade and greater tonnage of ore processed. Much greater output by Northair Mines Ltd., that completed its first full year of operations in 1977 at its silver-gold-base-metals property, helped account for British Columbia's higher silver production in the same year. Silver output of some 10 130 kg at Northair's 270-tonne-a-day concentrator at Brandywine Falls, 113 km north of Vancouver, was almost triple that of 1976.

Silvana Mines Inc. embarked on an extensive program of underground exploration and development work at its silver-lead-zinc mine near New Denver in the Slocan district of British Columbia. This $1 million program is expected to be completed by early 1979 and includes rehabilitation of the 1 220-m adit level, the erection of mining plant at the portal together with driving an ore and waste pass system to the upper levels of the mine. The development program should greatly increase mining production capacity and ultimately provide ore production at the mill's capacity of 36 000 to 41 000 tonnes annually. Ore production in 1977 was about 15 900 tonnes. At mid-1977 probable ore reserves were estimated at some 44 300 tonnes grading 5.8 per cent lead, 5.9 per cent zinc and 511.0 g of silver a tonne.

Equity Mining Corporation continued exploration at its silver-gold-copper-antimony property near Houston, B.C. The company is considering plans to bring the property into production late in 1979 at a rate of 3 000 to 4 500 tonnes of ore a day if suitable arrangements can be made to obtain senior financing. Reserves of ore mineable by open-pit methods are reported to estimate some 39.5 million tonnes, grading 0.33 per cent copper, 0.82 per cent antimony and 95.3 g of silver and 0.89 g of gold a tonne.

Yukon Territory. Mine production of silver in the Yukon Territory in 1977 was much higher than in 1976 when operations at all three producers were plagued by labour strikes. The largest producer was again the silver-lead-zinc property of United Keno Hill Mines Limited at Elsa, Y.T. where silver production rose from 74 306 kg in 1976 to 87 003 kg in 1977. In 1977, production from underground ore reserves began to decline, and an increasing portion of the ores mined by Keno Hill will now come from near surface vein deposits mined by open-pit methods. The tonnage potential from this source is comparatively large but grade and metallurgical recovery of the non sulphide ores derived therefrom are lower than usual. Ore from these known near surface vein systems, which include the Black Cap and Bermingham open pits, is to be treated in the rehabilitated cyanide extraction section of the concentrator which began operations in August 1978.

A major capital expenditure program involving new equipment and facilities at the silver-lead-zinc mine of Cyprus Anvil Mining Corporation at Faro, Y.T., was completed in 1977. Included in this program was the



Principal Mine Producers
(numbers refer to numbers on the map)

1. ASARCO Incorporated
   (Buchans Unit)
2. Consolidated Rambler Mines Limited
3. Brunswick Mining and Smelting Corporation Limited
   (Nos. 12 and 6 mines)
   Heath Steele Mines Limited
   Nigadoo River Mines Limited
4. Gaspé Copper Mines Limited
5. Sullivan Mining Group Ltd.,
   Cupra Division and D'Estrie Mining Company Ltd.
6. Campbell Chibougamau Mines Ltd.
   Falconbridge Copper, Limited, Opemiska Division
   Lemoine Mines Limited
   Patino Mines (Quebec) Limited
7. Mattagami Lake Mines Limited
   Orchan Mines Limited
8. Falconbridge Copper Limited, Lake Dufault Division
9. Agnico-Eagle Mines Limited
   Canadaka Mines Limited
   Teck Corporation Limited, Silverfields Division
10. Falconbridge Nickel Mines Limited
    Inco Limited
11. Texasgulf Canada Ltd., Kidd Creek mine
12. Noranda Mines Limited, Geco Division
    Willroy Mines Limited
13. Falconbridge Copper Limited, Sturgeon Lake Joint Venture
    Mattabi Mines Limited
14. Union Miniere Explorations and Mining Corporation Limited, Thierry mine
15. Selco Mining Corporation Limited, South Bay Division
16. Hudson Bay Mining and Smelting Co., Limited
    (Anderson Lake, Centennial, Chisel Lake, Osborne Lake, and Stall Lake mines)
17. Hudson Bay Mining and Smelting Co., Limited
    (Flin Flon, Ghost Lake, Schist Lake and White Lake mines)
18. Sherritt Gordon Mines Limited
    (Fox and Ruttan mines)
19. Cominco Ltd. (Sullivan mine)
20. Silvana Mines Inc.
    (Silmonac mine)
21. Brenda Mines Ltd.
    Similkameen Mining Company Limited

22. Granby Mining Corporation,
    Phoenix Copper Division
23. Dankoe Mines Ltd.
    Teck Corporation Limited
    (Beaverdell mine)
24. Bethlehem Copper Corporation
    Lornex Mining Corporation Ltd.
25. Gibraltar Mines Ltd.
26. Northair Mines Ltd.
27. Western Mines Limited
28. Utah Mines Ltd.
29. Wesfrob Mines Limited
30. Granby Mining Corporation, Granisle mine
31. Newmont Mines Limited, Granduc mine
32. Whitehorse Copper Mines Ltd.
33. Cyprus Anvil Mining Corporation
34. United Keno Hill Mines Limited
35. Echo Bay Mines Ltd.
    Terra Mining and Exploration Limited
36. Nanisivik Mines Ltd.

Primary Refineries

(numbers refer to numbers on the map)

37. Brunswick Mining and Smelting Corporation Limited, Smelting Division
38. Canadian Copper Refiners Limited
39. Royal Canadian Mint
40. Inco Limited
41. Canadian Smelting & Refining (1974) Limited
42. Cominco Ltd.

placing into service of new and larger mining equipment which has resulted in a substantial reduction in unit mining costs. Cyprus Anvil gave top priority in 1977, and will again in 1978, to its exploration work on the DY deposit discovered in 1976 and located 19 km southeast of the Anvil mine and 14.5 km by road from Faro. The deposit represents a potentially substantial addition to reserves in the Anvil District. Much more drilling will be required to outline the deposit, establish reserves and provide detailed data for engineering study. The economics of the deposit, which would require underground mining methods, will be evaluated with a view to transporting ore production to the existing concentrator to supplement lower grade open pit ore and thereby extend the life of the Faro operations.

Northwest Territories. Silver production in the Northwest Territories was substantially higher in 1977 than in 1976 mainly because of increased byproduct output by Nanisivik Mines Ltd., which completed its first full year of operations at its lead-zinc-silver mine at Strathcona Sound on Baffin Island, 800 km north of the Arctic Circle. Greater output by Echo Bay Mines Ltd. at its silver-copper property near Port Radium on the east shore of Great Bear Lake also contributed to the Territories' increased output in 1977.

Terra Mining and Exploration Limited planned to sink a vertical shaft and bore a ventilation raise from

Table 7. United States consumption of silver by end-use[1], 1976 and 1977

	1976[3]		1977[3]	
	(kilograms)[4]	(%)	(kilograms)[4]	(%)
Electroplated ware	296 541	5.6	212 872	4.5
Sterling ware	616 315	11.6	519 117	10.9
Jewelry	341 983	6.4	250 663	5.2
Photographic materials	1 727 176	32.6	1 669 604	34.9
Dental and medical supplies	60 403	1.1	69 423	1.4
Mirrors	143 760	2.7	66 282	1.4
Brazing alloys and solders	348 297	6.6	384 501	8.0
Electrical and electronic products:				
Batteries	108 551	2.0	179 871	3.8
Contacts and conductors	1 005 544	19.0	974 036	20.4
Bearings	8 491	0.2	16 267	0.3
Catalysts	381 546	7.2	276 292	5.8
Coins, medallions and commemorative objects	256 293	4.8	132 252	2.8
Miscellaneous[2]	10 078	0.2	26 718	0.6
Total net industrial consumption	5 304 978	100.0	4 777 898	100.0
Coinage	40 901		2 830	
Total consumption	5 345 879		4 780 728	

Sources: United States Department of the Interior, Bureau of Mines, Mineral Industry Surveys, Gold and Silver in December 1977, for 1976 statistics; United States Department of the Interior, Bureau of Mines, Mineral Industry Surveys, Gold and Silver in March 1978, for 1977 statistics.
[1]End-use as reported by converters of refined silver. [2]Includes silver-bearing copper, silver-bearing lead anodes, ceramic paints, etc. [3]Final figures: includes companies reporting annually. [4]Statistics, originally reported in troy ounces, have been converted to kilograms.

the 400-m level of the Silver Bear mine to surface in order to reduce operating costs and permit more rapid development, at depth, of its Silver Bear and North silver-copper mines on the east shore of Great Bear Lake. A decline tunnel is also to be driven to intersect the 54 and 55 veins at the 215-m level in the North mine. Terra's new North mine, discovered in 1976, contains a series of high-grade silver-uranium bearing vein structures. A 460-m exploration drift was driven north from the Silver Bear mine in 1977 to permit exploration and development of the North mine. Terra also reached agreement with Norex Resources Ltd. for further exploration work at the 50 per cent owned Terra-Norex property operated by Terra under a joint venture agreement with Norex Resources. The Terra-Norex mine is located 10.5 km east of the Silver Bear mine and was brought into production about mid-1977.

Uses

Although the number of industrial applications for silver has increased, significant quantities of the metal are still used in the manufacture of coinage, especially commemorative coins. This is because it strongly resists corrosion, has good alloying properties, an attractive appearance and intrinsic value. The quantity of silver required for coinage decreased somewhat in 1977, mainly because of a decline in consumption in Canada due to the completion of production of Olympic coins in 1976. According to Handy & Harman, non-communist world consumption of silver for coinage dropped from a high of 11 853.5 tonnes in 1965 to 684.3 tonnes in 1977. Silver is used extensively in jewellery, sterling and plated silverware, and as a decorative material because of the same properties that make it popular as a coinage metal, as well as for its high malleability, ductility and ability to take a fine finish. Phillips Petroleum Company recently developed a very promising antitarnish compound called Meos which permits treated silver to remain untarnished 20 to 60 times longer than untreated silver. The photographic industry, in which the use of silver is based on the light sensitivity and ease of reduction of certain silver compounds, is still the metal's greatest single user. The light-sensitive silver halide emulsion on photographic film is the compound that preserves the image after the camera shutter has snapped. Higher silver prices in recent years, however, have helped to bring about technological developments which could lead to a lower growth rate in the use of silver in photography, particularly in the area of X-ray film. Substitution for traditional X-ray film is found in scanners, which use a computer to synthesize numbers from an electronic detector receiving X-ray beams, and then display the picture on a TV-like screen. One such method of silverless X-ray technique makes X-ray images on low-cost thin plastic sheets instead of expensive photographic film. While such new photographic processes, which require no silver, have been developed in black and white photography, the new techniques are not yet adaptable to colour films. Silver-sensitized film for printing purposes is being increasingly replaced by electronic devices and photopolymer films. Copying through xerography, and the use of contact lithographic films with no silver, are also contributing to the reduction of the printing industry's use of silver, even though these processes are only suitable for low-definition copy work. In spite of the progress that has been made in the development of silverless photographic processes, no major breakthrough appears to be on the horizon, especially in the field of colour films. Even if a satisfactory substitute should be found, it could take several years to effect the transition.

Substantial quantities of silver are used in the electrical and electronics industries because of the good demand for silver contacts, conductors and other silver-bearing components. These applications include extensive quantities of silver used in the component parts of complex electronics systems to assure maximum conductivity and reliability in guidance systems for spacecraft. Silver is an important constituent of many brazing and soldering alloys because of the low melting point of silver-copper and silver-copper-zinc alloys, their resistance to corrosion, high tensile strength and ability to join together almost all nonferrous metals and alloys as well as iron and silver. These solders and brazing alloys are widely used in the manufacture of air conditioning and refrigeration equipment, electrical appliances and automotive parts. Some jet engines contain rings plated with silver since silver is an excellent lubricant without the presence of oil.

Silver-zinc and silver-cadmium batteries, in spite of their limited life when in use, are increasingly used in portable equipment where good output, long shelf life and rechargeability are required. However, because of their high cost, such silver-containing batteries are restricted to applications where the requirements are rigorous, especially where weight and dependability are of prime importance, such as in jet aircraft, missiles, satellites and space capsules. High-energy silver-zinc batteries played a vital part in the historic Apollo flights to the moon, servicing both the command and lunar excursion modules. Silver-zinc batteries powered TV transmissions from Apollo 17's Lunar Rover. Similar batteries also provide high-intensity light for lanterns and flashlights for plant protection and security officers. A single silver-zinc battery in a nuclear submarine may use as much as 5 200 kg of silver.

An increase in the use of silver in the battery field could develop as a result of extensive research being done in the use of silver-zinc batteries to power motorcycles and small cars. The silver-zinc battery would, however, have to be leased instead of purchased by the users of such motorcycles, and small cars because its purchase price would be very high. Since the sizeable silver content of such batteries is fully recoverable at the end of their useful lives, marketing on a rental basis is thought to be quite feasible.

Table 8. Annual average silver prices: Canada, United States and United Kingdom, 1968-77

	Canada	United States Handy & Harman, New York	United Kingdom London Spot	London Spot
	($Can.)	($U.S.)	(pence)	($U.S. equiv.)[3]
		(per troy ounce)		
1968	2.311	2.145	219.529	2.189
1969	1.931	1.791	180.774	1.800
1970	1.851	1.771	177.068	1.768
1971	1.571	1.546	63.086[2]	1.542
1972	1.671	1.685	67.403[2]	1.686
1973	2.567	2.558[1]	103.783[2]	2.544
1974	4.595	4.708	199.819[2]	4.675
1975	4.503	4.419	200.118[2]	4.446
1976	4.291	4.353	242.423[2]	4.377
1977	4.922	4.623	265.512[2]	4.634

Sources: Canadian prices are those quoted by the *Northern Miner* (arithmetical average of daily quotations). United States and United Kingdom prices are those quoted by *Metals Week*.
[1]The 60-day general price freeze in effect in the United States from June 13 through August 12, 1973 forced intermittent suspension of Handy and Harman's daily quotation during July and August for a total of 22 days. [2]1971-77 prices are expressed in new British pence, following British conversion to decimal currency, February 11, 1971, at the rate of 100 pence a pound sterling. Previous rate was 240 pence a pound. [3]Prices have been converted at the yearly average exchange rates quoted by *Metals Week*.

In the United States, the National Aeronautics Space Administration's $6.7 billion space shuttle program scheduled for liftoff in 1979 could require a significant quantity of silver. The rocket engines to be used in this program are expected to require an alloy, NARloy-Z, which contains 3 per cent silver and traces of titanium to provide high thermal conductivity and high strength.

Silver is used as a catalyst to control the oxidation of methanol to formaldehyde, and ethylene to ethylene oxide, all of which is essential to the production of plastics, antifreeze and polyester products. Silver catalysts are also used in the manufacture of carpets and permanent-press synthetic fabrics. Low-cost, highly effective silver nitrate cream has been developed for the treatment of severe burns. Silver powder, 99.999 per cent pure, in the form of round beads has applications in powder metallurgy, electronic circuits, and in silver brazing. Other new outlets for the metal are as fungicides and bactericides because of the increasing attention being paid to the ecology and environment. Research is being done on the use of silver in compounds for the improved treatment of swimming-pool water. Tests indicate that the addition of small amounts of silver or silver compounds can significantly reduce the quantities of other chemicals required in swimming pools for purification purposes. Recycling water with minute quantities of silver chloride also helps to eliminate unpleasant odours and tastes in the water and acts as a bactericide.

A new system called "laser photo" was recently developed. This system will enable an office to transmit, within minutes, a detailed positive print photograph to a branch office a continent away, without requiring wet processing or other intermediate steps. This system uses a laser as a light source and dry silver paper as the reproductive medium, which is processed simply by the application of heat.

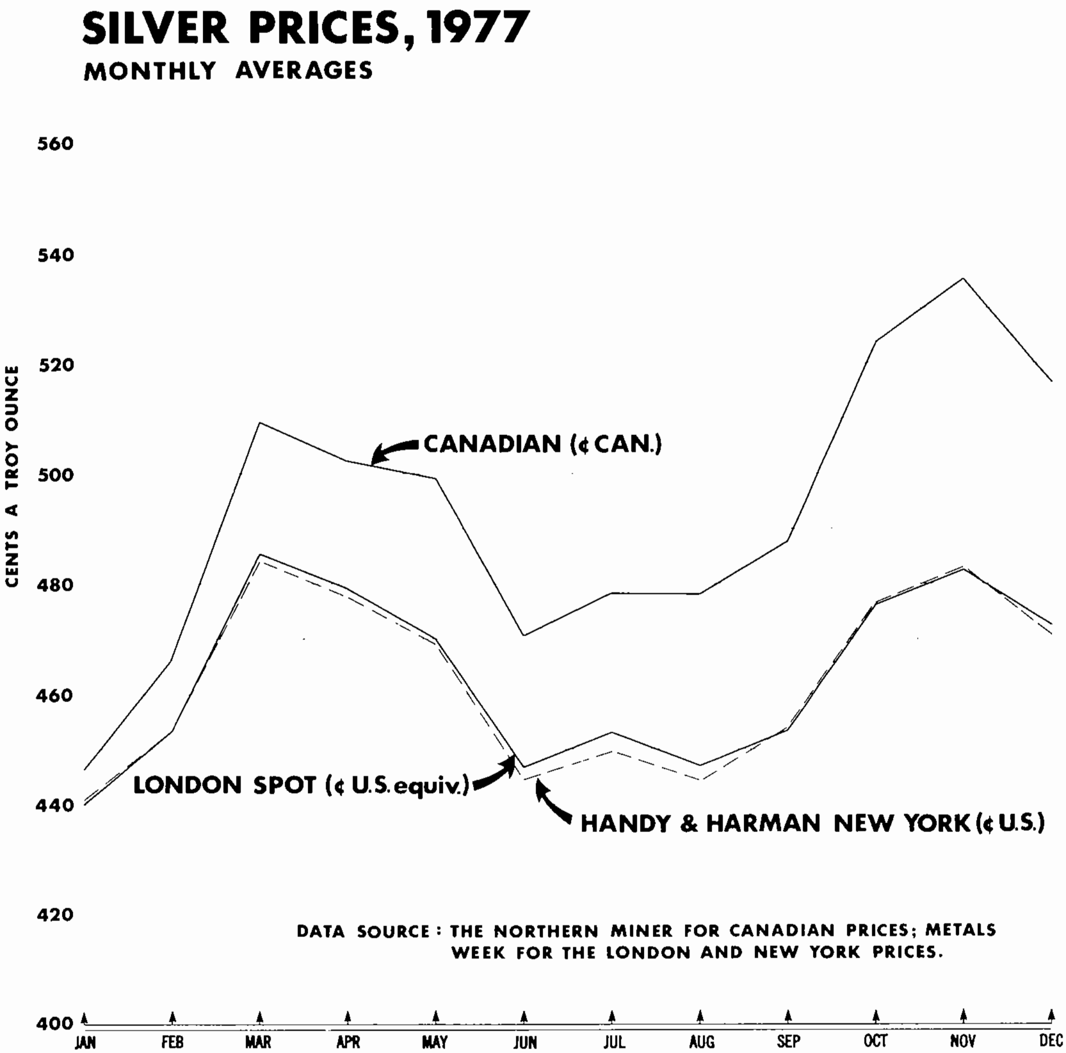
Another potential use for silver is in the conversion of solar energy. In this application pure metallic silver-backed mirrors catch and reflect the sun's light rays to produce heat; this heat can then be used to generate electricity. The optical properties of polished silver surfaces are distinctive because of their exceptionally-high reflectivity and very low emissivity. Substitutes for silver in this application include copper and super-purity aluminum.

Silver is being used increasingly with tin in low-temperature soldering applications. Comparisons of the mechanical properties of solders containing 95 per cent tin and 5 per cent silver with solders containing 80 per cent lead and 20 per cent tin show that both the ultimate tensile strength and the shear strength of the silver-containing solders are approximately twice that of the lead-tin products. The silver solders are also about 30 per cent harder, and elongate less than one-fourth as much as the lead-tin solders when the end products have to withstand stress, impact or heat. Also, tin-silver solders are nontoxic, which is an essential consideration for joints that come in contact with food or drink. Applications today vary from plumbing, heating, refrigeration and air conditioning, to food service and processing utensils, hollow ware, and the electronics industry.

While silver has been used for years in dentistry, Russian and Japanese experts have reportedly developed a nontoxic silver amalgam with gallium to fill cavities in teeth. Also, researchers have recently unveiled a cyanide-free silver electroplating solution. The new product is said to be comparable to the best available silver baths containing cyanide. In addition to being able to comply with antipollution measures, the noncyanide silver solution is believed to have good electroplating qualities.

Prices

In 1977 the New York Handy & Harman silver price fluctuated considerably but the price changes were less volatile than in 1976. On January 3, the opening price was $U.S. 4.370 an ounce. A low of $4.300 obtained on January 11 and a high of $4.960 was reached on March 21; at year-end the price was $4.780. Average for the year was $4.623. The London spot silver price ranged between a low of 246.9 pence an ounce, equivalent to $U.S. 4.669, on December 20, and a high of 289.7 pence ($U.S. 4.973) on March 23. At year-end the price was 249.7 pence ($U.S. 4.756). Average for the year was 265.5 pence ($U.S. 4.634). In 1977 the Canadian silver price closely followed its United States counterpart, with the essential difference being the currency exchange differential. It fluctuated between a low of $Can. 4.347 an ounce on January 11 and a high of $5.511 on November 9. At year-end the price was $5.237. Average for the year was $4.922.



Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
32900-1	Ores of metals, nop	free	free	free	free
35800-1	Anodes of silver	free	free	10%	free
35900-1	Silver in ingots, blocks, bars, drops, sheets or plates, unmanufactured; silver sweepings	free	free	free	free
35905-1	Scrap silver and metal alloy scrap containing silver (expires June 30, 1984)	free	free	25%	free
36100-1	Silver leaf (expires June 30, 1984)	12½%	20%	30%	12½%
36200-1	Articles consisting wholly or in part of sterling or other silverware, nop; manufactures of silver, nop (expires June 30, 1984)	17½%	22½%	45%	15%

United States

Item No.		Non-communist countries	Communist countries except Yugoslavia
420.60	Silver compounds	5%	25%
601.39	Precious metal ores, silver content	free	free
605.20	Silver bullion, silver dore and silver precipitates	free	free
605.46	Platinum-plated silver, unwrought or semimanufactured	16%	65%
605.47	Gold-plated silver, unwrought or semimanufactured	25%	65%
605.48	Other unwrought or semimanufactured silver	10.5%	65%
605.65	Rolled silver, unworked or semimanufactured	10.5%	65%
605.70	Precious metal sweepings and other precious metal waste and scrap, silver content	free	free
644.56	Silver leaf	2.5¢ per 100 leaves	5¢ per 100 leaves

Sources: For Canada, the Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1978), TC Publication 843.
nop — Not otherwise provided for.

Sodium Sulphate

A.F. KILLIN

Sodium sulphate is an industrial chemical used principally in the manufacture of pulp and paper by the "kraft" process, in detergents, and in glass. It can be produced from natural brines and deposits in alkaline lakes in areas with dry climates and little or no drainage, from subsurface deposits and brines, or as a byproduct of chemical processes. Canada's sodium sulphate industry is based on natural brines and deposits in many alkaline lakes in the southern prairies of Saskatchewan and Alberta. Nine plants operated in Canada in 1977. Small quantities of byproduct sodium sulphate are recovered at a viscose-rayon plant and at a pulp and paper mill in Ontario.

In the United States, naturally occurring sodium sulphate is produced in California, Texas and Utah, and byproduct material in the eastern states.

Production and developments in Canada

Shipments of sodium sulphate from Canadian producers declined in 1977 to 416 000 tonnes*, 10 per cent less than in 1976. The value of shipments, at $21 620 000, was 7 per cent lower than in 1976. Production was lower at Saskatchewan and Alberta plants because of market constraints, in particular for saltcake-grade product.

Deposits. In addition to the lakes in Saskatchewan and Alberta, sodium sulphate has been found in association with magnesium sulphate in lakes in British Columbia and with calcium sulphate in deeply buried deposits of glauberite in New Brunswick. Only minor production has been obtained in British Columbia and none in New Brunswick.

The sodium sulphate deposits in Saskatchewan and Alberta have formed in shallow, undrained lakes and ponds where in-flow is greater than out-flow. Percolating ground waters carry dissolved salts into the basins from the surrounding soils. High rates of summer evaporation concentrate the brine, and cooler fall temperatures cause crystallization and precipitation of sodium sulphate as mirabilite ($Na_2SO_4 \cdot 10H_2O$). The cycle has been repeated year after year and thick deposits of hydrous sodium sulphate, accompanied by mud and other salts, have accumulated. Occasionally, where sodium chloride is present, some of the sodium sulphate is precipitated as thenardite (Na_2SO_4), the anhydrous variety of the salt.

Some lakes have not accumulated thick beds because the crystals of sodium sulphate deposited in the fall and winter are redissolved each spring, to re-form a brine rich in sodium sulphate. These same lakes commonly contain a high concentration of magnesium sulphate, a mineral that may prove valuable in the future.

Deposits in Saskatchewan have been identified that contain, in total, approximately 90 million tonnes of anhydrous sodium sulphate. Of this amount, a total of about 51 million tonnes is in 21 individual deposits, each containing more than 500 000 tonnes of sodium sulphate. One deposit in Alberta contains 2.7 million tonnes of Na_2SO_4.

Recovery and processing. Because sodium sulphate is recovered by evaporation of concentrated brines or by dredging of the permanent beds of crystals, weather is as important for recovery of sodium sulphate as it is for its deposition. A large supply of fresh water is also essential. One method of sodium sulphate recovery is to pump lake brines that have been concentrated by hot summer weather into evaporating ponds or reservoirs. Continued evaporation produces a saturated or near-saturated solution of mirabilite. Differential crystallization occurs in the fall when the solution cools. Hydrous sodium sulphate crystallizes and precipitates, wheras sodium chloride, magnesium sulphate and other impurities remain in solution. Before freezing weather sets in, the impure solution remaining in the reservoir is drained or pumped back into the source lake. After the crystal bed has become frozen, harvesting is carried out using conventional earthmoving equipment. The harvested crystal is stockpiled adjacent to the plant.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Canada, sodium sulphate production and trade, 1976 and 1977

	1976		1977^p	
	(tonnes)	($)	(tonnes)	($)
Production				
Shipments	460 193	23 309 533	416 000	21 620 000
Imports				
Total salt cake and Glauber's salt				
Belgium and Luxembourg	9 713	465 000	11 214	632 000
United States	12 148	711 000	9 840	546 000
United Kingdom	7 405	365 000	13 569	511 000
West Germany	—	—	17	14 000
Total	29 266	1 541 000	34 640	1 703 000
Exports				
Crude sodium sulphate				
United States	145 463	8 139 000	117 010	6 954 000
New Zealand	837	99 000	18	3 000
Australia	—	—	1	. . .
Liberia	87	5 000	—	—
Cuba	9	1 000	—	—
Total	146 396	8 244 000	117 029	6 957 000

Source: Statistics Canada.
^{p} Preliminary; — Nil; . . . Less than $1000.

Table 2. Canada, natural sodium sulphate plants, 1976

	Plant Location	Source Lake	Annual Capacity
			(tonnes)
Alberta			
Alberta Sulphate Limited	Metiskow	Horseshoe	90 700
Saskatchewan			
Francana Minerals Ltd.	Grant	Snakehole	90 700
Francana Minerals Ltd.	Hardene	Alsask	45 350
Midwest Chemicals Limited	Palo	Whiteshore	109 000
Ormiston Mining and Smelting Co. Ltd.	Ormiston	Horseshoe	90 700
Saskatchewan Minerals	Chaplin	Chaplin	135 000
Saskatchewan Minerals	Bishopric[1]	Frederick	35 000
Saskatchewan Minerals	Fox Valley	Ingebrigt	135 000
Sybouts Sodium Sulphate Co., Ltd.	Gladmar	East Coteau	45 350
Total			776 800

Source: Company reports.
[1] Closed at end of June 1977.

In Saskatchewan, three operators: Francana Minerals Ltd. at Snakehole Lake, Ormiston Mining and Smelting Co. Ltd. at Horseshoe Lake, and Sybouts Sodium Sulphate Co., Ltd. at East Coteau Lake, use floating dredges to mine the permanent crystal bed. The slurry of crystal and brine is transported to a screening house at the plant by pipeline. If sufficiently concentrated, the brine from the screens is collected in an evaporation pond.

The Ingebrigt Lake plant of Saskatchewan Minerals uses a combination of dredging and solution mining and pumps a concentrated brine to an aircooled crystallizer at the plant. In Alberta, Alberta Sulphate Limited uses solution-mining techniques at Horseshoe lake near Metiskow.

Processing of the natural salt consists of dehydration (Glauber's salt contains 55.9 per cent water of crystallization) and drying. Commercial processes used in Saskatchewan include rotary kilns, Holland evaporators, submerged combustion and multiple effect evaporators. Auxiliary equipment includes screens, classifiers, centrifuges, rotary kiln driers and crushers. Saltcake, the product used principally in the pulp and paper industry, contains a minimum of 97 per cent Na_2SO_4. Detergent-grade material analyzes up to 99.77 per cent Na_2SO_4. Uniform grain size and free flow are important in material handling and use.

Weak markets, in particular for saltcake grade, brought about reduced production at many plants in Saskatchewan and Alberta in 1977. The Bishopric plant of Saskatchewan Minerals suspended production at the end of June 1977 and the Ingebrigt plant operated at a reduced level during the year.

Byproduct recovery. Courtaulds (Canada) Limited produces approximately 16 000 tonnes of detergent-grade sodium sulphate as a byproduct of viscose rayon production at its Cornwall, Ontario plant. Ontario Paper Company Limited at Thorold, Ontario produces up to 54 000 tonnes of saltcake, as a byproduct of paper manufacturing. Kaiser Aluminum & Chemical of Canada Limited closed its strontium carbonate plant at Point Edward, Nova Scotia where coproduct sodium sulphate was also produced.

Consumption and trade

There are three main consuming industries for sodium sulphate, the kraft pulp and paper industry, the detergent industry and the glass industry. Other users include the dyeing industry and the producers of mineral feed supplements and chemical products. Because of reduced activity in the pulp and paper industry in North America, consumption of saltcake for the production of kraft paper declined in 1977. Shipments of detergent grade increased marginally but not enough to offset the decline in saltcake shipments.

Table 3. Canada, sodium sulphate production, trade and consumption, 1960, 1965, 1970, 1975, 1976 and 1977

	Production[1]	Imports[2]	Exports	Consumption
	(tonnes)			
1960	194 326	23 457	57 907	166 071
1965	313 404	26 623	105 546	250 038
1970	445 017	26 449	108 761	291 439[r]
1975	472 196	22 638	178 109	256 385
1976	460 193	29 266	146 396	265 608
1977[p]	416 000	34 640	117 029	. .

Source: Statistics Canada.
[1]Producers' shipments of crude sodium sulphate. [2]Includes Glauber's salt and crude salt cake.
[p]Preliminary; [r]Revised; . . Not available.

Table 4. Canada, available data on sodium sulphate consumption, 1975, 1976 and 1977

	1975	1976	1977
	(tonnes)		
Pulp and paper	197 843	208 601	. .
Soaps	39 302	37 341[e]	. .
Glass and glass wool	9 827	9 746	. .
Other products[1]	9 413	9 920	. .
Total	256 385	265 608	. .

Source: Statistics Canada, breakdown by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
[1]Colours, pigments, foundries, feed supplements and other minor uses.
[e]Estimated; . . Not available.

Table 5. Canada, railway loadings of sodium sulphate, 1976 and 1977

	1976	1977
	(tonnes)	
Nova Scotia	3 907	127
New Brunswick	85	259
Quebec	325	197
Ontario	20 987	17 468
Manitoba	—	222
Saskatchewan	406 209	352 188
Alberta	35 714	25 556
British Columbia	42 723	52 639
Canada	509 950	448 656

Source: Statistics Canada.
— Nil.

Canadian exports of sodium sulphate at 117 029 tonnes decreased by 29 367 tonnes from the total exported in 1976 because of reduced exports of saltcake. Over 99 per cent of Canadian exports go to the United States. Imports of sodium sulphate in 1977 increased 18 per cent to 34 640 tonnes. Two-thirds of these imports came into eastern Canada from western Europe, the remainder was imported into western Canada from the United States.

Outlook

The outlook for 1978 is for decreased sales of saltcake in the Canadian and United States markets. Sales of detergent-grade sodium sulphate will probably remain constant, or rise slightly. Prices should remain firm at, or marginally higher than, in 1977.

Prices

Prices quoted by western producers fob plant in 1977 were $49.60 a tonne for saltcake, and $60.63 a tonne for detergent-grade sodium sulphate. *Canadian Chemical Processing* quoted the prices at $60.63 a tonne for saltcake and $121.25 a tonne for detergent grade.

United States prices, according to *Chemical Marketing Reporter,* December 1977 were:

	$ U.S. per short ton
Salt cake, 100% Na_2SO_4 basis, fob plant east	60.00
Same basis, west	35.00
Sodium sulphate, detergent rayon-grade, bags, carload lots, works east	70.00-72.00

Tariffs

Canada

Item no.		British Preferential	Most Favoured Nation	General	General Preferential
21000-1	Natural sodium sulphate	10%	15%	25%	10%

United States

Item No.		
421-42	Crude sodium sulphate (saltcake)	Free
421-44	Anhydrous	40¢ per long ton
421-46	Crystallized (Glauber's salt)	80¢ per long ton

Sources: For Canada, the Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa, For United States, Tariff Schedules of the United States Annotated (1975), TC Publication 706.

Stone

D.H. STONEHOUSE

Naturally occurring rock material, quarried or mined for industrial use with no change in its chemical state and with its physical character altered only by shaping or by sizing, is commercially termed "stone". Dimension stone is shaped for use as a building block, slab or panel. It may be rough-cut, sawn or polished, and its application may depend on its strength, hardness, durability and ornamental qualities. Broken, irregular, screened and sized pieces constitute the crushed stone category. Material in this category is used mainly as an aggregate in concrete and asphalt, in highway and railway construction, and as heavy riprap for facing wharves and breakwaters.

Stone production in Canada, either as dimension stone or crushed stone, is used directly or indirectly by the construction industry, except for small amounts used in the manufacture of monuments. Indirect usage includes that portion of the resource that is utilized in the manufacture of lime, cement, iron and steel, all of which are associated with various phases of the construction industry. Activity in both building construction and heavy or engineering construction can be indicative of demands for quarried stone.

The large number of stone-producing operations in Canada precludes describing within this review individual plants or facilities. Many are part-time or seasonal operations, many are operated subsidiary to construction or manufacturing activities by establishments not classified to the stone industry, and some are operated directly by municipal or provincial government departments producing stone for their own direct use. Detailed information can be obtained through the individual provincial departments of mines or equivalent. Most provinces have accumulated data relative to occurrences of stone of all types and in many cases have published such studies. The federal government, through the Geological Survey of Canada, has also gathered and published a great number of geological papers pertaining to stone occurrences. Works by W.A. Parks[1] and by M.F. Goudge[2] have become classics in the fields of building stones and limestones, respectively.

Dimension stone. Granite, limestone, marble and sandstone are the principal rock types from which building and ornamental stone is fashioned. Over 90 per cent is used in construction-oriented projects while less than 10 per cent is used as monumental stone. Imports of rough blocks, particularly of granite, for sawing and polishing, as well as of finished stones for distribution to retailers, have cut into markets formerly supplied from domestic sources.

Today, in the building sector of the construction industry, granite, limestone and marble are used as facing stone in the form of cut and polished panels, in conjunction with steel and concrete, for institutional and commercial buildings. In residential buildings the use of a limestone or sandstone ashlar, or coursing stone, is becoming increasingly popular. The emphasis has changed from stone used for structural purposes to stone used for its aesthetic qualities. The architect and contractor can design and build for lasting beauty using Canadian building stone.

High costs associated with quarrying, finishing, transporting and placing dimension stone in the building construction sector have contributed to the erosion of this industry and have made market penetration by concrete products possible.

Crushed stone. Many quarries that produce crushed stone are operated primarily to produce stone for other purposes, e.g., granite for building blocks and monuments, limestone for cement or lime manufacture, or for metallurgical use, marble for monuments and building panels, sandstone for riprap, and cut stone. Quarries removing solid rock by drilling, blasting and crushing are not likely to be operated for small, local needs as are gravel pits and are, therefore, usually operated by large companies associated with the construction industry. Depending on costs and availability, crushed stone competes with gravel and crushed gravel as an aggregate in concrete and asphalt, and as railway ballast and road metal. In these applications it is subject to the same physical and chemical testing procedures as the gravel and sand aggregates.

Other uses for crushed stone include the manufacture of roofing granules from granite and marble; the production of poultry grit from limestone, silica and granite; and the production of rock wool from limestone and sandstone. Pulverized stone is used as follows: granite, limestone and sandstone as asphalt filler; limestone for dusting coal mines; and limestone and marble for agricultural application. Limestone is also produced for chemical and metallurgical uses in the iron and steel industry, the glass industry, the pulp and paper industry and in sugar manufacture.

Canadian industry

Atlantic provinces. *Limestone.* The many occurrences of limestone in the Atlantic provinces have been systematically catalogued during the past few years[3,4,5]. Deposits of commercial importance are being worked in three of the four provinces.

In Newfoundland limestone is available from small, impure exposures in the eastern portion of the island, from small, high-calcium deposits in the central region, and from large, high-purity, high-calcium occurrences in the west. Other than periodic operation to secure aggregate for highway work, the main exploitation is by North Star Cement Limited at Corner Brook[6]. Large quantities of high-calcium limestone have been outlined in the Port au Port district. The provincial government is continuing its efforts to identify available aggregates near major use centres and adjacent to the Trans Canada Highway route through the province.

In Nova Scotia limestones occur in the central and eastern parts of the province in thin, tilted lenses typical of deposits in Atlantic Canada and in contrast to deposits of much greater thickness and areal extent in central Canada. Large proven reserves in the Glencoe region of Inverness County have been assessed with the object of establishing a portland cement facility on site or at the Strait of Canso to supply an offshore market. As was the case when Lehigh Portland Cement Company of Allentown, Pennsylvania, in association with British Newfoundland Exploration Limited (Brinex), surveyed the limestone at Port au Port, Newfoundland, a bouyant and continuing market for cement and clinker would be necessary to support such an undertaking.

Mosher Limestone Company Limited quarries a dolomitic limestone at Upper Musquodoboit, Nova Scotia. Pulverized material is sold for agricultural use throughout the Atlantic provinces. Sydney Steel Corporation (Sysco) produces a high-calcium, fossiliferous limestone at Irish Cove, Nova Scotia, and a high-purity dolomite at Frenchvale, Nova Scotia, for use in the Sydney steel plant. Studies to determine the viability of a lime-manufacturing plant in the Sydney area have been made in connection with incorporation of a basic oxygen process at the Sysco plant. Calpo Limited continues to supply sized, high-calcium limestone from an area near Antigonish Harbour to Scott Paper Limited at Abercrombie, and Canada Cement Lafarge Ltd. obtains limestone for portland cement manufacture on site at its Brookfield location[6].

In New Brunswick, limestone is quarried at three locations — Brookville, Elm Tree and Havelock — for use as a crushed stone, as an aggregate, or for agricultural application. Brookville Manufacturing Company, Limited, Saint John, following a recent expansion program, is now the largest supplier of coarse aggregate in southern New Brunswick, and the company also supplies agricultural limestone. Havelock Lime Works Ltd. has expanded its plant to offer a range of products including washed, crushed and sized aggregates for asphalt and concrete application and finely pulverized filler material. Havelock Processing Ltd. produces high-calcium lime at Havelock[7], and Canada Cement Lafarge Ltd. uses limestone at its Havelock plantsite in the production of portland cement[6].

Granite. Occurrences of granites in the Atlantic region have been described by Carr[8]. Current operations in Nova Scotia are at Nictaux, Shelburne and Erinville. A grey granite is produced from operations near Nictaux

Table 1. Canada, total production (shipments) of stone, 1975-77

	1975		1976		1977^p	
	(tonnes)[1]	($)	(tonnes)	($)	(tonnes)	($)
By province						
Newfoundland	876 642	2 889 457	365 350	1 282 914	454 000	1 600 000
Prince Edward Island	—	—	—	—	—	—
Nova Scotia	1 581 383	4 637 276	1 576 652	4 843 827	1 451 000	4 600 000
New Brunswick	3 240 756	8 247 571	3 029 114	8 513 926	3 084 000	9 200 000
Quebec	50 763 419	110 409 777	48 861 437	124 670 778	49 532 000	133 500 000
Ontario	27 525 859	62 249 745	28 165 405	71 860 589	29 484 000	79 300 000
Manitoba	969 384	2 234 843	2 338 661	8 558 370	1 905 000	7 200 000
Alberta	235 145	1 158 980	357 735	1 498 982	363 000	1 600 000
British Columbia	4 221 023	10 896 391	3 181 582	9 409 076	2 994 000	9 400 000
Canada	89 413 611	202 724 040	87 875 936	230 638 462	89 267 000	246 400 000

Table 1. (concl'd)

	1975		1976		1977p	
	(tonnes)	($)	(tonnes)	($)	(tonnes)	($)
By use						
Building stone, rough	72 833	2 058 987	248 570	2 817 725		
Monumental and ornamental stone	32 316	1 508 639	30 869	1 700 371		
Other (flagstone, curbstone, paving blocks, etc.)	26 617	648 831	22 411	718 516		
Chemical and metallurgical						
Cement plants, foreign	1 120 764	1 375 714	1 157 935	1 639 205		
Lining, open-hearth furnaces	350 960	583 798	39 545	67 714		
Flux in iron and steel furnaces	1 027 776	3 006 006	411 192	987 127		
Flux in nonferrous smelters	77 011	146 092	71 209	154 358		
Glass factories	294 860	1 810 879	221 529	1 453 106		
Lime kilns, foreign	255 330	792 887	523 993	961 622		
Pulp and paper mills	284 457	1 383 735	258 947	1 725 919		
Sugar refineries	67 806	282 369	50 458	245 198		
Other chemical uses	140 089	430 802	818 762	3 073 218		
Pulverized stone						
Whiting (substitute)	13 499	459 986	16 449	549 724		
Asphalt filler	33 113	277 549	49 512	457 136		
Dusting, coal mines	4 332	73 639	9 733	69 682		
Agricultural purposes and fertilizer plants	904 750	4 603 496	642 337	4 111 008		
Other uses	703 940	2 674 155	48 677	416 064		
Crushed stone for						
Manufacture of artificial stone	15 952	188 127	9 936	167 620		
Roofing granules	198 170	4 962 399	245 297	7 216 482		
Poultry grit	63 770	429 194	38 064	295 916		
Stucco dash	23 222	865 176	31 564	1 192 315		
Terrazzo chips	9 403	285 367	12 674	359 435		
Rock wool	181	1 000	43 558	156 324		
Rubble and riprap	2 790 364	5 856 607	13 218 391	23 304 609		
Concrete aggregate	13 144 766	28 119 894	10 976 873	29 955 214		
Asphalt aggregate	6 448 373	13 490 655	5 177 432	13 603 481		
Road metal	32 807 692	68 893 302	24 113 247	61 208 838		
Railroad ballast	3 154 293	6 111 642	4 570 121	12 806 805		
Other uses	25 346 972	51 403 113	24 816 651	59 223 730		
Total	89 413 611	202 724 040	87 875 936	230 638 462		

Source: Statistics Canada.
[1]The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.
pPreliminary; — Nil.

and from one quarry at Shelburne for use mainly in the monument industry. A black granite from Shelburne and a diorite from Erinville are used for monuments and for dimension stone. Quartzitic rock referred to as "bluestone" is quarried at Lake Echo, north of Dartmouth, for use as facing stone. Crushed quartzite for use as an aggregate is produced at a number of locations in Halifax County. At Folly Lake in Colchester County a diorite rock is quarried, mainly for use as railway ballast. A new quarry in a "quartzite-granite" on the mainland side of the Strait of Canso has been opened recently to supply aggregate material to Prince Edward Island and other Atlantic areas. The company indicates its long term objectives include marketing aggregates in offshore regions.

Granites are quarried intermittently from a number of deposits within New Brunswick to obtain stone of required colour and texture for specific application. A red, fine- to medium-grained granite is quarried near St. Stephen, and fine-grained, pink, grey and blue-grey granites are available in the Hampstead (Spoon Island) district. In the Bathurst area, a brown-to-grey, coarse-grained granite is quarried upon demand, as is a salmon-coloured, medium-grained granite near Antinouri Lake, and a black, ferromagnesian rock in the Bocabec River area. Red granite is available in the St. George district. Granite for use as a crushed stone is produced near Fredericton and near Moncton.

Sandstone. A medium-grained, buff sandstone is quarried at Wallace, Nova Scotia, for use as heavy riprap and for dimension stone applications. Recently, considerable tonnages were used in the reconstruction of the fortress at Louisbourg. Small deposits in many parts of the province are quarried periodically for local use.

In New Brunswick a red, fine- to medium-grained sandstone has been quarried in Sackville for use in construction of buildings on the Mount Allison University campus. Deposits are exploited from time to time throughout Kent and Westmorland counties for local projects and for highway work.

Quebec. *Limestone.* Limestone occurs in the St. Lawrence and Ottawa river valleys and in the Eastern

Table 2. Canada, production (shipments) of limestone, 1975 and 1976

	1975		1976	
	(000 tonnes)	($000)	(000 tonnes)	($000)
By province				
Newfoundland	645	1 924	132	470
Nova Scotia	163	581	81	446
New Brunswick	888	2 995	722	3 289
Quebec	39 864	81 232	27 275	74 036
Ontario	26 794	55 482	26 299	58 959
Manitoba	471	1 281	789	1 866
Alberta	139	1 017	133	1 171
British Columbia	3 320	8 010	2 361	6 463
Canada[1]	72 284	152 522	57 793	146 700
By use	(tonnes)	($)	(tonnes)	($)
Building stone, rough	35 484	706 522	205 642	1 106 389
Monumental and ornamental	2 213	72 673	916	57 880
Other (flagstone, curbstone, paving blocks, etc.)	7 369	192 228	7 458	223 575
Chemical and metallurgical				
Cement plants, foreign	1 120 764	1 375 714	1 157 935	1 639 205
Lining, open-hearth furnaces	350 960	583 798	39 545	67 714
Flux, iron and steel furnaces	1 027 776	3 006 006	411 192	987 127
Flux, nonferrous smelters	77 011	146 092	71 209	154 358
Glass factories	294 860	1 810 879	221 529	1 453 106
Lime kilns, foreign	255 330	792 887	523 993	961 622
Pulp and paper mills	276 298	1 319 842	252 968	1 671 682
Sugar refineries	67 806	282 369	50 458	245 198
Other chemical uses	140 089	430 802	818 762	3 073 218
Pulverized stone				
Whiting substitute	13 499	459 986	16 449	549 724
Asphalt filler	28 248	258 726	41 902	429 830
Dusting coal mines	4 332	73 639	9 733	69 682
Agricultural purposes and fertilizer plants	801 292	4 072 306	589 504	3 824 407
Other uses	701 802	2 622 189	46 085	372 773

Table 2. (concl'd)

	1975		1976	
	(tonnes)	($)	(tonnes)	($)
Crushed stone for				
Artificial stone	1 814	40 000	2 313	71 656
Roofing granules	44 409	203 873	39 137	135 279
Poultry grit	63 224	418 400	37 384	281 426
Stucco dash	21 118	794 875	27 883	1 065 594
Rock wool	181	1 000	43 558	156 324
Rubble and riprap	807 261	1 444 529	538 046	1 016 566
Concrete aggregate	11 026 967	22 089 495	9 157 690	23 280 034
Asphalt aggregate	4 743 703	9 785 145	3 547 019	8 916 390
Road metal	26 214 832	51 694 106	17 772 106	44 585 715
Railroad ballast	2 460 236	4 308 966	2 452 526	5 144 952
Other uses	21 695 154	43 534 540	19 710 062	45 158 398
Total	72 284 032	152 521 587	57 793 004	146 699 824

Source: Statistics Canada.
[1]Figures may not add to totals due to rounding.

Townships. Other major deposits in the province are located in the Lac Saint-Jean - Saguenay River area and in the Gaspé region. The limestones range in geologic age from Precambrian to Carboniferous and vary widely in purity, colour, texture and chemical composition[2].

Quebec Department of Natural Resources listed 55 operating limestone properties in 1976[9] including portland cement and lime producers. Quarries are located near major market areas such as Montreal, Quebec City, Sherbrooke, Ottawa-Hull and Trois-Rivières and supply crushed stone to the construction industry, mainly for use in concrete and asphalt and as highway subgrade. In addition three operations were listed as producers of building stone.

The pulp and paper, metallurgical and agricultural industries use substantial quantities of limestone. At Kilmar, in western Quebec, Dresser Industries Canada, Ltd., formerly Canadian Refractories Limited, mines a magnesite-dolomite ore from which it produces refractory-grade magnesia and magnesia products.

Portland cement was produced in 1977 at five plants[6] in Quebec with a combined annual capacity of just over 4 million tonnes*. Four companies produce lime at four locations within the province[7].

Limestone blocks and other shapes are produced for the construction trade in the Montreal region and at various locations throughout the province as the need arises. Marble has been produced in the Stukely and Philipsburg areas. Five operations are listed by the Quebec Department of Natural Resources[9].

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Granite. Nearly 60 per cent of Canada's granite production comes from Quebec from long-established operations in two general regions — one north of the St. Lawrence and Ottawa rivers, including the Lac Saint-Jean area, and one south of the St. Lawrence River. Precambrian rocks contain granites of various colours, compositions and textures. The Quebec Department of Natural Resources indicated that 25 plants were processing granite as building or ornamental stone[9]. Many areas underlain by granite are too remote from transportation and markets to be economically attractive.

Sandstone. There are far fewer sandstone-producing operations in Quebec than there are producers of limestones and granites. Of four operations producing from sandstone resources three are marketing flagstone and construction blocks, all produce riprap and aggregate[9].

Ontario. *Limestone.* Although limestones in Ontario range from Precambrian through Devonian, the major production comes from Ordovician, Silurian and Devonian deposits[10,11]. Of particular importance are the limestones and dolomite from the following geological sequences: the Black River and Trenton formations, extending from the lower end of Georgian Bay across southern Ontario to Kingston; the Guelph-Lockport Formation, extending from Niagara Falls to the Bruce Peninsula and forming the Niagara Escarpment; and the Middle Devonian limestone extending from Fort Erie through London and Woodstock to Lake Huron. Production of building stone, fluxstone and crushed aggregate from the limestones of these areas normally accounts for over 90 per cent of total stone production in Ontario.

Marble is widely distributed over southeastern Ontario and, according to the Ontario Ministry of

Table 3. Canada, production (shipments) of marble, 1975 and 1976

	1975		1976	
	(000 tonnes)	($000)	(000 tonnes)	($000)
By province				
Quebec	349	1 583	391	1 703
Ontario	7	260	7	272
Canada[1]	356	1 843	398	1 974
By use	(tonnes)	($)	(tonnes)	($)
Chemical process stone				
Pulp and paper mills	8 159	63 893	5 979	54 237
Pulverized stone				
Agricultural purposes and fertilizer plants	103 458	531 190	52 833	286 601
Other uses	2 138	51 966	2 592	43 291
Crushed stone				
For manufacture of artificial stone	14 138	148 127	7 623	95 964
Roofing granules	1 760	21 014	—	—
Stucco dash	—	—	1 478	44 769
Terrazzo chips	9 403	285 367	12 674	359 435
Concrete aggregate	31 019	193 190	82 424	529 735
Asphalt aggregate	—	—	13 942	50 243
Road metal	92 306	302 250	133 605	325 958
Other uses	93 730	245 718	85 167	184 235
Total	356 111	1 842 715	398 317	1 974 468

Source: Statistics Canada.
[1]Figures may not add to totals due to rounding.
— Nil.

Natural Resources reports, underlies as much as 250 square kilometres[12].

During 1977 production of calcium carbonate for filler markets, for the glass and ceramics industries and for agriculture use was begun near Perth, while financing was being arranged for development of a high-grade calcite deposit in Belmont Township. The filler markets have become extremely attractive recently, not only to new ventures but also to companies hitherto interested in production of only coarser aggregate materials. Many lime operations now produce a filler-grade limestone product.

Legislation, now in effect in Ontario, controls the development, operation and rehabilitation of existing pits and quarries, designates areas in which such operations may be started, and provides for regulated sequential land use. The necessity for an advance assessment of the total impact of all developments affecting land use is recognized in the total legislative package. Complications arise, however, because of the number of government levels implementing and administrating the legislation. In early 1976 the Ministry of Natural Resources established a "Mineral Aggregate Working Party" bringing together representatives of the provincial and municipal governments, aggregate producers, the Conservation Council of Ontario and the Niagara Escarpment Commission. The Working Party produced, for consideration of Cabinet, a document outlining steps toward a mineral aggregate resource management policy for Ontario. The recommendations are far-reaching and include proposed changes in current legislation that impinges on pit and quarry operation and land use. Mineral aggregate studies have been done over three major areas of Ontario; central, east and south, as part of a provincial program to determine the future availability of sand, gravel and crushed stone.

Although there is no absolute shortage of aggregate in Ontario, a shortage of aggregate at reasonable prices could result from growing opposition to the industry. Already large deposits of accessible aggregate material have been removed from the "reserves" category by legislation. Further restrictions could curtail sand and gravel operations in Ontario in about 20 years. Industry has been hesitant to invest in new plant sites, which would increase their reserves base, until the impact of proposed legislation is known.

During 1977 portland cement was produced by four

Table 4. Canada, production (shipments) of granite, 1975 and 1976

	1975		1976	
	(000 tonnes)	($000)	(000 tonnes)	($000)
By province				
Newfoundland	45	422	58	243
Nova Scotia	1	12	2	18
New Brunswick	2 056	4 533	1 901	4 178
Quebec	7 274	20 035	18 519	42 287
Ontario	711	6 112	1 842	12 192
Manitoba	499	954	1 549	6 692
Alberta	2	4	—	—
British Columbia	882	2 840	820	2 947
Canada[1]	11 470	34 913	24 691	68 557
By use	(tonnes)	($)	(tonnes)	($)
Building stone, rough	16 220	832 793	16 978	927 238
Monumental and ornamental	28 872	1 375 328	26 778	1 614 491
Other (flagstone, curbstone, paving blocks, etc.)	3 116	85 270	2 670	117 132
Pulverized stone				
Asphalt filler	4 865	18 823	7 610	27 306
Crushed stone for				
Roofing granules	151 901	4 737 017	206 160	7 081 203
Poultry grit	546	10 794	680	14 490
Stucco dash	2 104	70 301	2 203	81 952
Rubble and riprap	641 143	1 791 004	12 234 023	21 380 229
Concrete aggregate	1 585 545	4 166 880	1 418 037	5 102 170
Asphalt aggregate	1 538 358	3 264 202	991 963	2 772 494
Road metal	5 258 405	13 662 500	5 078 386	13 232 696
Railroad ballast	344 265	1 059 936	1 698 561	6 493 199
Other uses	1 894 316	3 837 939	3 006 934	9 712 752
Total[1]	11 469 656	34 912 787	24 690 983	68 557 352

Source: Statistics Canada.
[1]Figures may not add to totals due to rounding.
— Nil.

companies at a total of six locations in Ontario[6], while eight companies operated a total of ten lime-producing facilities in the province[7].

Granite. Granites occur in northern, northwestern and southeastern Ontario[13]. Few deposits have been exploited for the production of building stone because the major consuming centres are in southern and southwestern Ontario where ample, good-quality limestones and sandstones are readily available for building. The areas most active in granite building stone production have been the Vermilion Bay area near Kenora, the River Valley area near North Bay, and the Lyndhurst-Gananoque area in southeastern Ontario. Rough building blocks were quarried from a gneissic rock near Parry Sound, while at Havelock a massive red-granite rock was quarried.

Sandstone. Sandstone quarried near Toronto, Ottawa and Kingston has been used widely in Ontario as building stone[14]. Production is currently from the Limehouse-Georgetown-Inglewood district where Medina sandstone is quarried, and from the Kingston area where Potsdam sandstone is quarried. Medina sandstones vary from grey, through buff and brown to red, and some are mottled. They are fine- to medium-grained. The Potsdam stone is medium-grained; the colour ranges from grey-white through salmon-red to purple, and it can also be mottled. Current uses are as rough building stone, mill blocks from which sawn pieces are obtained, ashlar, flagstone and as a source of silica for ferrosilicon and glass.

Western provinces. *Limestone.* From east to west through the southern half of Manitoba rocks of the

Table 5. Canada, production (shipments) of sandstone, 1975 and 1976

	1975		1976	
	(000 tonnes)	($000)	(000 tonnes)	($000)
By province				
Newfoundland	140	492	163	557
Nova Scotia	1 418	4 044	1 495	4 379
New Brunswick	297	719	406	1 047
Quebec	1 862	5 174	1 599	4 846
Ontario	15	396	15	438
Alberta	4	9	15	31
British Columbia	18	46	—	—
Canada[1]	3 753	10 881	3 694	11 298
By use	(tonnes)	($)	(tonnes)	($)
Building stone, rough	21 129	519 672	25 950	784 098
Monumental and ornamental	1 231	60 638	3 175	28 000
Other (flagstone, curbstone, paving blocks, etc.)	16 132	371 333	12 283	377 809
Crushed stone for				
Roofing granules	100	495	—	—
Rubble and riprap	714 305	1 375 706	376 469	800 014
Concrete aggregate	501 235	1 670 329	318 722	1 043 275
Asphalt aggregate	166 312	441 308	413 622	1 249 707
Road metal	1 047 772	2 930 516	1 006 680	2 874 217
Railroad ballast	258 739	614 268	419 034	1 168 654
Other uses	1 026 402	2 896 380	1 117 982	2 972 267
Total[1]	3 753 357	10 880 645	3 693 917	11 298 041

Source: Statistics Canada.
[1]Figures may not add to totals due to rounding.
— Nil.

Table 6. Canada, production (shipments) of shale, 1975 and 1976

	1975		1976	
	(000 tonnes)	($000)	(000 tonnes)	($000)
By province				
Newfoundland	46	52	12	13
Quebec	1 413	2 386	1 078	1 799
Alberta	91	128	210	297
Canada[1]	1 550	2 566	1 300	2 109
By use	(tonnes)	($)	(tonnes)	($)
Crushed stone for				
Rubble and riprap	627 655	1 245 368	69 853	107 800
Asphalt aggregate	—	—	210 886	614 647
Road metal	194 377	303 930	122 470	190 252
Railroad ballast	91 053	128 472	—	—
Other uses	637 365	888 536	896 506	1 196 078
Total[1]	1 550 450	2 556 306	1 299 715	2 108 777

Source: Statistics Canada.
[1]Figures may not add to totals due to rounding.
— Nil.

Table 7. Canada, production (shipments) of stone by types, 1965, 1970, 1974-76

	1965		1970		1974		1975		1976	
	(tonnes)	($)	(tonnes)	$	(tonnes)	$	(tonnes)	$	(tonnes)	$
Granite	7 102 549	16 569 762	4 388 270	15 231 891	13 889 918	34 396 771	11 469 656	34 912 787	24 690 983	68 557 352
Limestone	56 407 688	69 974 005	52 522 637	67 563 790	72 766 531	127 617 700	72 284 032	152 521 587	57 793 004	146 699 824
Marble	71 160	1 049 264	56 096	350 903	343 481	1 618 642	356 111	1 842 715	398 317	1 974 468
Sandstone	3 785 665	5 328 404	2 112 794	4 133 708	3 989 757	10 287 417	3 753 357	10 880 645	3 693 917	11 297 041
Shale	2 121 415	1 837 492	180 087	695 458	1 843 361	3 313 548	1 550 450	2 566 306	1 299 715	2 108 777
Slate	145 305	88 094	—	—	—	—	—	—	—	—
Total	69 633 782	94 847 021	59 259 884	87 975 750	92 833 054	177 207 078	89 413 611	202 724 040	87 875 936	230 638 462

Source: Statistics Canada.
Note: Figures may not add to totals due to rounding.
— Nil.

following geologic ages are represented: Precambrian, Ordovician, Silurian, Devonian and Cretaceous. Limestones of commercial importance occur in the three middle periods and range from magnesian limestone through dolomite to high-calcium limestones[2,15]. Although building stone does not account for a large percentage of total limestone produced, the best known of the Manitoba limestone is Tyndall Stone, a mottled dolomitic limestone often referred to as "tapestry" stone. It is widely accepted as an attractive building stone, and is quarried at Garson, Manitoba, about 50 kilometres (km) northeast of Winnipeg.

Limestone from Moosehorn, 160 km northwest of Winnipeg and from Mafeking, 40 km east of the Saskatchewan border and 160 km south of The Pas, is transported to Manitoba and Saskatchewan centres for use in the metallurgical, chemical, agricultural and construction industries. Limestone from Steep Rock and from Lily Bay is used by cement manufacturers in Winnipeg, and limestone from Faulkner is now being used by the lime plant at Spearhill. The possibility of utilizing marl, an unconsolidated calcareous material, from deposits in the Sturgeon Lake region of Saskatchewan in the pulp and paper, cement, and lime industries has been investigated. Marl from a deposit 100 km north of Edmonton is being used as raw material in cement manufacture[6,7]. Two limestone deposits in the Lac La Ronge region of northern Saskatchewan are being assessed, principally for use in construction.

The eastern ranges of the Rocky Mountains contain limestone spanning the geologic ages from Cambrian to Triassic, with major deposits in the Devonian and Carboniferous periods in which a wide variety of types occur[16]. In southwestern Alberta high-calcium limestone is mined at Exshaw, Kananaskis and Crowsnest, chiefly for the production of cement and lime, for metallurgical and chemical uses, and for use as a crushed stone. Similar uses are made of limestone quarried at Cadomin, near Jasper[6,7].

In British Columbia, large volumes of limestone are mined each year for cement and lime manufacture, for use by the pulp and paper industry and for various construction applications[6,7]. A large amount is exported to the northwestern United States for cement and lime manufacture. Four companies mined lime-

Table 8. Canada, stone exports and imports, 1975-77

	1975		1976		1977^p	
	(tonnes)	($)	(tonnes)	($)	(tonnes)	($)
Exports						
Building stone, rough	11 609	974 000	10 349	1 013 000	13 494	1 447 000
Crushed limestone, limestone refuse	1 217 564	2 417 000	1 287 976	2 733 000	1 502 484	3 251 000
Stone crude, nes	288 898	976 000	559 125	1 574 000	182 047	683 000
Natural stone, basic products	. .	1 792 000	. .	1 989 000	. .	1 731 000
Total	1 518 071	6 159 000	1 857 450	7 309 000	1 698 025	7 112 000
Imports						
Building stone, rough	18 891	953 000	16 231	937 000	13 755	1 226 000
Crushed limestone, limestone refuse	3 281 801	6 963 000	3 513 824	7 381 000	2 922 669	8 611 000
Crushed stone including stone refuse, nes	84 613	3 537 000	507 860	3 143 000	69 226	3 459 000
Stone crude, nes	2 038	163 000	6 771	351 000	6 469	488 000
Granite, rough	28 525	1 449 000	19 167	922 000	22 156	1 686 000
Marble, rough	5 964	899 000	9 095	1 247 000	7 665	1 153 000
Shaped or dressed granite	. .	1 375 000	. .	1 912 000	. .	842 000
Shaped or dressed marble	. .	1 885 000	. .	1 701 000	. .	1 526 000
Natural stone basic products	. .	584 000	. .	696 000	. .	960 000
Total	3 421 832	17 808 000	4 072 948	18 290 000	3 041 940	19 951 000

Source: Statistics Canada.
^{p}Preliminary; . . Not available; nes Not elsewhere specified.

Table 9. Value of construction in Canada, 1976-78

	1976[1]	1977[2]	1978[3]	Change from 1977 to 1978
	(millions of dollars)			(%)
Building construction				
Residential	12 669	12 951	13 584	4.9
Industrial	1 450	1 652	1 479	−10.5
Commercial	3 628	3 446	3 555	3.2
Institutional	1 595	1 663	1 719	3.4
Other building	1 130	1 230	1 319	7.2
Total	20 472	20 942	21 656	3.4
Engineering construction				
Marine	171	201	221	10.0
Highways, aerodromes	2 394	2 757	2 864	3.9
Waterworks, sewage systems	1 462	1 586	1 653	4.2
Dams, irrigation	124	139	159	14.4
Electric power	2 897	3 691	4 364	18.2
Railway, telephones	1 279	1 409	1 526	8.3
Gas and oil facilities	2 154	2 624	3 054	16.4
Other engineering	2 178	2 404	2 368	−1.5
Total	12 659	14 811	16 209	9.4
Total construction	33 131	35 753	37 865	5.9

Source: Statistics Canada.
[1]Actual; [2]Preliminary; [3]Forecast.

stone on Texada Island, with the entire output being moved by barge to Vancouver and the State of Washington. Deposits on Aristazabal Island have recently been developed for the export market. Other operations at Terrace, Clinton, Westwold, Popkum, Dahl Lake, Doeye River and Cobble Hill produced stone for construction and filler use, and for cement manufacture[17]. Periodically, interest is revived in the possible use of travertine from a British Columbia source.

Granite. In Manitoba at Lac du Bonnet northeast of Winnipeg, a durable, red granite is quarried for building and monument use. Grey granite located east of Winnipeg near the Ontario border is a potential source of building stone.

In British Columbia a light-grey to blue-grey, even-grained granodiorite of medium texture is available from Nelson Island. An andesite has been quarried at Haddington Island, off the northeast coast of Vancouver Island, for use as a building stone.

Sandstone. Sandstone for building and ornamental uses, quarried near Banff, Alberta is hard, fine-grained, medium-grey and is referred to as "Rundal Stone".

Markets, outlook and trade

Limestones are widely distributed in Canada and generally are available in sufficient quantity and with such chemical or physical specifications that long transportation hauls are unnecessary. Limestone products are low-priced commodities and only rarely, when a market exists for a high-quality, specialized product such as white portland cement or a high-purity extender, are they beneficiated or moved long distances. Provided the specifications are met, the nearest source is usually considered, regardless of provincial or national boundaries.

Over 70 per cent of Canada's annual production of limestone is used as crushed stone. This includes about 50 per cent used as road metal (broken, screened stone for asphalt roads), about 20 per cent as concrete aggregate and about 2 per cent as railroad ballast.

Some major uses in the chemical field are: neutralization of acid waste liquors; extraction of aluminum oxide from bauxite; manufacture of soda ash, calcium carbide, calcium nitrate and carbon dioxide; in pharmaceuticals; as a disinfectant; in the manufacture of dyes, rayons, paper, sugar and glass; and in the treatment of water. Dolomitic limestone is used in the production of magnesium chloride and other magnesium compounds.

Limestone is used in the metallurgical industries as a fluxing material where it combines with impurities in ore to form a fluid slag that can be separated from molten metal. Calcium limestones are used in open-hearth steel manufacture, whereas both calcium limestones and dolomitic limestones are used as a flux in

Table 10. Canada, value of construction work performed by principal type of construction, by industry, 1975-78

Industry	1975[1]			1976[1]			1977[2]			1978[3]		
	Building	Engi-neering	Total	Building	Engi-neering	Total	Building	Engi-neering	Total	Building	Engi-neering	Total
	(millions of dollars)											
Agriculture & fishing	435	235	670	481	262	743	554	301	855	600	327	927
Forestry	20	104	124	20	115	135	21	140	161	19	151	170
Mining, quarrying, oil wells	318	1 952	2 270	351	2 374	2 725	390	2 858	3 248	226	3 132	3 358
Construction	98	1	99	136	2	138	147	2	149	154	2	156
Manufacturing	1 175	776	1 951	1 116	762	1 878	1 298	857	2 155	1 221	926	2 147
Utilities	594	4 507	5 101	489	4 737	5 226	557	5 676	6 233	697	6 476	7 173
Trade	429	20	449	493	25	518	463	18	481	468	20	488
Finance, insurance, real estate	1 544	110	1 654	1 612	239	1 851	1 628	176	1 804	1 657	170	1 827
Commercial services	892	5	897	643	6	649	349	13	362	362	10	372
Housing	8 690	—	8 690	12 669	—	12 669	12 951	—	12 951	13 584	—	13 584
Institutional services	1 334	20	1 354	1 341	15	1 356	1 374	15	1 389	1 465	15	1 480
Government departments	1 080	4 037	5 117	1 121	4 122	5 243	1 210	4 755	5 965	1 203	4 980	6 183
Total	16 609	11 767	28 376	20 472	12 659	33 131	20 942	14 811	35 753	21 656	16 209	37 865

Source: Statistics Canada.
[1]Actual; [2]Preliminary; [3]Forecast.
— Nil.

the production of pig iron in blast furnaces.

Limestone is used extensively as a filler or an extender and, where quality permits, as whiting. In such applications both physical and chemical properties are important. Specifications vary widely but, in general, a uniform, white material passing 325 mesh would meet the physical requirements. Whiting is used in ceramic bodies, plastics, floor coverings, insecticides, paper, wood putty, rubber, paints and as a filler in many other commodities. In paint manufacture the material may be used as a pigment extender.

Agricultural limestone is used to control soil acidity and to add calcium and magnesium to the soil. Limestone and lime are used as soil stabilizers, particularly on highway construction projects.

Dolomite is the source of magnesium metal produced at Haley, Ontario; the company also uses a high-calcium lime from southeastern Ontario in the production of calcium metal. Dead-burned dolomitic limestone for use as a refractory is produced at Dundas, Ontario, by Steetley of Canada (Holdings) Limited.

Limestone from deposits in coastal areas of British Columbia is mined, crushed, loaded on barges of up to 20 000 tonnes capacity, and transported as much as 600 km to consuming centres along the west coast in both Canada and the United States. One Canadian company, Domtar Inc. manufactures lime at Tacoma, Washington, using limestone from Texada Island.

Crushed stone will continue to compete with sand and gravel for major markets where the latter are scarce. Through vertical integration, large operations based on construction materials can, by mergers and acquisitions, obtain captive markets for their products in operating construction firms. Construction firms can also integrate backwards into the resource field.

The possibility of substitutes for aggregates is not likely to occur soon in Canada, although in countries where such resources are scarce other materials such as compressed garbage are being used. The use of lime or cement to stabilize soils could reduce the amount of aggregate fill required on some highway or railway projects.

Traditional markets for building stone have been lost to competitive building materials such as steel and concrete. Modern design and construction methods favour the flexibility offered by use of steel and precast or cast-in-place concrete. For aesthetic qualities not available in other materials, rough or polished stone is used in many modern structures. Monumental stone continues to be in demand.

The present structure of the building stone industry in Canada is unlikely to change very soon. Recent efforts have been made on behalf of the industry to illustrate to contractors and architects the availability of a wide range of Canadian building stones and their adaptability in modern building design.

There is justifiable concern for the future development, operation, and rehabilitation of pits and quarries in all locations, especially in and near areas of urban development. Rehabilitation of stone quarries for subsequent land use is generally more difficult and costly than rehabilitation of gravel pits.

Although an open-pit mining operation close to residential areas is seldom desirable, nonrenewable mineral resources must be fully and wisely utilized. Where urban sprawl has been unexpectedly rapid, conflicts for land use can materialize and potential sources of raw mineral materials for the construction industry can be overrun. Master plans for land use are required to co-ordinate all phases of development so that mineral exploitation is part of the urban growth pattern.

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Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
		(%)	(%)	(%)	(%)
29635-1	Limestone, not further processed than crushed or screened	free	free	25	free
30500-1	Flagstone, sandstone and all building stone, not hammered, sawn or chiselled	free	free	20	free
30505-1	Marble, rough, not hammered or chiselled	10	10	20	free
30510-1	Granite, rough, not hammered or chiselled	free	free	20	free
30515-1	Marble, sawn or sand rubbed, not polished	free	10	35	free
	General Agreement on Tariffs and Trade		5		
30520-1	Granite, sawn	free	7½	35	free
30525-1	Paving blocks of stone	free	7½	35	free
30530-1	Flagstone and building stone, other than marble or granite, sawn on not more than two sides	free	7½	35	free
30605-1	Building stone, other than marble or granite, sawn on more than two sides but not sawn on more than four sides	5	7½	10	5
30610-1	Building stone, other than marble or granite planed, turned, cut or further manufactured than sawn on four sides	7½	12½	15	7½
30615-1	Marble, not further manufactured than sawn, when imported by manufacturers of tombstones to be used exclusively in the manufacture of such articles, in their own factories	free	15	20	free
	General Agreement on Tariffs and Trade		free		
30700-1	Marble, nop	17½	17½	40	11½
30705-1	Manufacturers of marble, nop	17½	17½	40	11½
30710-1	Granite, nop	17½	17½	40	11½
30715-1	Manufacturers of granite, nop	17½	17½	40	11½
30800-1	Manufacturers of stone, nop	17½	17½	35	11½
30900-1	Roofing slate, per square of 100 square feet	free	free	75¢	free
30905-1	Granules, whether or not coloured or coated, for use in manufacture of roofing, including shingles and siding	free	free	25	free

United States

Item No.		
513.21	Marble chips and crushed	5% ad valorem
513.61	Granite, not manufactured, and not suitable for use as monumental, paving or building stone	free
514.11	Limestone, crude, not suitable for use as monumental, paving or building stone, per short ton	10¢
514.91	Quartzite, whether or not manufactured	free
515.11	Roofing slate	12.5% ad valorem
515.14	Other slate	5% ad valorem
515.41	Stone, other, not manufactured and not suitable for use as monumental, paving or building stone	free

Sources: For Canada, the Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division. For United States, Tariff Schedules of the United States, Annotated (1978) T.C. Publication 843.
Note: Varying tariffs are in effect on the more-fabricated stone categories.
nop Not otherwise provided for.

Sulphur

G.H.K. PEARSE

Sulphur, one of the most important industrial raw materials, is distributed throughout the world in both elemental and combined forms. It has been used by man since antiquity and today is used at some stage in the production of almost everything we eat, wear or use. More than half of the world's sulphur output is in elemental form, nearly all obtained from native sulphur deposits and sour natural gas. The remainder is recovered from pyrite and smelter stack gases, principally as sulphuric acid, in which form 87 per cent of all sulphur is consumed. Fertilizer manufacture accounts for over half of all sulphur consumed, followed by chemicals, pigments, and pulp and paper as the next-largest consuming sectors.

World sulphur production in all forms at 52.5 million tonnes* in 1977 is little changed from the previous three years. Western world production declined for the third consecutive year. The 33.3 million-tonne output is 8 per cent below the peak year, 1974.

World consumption, on the other hand, rose an estimated 6.0 per cent to a new high of 50.5 million tonnes. Western world consumption equalled production for the first time since 1971.

Canada's total elemental sulphur sales in 1977, a record 5.2 million tonnes, were 30 per cent greater than in 1976. Sulphur stockpiles on the prairies were 20.1 million tonnes at year-end.

The Canadian sulphur industry

Canadian sulphur is obtained from three sources: elemental sulphur derived from sour natural gas and petroleum, sulphur recovered from smelter gases in the form of sulphuric acid, and sulphur contained in pyrite concentrates used in sulphuric acid manufacture. Minor tonnages of elemental sulphur are recovered as a byproduct of electrolytic refining of nickel sulphide matte, and liquid sulphur dioxide is produced from pyrites and smelter gases. In 1977, 87 per cent of Canadian sulphur shipments were in elemental form, nearly all from sour natural gas in western Canada. Canada has been the world's largest exporter of elemental sulphur since 1968.

Canadian elemental sulphur production from sour natural gas rose marginally in 1977 after three consecutive years of decline.

Hydrocarbon sources. Where the sulphur content of hydrocarbons is unacceptably high, as it is in many gas reservoirs in western Canada, it must be removed. Highly toxic and corrosive hydrogen sulphide (H_2S), the dominant sulphur compound occurring in sour natural gas, is presently the most important source of sulphur in Canada.

Sulphur recovery from Athabasca oil sands and crude oil is comparatively minor at present, and from coal is virtually nil. However, with increasing energy requirements, and stringent air pollution regulations coming into force, these vast sources of sulphur will, in future, contribute substantially to world supply.

Sour natural gas. Although the H_2S content of sour gas fields ranges as high as 91 per cent by weight, most producing fields contain from 1 to 20 per cent. The modified Claus process is used to recover sulphur from sour natural gas. H_2S is extracted by absorption into a solution of either diethanolamine, monoethanolamine, hot potassium carbonate, or sulfinol. The solution is heated in a stripper tower where H_2S is evolved. The H_2S passes into a furnace where partial oxidation and reaction occurs as follows:

$$2H_2S + 3O_2 \leftrightarrows 2H_2O + 2SO_2$$

$$2H_2S + SO_2 \leftrightarrows 2H_2O + 3S$$

Gas from this furnace enters a condenser-converter series and liquid sulphur is removed in each unit until 95 per cent or more of the original sulphur has been drawn off. The liquid sulphur is fed into underground storage for pumping to: outside blocks (vats) where the liquid solidifies; storage tanks, for direct shipping to

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

North American markets in liquid form; a slating plant, where it is quenched in water on a special belt, subsequently breaking up into "slates"; or to a prilling plant.

A variety of prilling or pelletizing processes have been under investigation over the years and a few have been commercialized in Europe; the Sulpel and Kaltenback processes, which use water as a quenching medium; and a Polish process and the French Perlomatic process which use rising currents of air as a quenching medium. A 300-tonne-a-day Perlomatic plant was in-

Table 1. Canada, sulphur production and trade, 1976-77

	1976		1977^p	
	(tonnes)	($)	(tonnes)	($)
Production				
Pyrite and pyrrhotite[1]				
Gross weight	30 754	. .	19 000	. .
Sulphur content	15 377	240 638	9 500	197 000
Sulphur in smelter gases[2]	705 327	18 582 011	766 000	20 185 000
Elemental sulphur[3]	4 029 427	70 170 815	4 910 000	72 717 000
Total sulphur content	4 750 131	88 993 464	5 685 500	93 099 000
Imports				
Sulphur, crude or refined				
United States	15 717	1 111 000	14 065	774 000
Total	15 717	1 111 000	14 065	774 000
Exports				
Sulphur in ores (pyrite)				
United States	. .	152 000	. .	212 000
Total	. .	152 000	. .	212 000
Sulphuric acid and oleum (contained sulphur)				
United States	114 385	6 872 000	92 042	5 294 000
Other countries	. .	8 000	1 906	103 000
Total	114 392	6 880 000	93 948	5 397 000
Sulphur, crude or refined, nes				
United States	1 011 423	18 647 000	1 181 425	18 701 000
Australia	224 797	9 066 000	347 289	12 839 000
South Africa	292 367	11 008 000	371 700	12 396 000
Brazil	270 370	7 535 000	370 473	10 756 000
Taiwan	150 137	6 078 000	225 063	8 589 000
People's Republic of China	21 928	739 000	241 721	8 484 000
New Zealand	152 682	6 151 000	210 684	8 001 000
Italy	243 259	5 131 000	257 256	6 942 000
India	214 982	7 599 000	184 924	6 329 000
France	132 809	5 809 000	124 085	4 359 000
Netherlands	214 855	6 839 000	100 179	3 612 000
Tunisia	137 473	5 004 000	95 682	3 321 000
South Korea	77 484	3 260 000	82 375	3 074 000
Mozambique	37 453	1 532 000	79 284	2 749 000
Other countries	537 973	15 495 000	418 867	11 923 000
Total	3 719 992	109 893 000	4 291 007	122 075 000

Source: Statistics Canada.
[1]Producers' shipments of byproduct pyrite and pyrrhotite from the processing of metallic sulphide ores. [2]Sulphur in liquid SO_2 and H_2SO_4 recovered from the smelting of metallic sulphides and from the roasting of zinc-sulphide concentrates. [3]Producers' shipments of elemental sulphur produced from natural gas; also included are small quantities of sulphur produced in the refining of domestic crude oil and from the treatment of nickel-sulphide matte.
^{p} Preliminary; . . Not available; nes Not elsewhere specified.

stalled at Petrogas Processing Ltd's Balzac, Alberta operation and the product is mainly used as a soil nutrient.

Declining production has led to the development of sulphur melters to reclaim from vatted storage. Melters will become important in Canada's sulphur supply picture over the next few years.

In 1977, 46 sour gas sulphur plants were operating, including one in Saskatchewan and two in British Columbia, with a combined daily capacity of 27 039 tonnes, up 3 per cent from the previous year. Two new plants: Hudson's Bay Oil and Gas Company Limited's (HBOG) 74-tonne-a-day Zama plant and Aquitaine's 6-tonne-a-day Wimborne plant; and expansions to Shell Canada Resources Limited's Burnt Timber plant (190 to 403 tonnes a day) and Westcoast Transmission Company Limited's Fort Nelson plant (254 to 1 118 tonnes a day) accounted for the increment.

Production of elemental sulphur from natural gas in Alberta, as reported by the Alberta Energy Resources Conservation Board, was 6 324 880 tonnes in 1977, up less than one per cent from 1976. Production in British Columbia was 149 000 tonnes, more than double the previous year; and, in Saskatchewan, 1 800 tonnes. Total production was 6 475 680 tonnes.

Alberta sulphur sales were a record 5 102 620 tonnes in 1977, up 31 per cent from 1976. Reflecting a decline in prices, the value of sales increased only 16 per cent to $76 million. Alberta inventories stood at 20 056 000 tonnes at December 31, 1977. British Columbia and Saskatchewan elemental sulphur sales were 42 000 tonnes and 2 500 tonnes, respectively, and inventories were 279 000 tonnes and 5 000 tonnes.

Canadian elemental sulphur productive capacity, having doubled between 1968 and 1972, reached a plateau in 1973 from which output has declined almost one million tonnes. Only one new plant, the 18-tonne-a-day Stoney Indian Reservation plant, a PanCanadian Petroleum Limited — Morely Indian Band joint venture, is scheduled for completion late in 1978. Shell Canada Resources Limited's 155-tonne-a-day South Rosevear plant, under construction, will open by summer 1979, and Westcoast Transmission's Pine River, British Columbia plant with a capacity of 1 120 tonnes a day is expected to be ready in late 1979 or early 1980.

Higher gas prices and federal and provincial incentives have stimulated exploration, especially in the foothills belt in which most sour gas sulphur occurs. Several significant discoveries are under evaluation. With a lag of three to four years between discovery and plant start-up however, a marked increment in sulphur capacity cannot be expected before 1980-81.

Pollution abatement guidelines for natural gas plants laid down in November 1971 by the Alberta government include: mandatory stack clean-up facilities and recovery efficiencies between 97 and 99 per cent, depending on acid gas quality, for plants rating over 1 016 tonnes a day; minimal stack clean-up, or equipment with efficiency between 94 and 98 per cent, for plants rated between 406 and 1 016 tonnes a day; at least a three-stage Claus unit or equivalent, with efficiency between 92 and 96 per cent for 102-to 400-tonne plants; and a two-stage Claus unit with recovery efficiency between 90 and 94 per cent for smaller plants. As of December 31,1976 all Alberta plants comply with the requirements.

Prior to 1974, all sulphur destined for offshore markets was railed to loading terminals at Vancouver, some 650 miles from processing plants. For three years sulphur was shipped via Churchill, Manitoba; Thunder Bay, Ontario and Quebec City, Quebec. In 1977 no shipments were made through these ports, however, they could become important with the recovery of sulphur markets.

Athabasca oil sands. The Athabasca oil sands constitute a vast deposit of relatively unconsolidated sandstone impregnated with bitumen, covering some 30 000 square miles of northeastern Alberta. The estimated 300 billion barrels of recoverable oil in the formation contain about 2 billion tonnes of sulphur.

In 1967 Great Canadian Oil Sands Limited (GCOS) completed the first commercial oil-sand extraction plant at a cost of $240 million. The ancillary sulphur recovery plant is designed to produce 300 tonnes of sulphur daily. Sulphur production was 93 492 tonnes in 1977. Twinning of the sulphur unit to permit the expanded production required was completed in 1977.

Shipments of sulphur from GCOS began in October 1974 from Quebec City, destined for offshore markets, and reached 81 000 tonnes in 1976. Shipments of 7 963 tonnes to an Alberta customer were the only sales in 1977.

Another project, that of Syncrude Canada Ltd., is under construction and is expected to be completed in May 1978. It is designed to produce 125 000 b/d of synthetic crude oil and products and, when fully geared up in 1980, the total annual sulphur capacity from the tar sands will be some 400 000 tonnes. Imperial Oil Limited has applied for a permit to build the first commercial oil sands plant using *in situ* thermal technology. This could be in operation by 1985. Beyond this, it appears that two other projects originally scheduled for completion in the early 1980s, those of the Petrofina Canada Ltd. group and Shell Canada Limited, will now not likely come on stream before 1985, if at all. Sulphur from such projects could reach 2 million tonnes annually by the year 2000.

Oil refineries. Some crude oils contain as much as 5 per cent sulphur, either as hydrogen sulphide or in other compounds. Domestic crudes generally contain less than 1 per cent sulphur. The sulphur may either be removed in the form of H_2S, or treated to form nondeleterious di-sulphides. Recovery techniques employed during oil refining are similar to those used in the removal of sulphur from sour gas.

In Canada, sulphur is recovered from imported crudes at oil refineries in Nova Scotia, New Brunswick,

Table 2. Canada, sour gas sulphur extraction plants, 1977

Operating Company	Source Field or Plant Location	H_2S in Raw Gas	Daily Capacity
	(Alberta, except where noted)	(%)	(tonnes)
Amerada Hess Corporation	Olds	11	389
Amoco Canada Petroleum	Bigstone Creek	19	400
Amoco Canada Petroleum	East Crossfield	34	1 828
Aquitaine Company of Canada	Rainbow Lake	4	142
Aquitaine Company of Canada	Ram River	9-35	4 580
Aquitaine Company of Canada	Wimborne		6
Petro-Canada	Gold Creek		42
Saratoga Processing Company	Savannah Creek (Coleman)	13	405
Canadian Occidental	Taylor Flats, B.C.	3	330
Canadian Superior Oil	Harmattan-Elkton	53	490
Canadian Superior Oil	Lonepine Creek	12	153
CanDel Oil	Minnehik-Buck Lake		44
Chevron Standard	Kaybob South	19	3 520
Chevron Standard	Nevis	7	262
Gulf Oil Canada	Nevis	3-7	295
Gulf Oil Canada	Pincher Creek	10	199
Gulf Oil Canada	Rimbey	1-3	353
Gulf Oil Canada	Strachan	10	970
Home Oil	Carstairs	1	80
Hudson's Bay Oil and Gas	Brazeau River	1	91
Hudson's Bay Oil and Gas	Caroline	1	24
Hudson's Bay Oil and Gas	Edson	2	290
Hudson's Bay Oil and Gas	Hespero (Sylvan Lake)	1	17
Hudson's Bay Oil and Gas	Kaybob South (1)	17	1 087
Hudson's Bay Oil and Gas	Kaybob South (2)	17	1 036
Hudson's Bay Oil and Gas	Lonepine Creek	10	283
Hudson's Bay Oil and Gas	Sturgeon Lake South	10	97
Hudson's Bay Oil and Gas	Zama		74
Imperial Oil	Joffre		18
Imperial Oil	Quirk Creek	9	307
Imperial Oil	Redwater	3	34
Mobil Oil Canada	Wimborne	14	364
Petrofina Canada	Wildcat Hills	4	177
Petrogas Processing	Crossfield (Balzac)	31	1 727
Shell Canada	Burnt Timber Creek	8-5	403
Shell Canada	Innisfail	14	160
Shell Canada	Jumping Pound	3-5	539
Shell Canada	Simonette River	15	266
Shell Canada	Waterton	18-25	3 024
Steelman Gas	Steelman, Sask.	1	7
Sun Oil	Rosevear		84
Texaco Exploration	Bonnie Glen		13
CDC Oil & Gas Limited	Nordegg		45
Texasgulf Inc.	Okotoks	36	459
Texasgulf Inc.	Windfall	16	1 240
Westcoast Transmission	Fort Nelson, B.C.		1 118
Western Decalta	Turner Valley	4	10
Total Daily rated capacity — December 31, 1977			27 482

Sources: Compilation by *Oilweek;* "H_2S in Raw Gas" figures from Alberta Energy Resources Conservation Board publications.

Newfoundland and Quebec, and from domestic crudes at oil refineries near Toronto, Sarnia, Winnipeg, Edmonton and Vancouver. Total sulphur output from refineries in 1977 was an estimated 160 000 tonnes, including 60 000 tonnes from Montreal refineries alone. This recovery represents only 20 per cent of total sulphur contained in the crude.

Coal and oil shales. Coke oven gases generally contain some hydrogen sulphide, the quantity dependent upon the sulphur content of the coal being carbonized. Ordinarily the H_2S is removed in "iron oxide boxes", but it can also be recovered and converted to elemental sulphur.

In response to the demand for increasing amounts of clean fuel, numerous research projects have been initiated over the years with the aim of developing high quality, pollution-free gas from coal. Middle East oil supply cutbacks near the end of 1973, have given further impetus to gasification projects and oil shale studies. Annual sulphur recovery from these sources, largely in the United States, could reach 1 million tonnes by 1990 and 5 million tonnes by the end of this century. Although coal in western Canada is low in sulphur (less than 0.5%), coal from the Maritimes is notably sulphurous. With more stringent pollution regulations coming into force, coal gasification may become the only way in which this energy source can be utilized in the future.

Table 3. Proposed new sulphur capacity for 1978

Operating Company	Location	Proposed Daily Rated Capacity
		(tonnes)
PanCanadian Petroleum	Stoney Indian Reservation	18

Source: *Oilweek.*

Metallic sulphide sources. In Canada the use of metallic sulphides for their sulphur content dates back to 1866. Early operations consisted essentially of roasting pyrite for the direct manufacture of sulphuric acid. In the 1920s the use of base-metal smelter gases for the manufacture of byproduct H_2SO_4 began near Sudbury, Ontario, and at Trail, British Columbia. Virtually all Canada's sulphur production was from metallic sulphides prior to 1951 when the first sour gas sulphur recovery plant was built. In 1977 metallic sulphides, including smelter gas sulphur, provided an estimated 780 000 tonnes of contained sulphur.

Smelter gases. Effluent gas from smelting sulphide ores contains from 1 to 12 per cent sulphur dioxide (SO_2). Recovery of SO_2 includes processes for cleaning, purifying, cooling and concentrating. Concentrated SO_2 is then used directly for the manufacture of H_2SO_4 via the contact-acid process. Also, as much as 170 000 tonnes (85 000 tonnes sulphur content) of liquid SO_2 is produced for use as a processing agent in a variety of applications. Some SO_2 is used for the manufacture of oleum (fuming sulphuric acid, $H_2S_2O_7$). Total production in 1977 of sulphur contained in smelter gases was 766 000 tonnes, up 8 per cent from the previous year.

Persistence of recessionary demand for nonferrous metals has resulted in postponement of some smelter projects and cutbacks in production.

The largest sulphuric acid plant complex in Canada is that of Canadian Industries Limited (CIL) at Copper Cliff, Ontario. The company operates three acid plants that have a combined annual capacity of 900 000 tonnes of H_2SO_4 based on SO_2 gas from Inco Limited's iron ore recovery plant. In addition, CIL has a liquid sulphur dioxide plant at Inco's nearby Copper Cliff smelter. Much of the acid produced at Copper Cliff is shipped by unit-train about 475 miles to CIL's fertilizer works near Sarnia, Ontario. The company owns a sulphuric acid depot at Niagara Falls, Ontario, which consists of a 60 000-short-ton storage tank and equipment for unloading unit-trains and loading tank cars and trucks. Acid from Copper Cliff is shipped directly to the facility via 56-car unit-trains.

Subsidiaries of Noranda Mines Limited produce smelter acid at three localities: Gaspé Copper Mines, Limited's 245 000-tonne-a-year plant at Murdochville, Quebec; Brunswick Mining and Smelting Corporation Limited's 125 000-tonne-a-year plant at Belledune, New Brunswick; and Canadian Electrolytic Zinc Limited's zinc concentrate roasting facility at Valleyfield, Quebec with a capacity of 120 000 tonnes a year. Expanded zinc capacity at the latter is idle in the face of soft markets. A proposed new copper smelter and associated 100 000-tonne-a-year sulphuric acid installation to be built at Noranda, Quebec has been shelved for the time being.

Cominco Ltd.'s sulphuric acid capacity at Trail, British Columbia, based on its lead-zinc smelter, was increased 30 per cent in 1975 to 440 000 tonnes a year with the replacement of the older units by a single plant. Further expansion is planned for the early 1980s. Acid capacity at the company's Kimberley plant is 280 000 tonnes a year. Much of the acid produced is used by Cominco in the manufacture of fertilizers.

Allied Chemical Canada, Ltd. produces sulphuric acid from the roasting of zinc concentrates supplied under agreement with Canadian Electrolytic Zinc Limited whereby Allied retains the acid for its own use and delivers the zinc calcine to Canadian Electrolytic Zinc's nearby refinery.

Texasgulf Canada Ltd.'s Timmins, Ontario zinc plant has a sulphuric acid capacity of 200 000 tonnes a year. An expansion plan to raise acid output to 400 000

Table 4. Canada, principal sulphur operations based on metallic sulphides, 1977

Operating Company	Plant Location	Raw Material	Annual Capacity 100% H_2SO_4	Annual Capacity Approx. S. equiv.
			(tonnes)	
Smelter gases				
Brunswick Mining and Smelting	Belledune, N.B.	SO_2 lead-zinc	125 000	42 000
Allied Chemical	Valleyfield, Que.	SO_2 zinc conc.	140 000	47 000
Canadian Electrolytic Zinc	Valleyfield, Que.	SO_2 zinc conc.	120 000	40 000
Canadian Industries[1]	Copper Cliff, Ont.	SO_2 pyrrhotite	900 000	300 000
Cominco[1]	Trail, B.C.	SO_2 lead-zinc	440 000	145 000
	Kimberely, B.C.	SO_2 pyrrhotite	280 000	92 000
Texasgulf Canada Ltd.	Timmins, Ont.	SO_2 zinc conc.	205 000	70 000
Gaspé Copper Mines	Murdochville, Que.	SO_2 copper	245 000	82 000
Total			2 435 000	895 000
Pyrite and pyrrhotite				
Noranda Mines	Noranda, Que.	Sulphide ore	Pyrite concentrate[2]	
Normetal Mines Limited	Normetal, Que.	Sulphide ore	Pyrite concentrate[2]	

Sources: Company data.
[1]Does not include 85 000 tonnes sulphur content in liquid SO_2 production. [2]Currently inactive.

tonnes by 1978 has been stretched out a couple of years and a second stage to raise capacity to 560 000 tonnes by 1979 has been shelved. A proposed associated phosphate fertilizer works has also been deferred.

Falconbridge Nickel Mines Limited is continuing with construction of its $95-million electric smelter and associated 1 180-tonne-a-day acid plant. It is expected to be finished by April 1978.

Shipments of acid and oleum to the United States in 1977 were 92 042 tonnes of contained sulphur.* Small amounts were shipped elsewhere, mainly to the West Indies.

Pyrite and pyrrhotite. Pyrite and pyrrhotite concentrates produced as a byproduct of base metal mining operations are sometimes marketed for their sulphur content. A distinction is made in this review between this category of sulphur and that converted to SO_2 at integrated base metal operations. For example, although most of the acid production at Copper Cliff, Ontario is dependent upon the roasting of iron sulphides, the sulphur production is reported as smelter gases. In other instances, however, the iron sulphide concentrates are sold and shipped for roasting elsewhere and are reported as pyrite and pyrrhotite production.

Conversion to elemental sulphur feed at acid plants has resulted in a drastic reduction in pyrite usage. Noranda discontinued pyrite sales in 1973. In 1977, Canada's pyrite and pyrrhotite shipments amounted to an estimated 19 000 tonnes of concentrates (9 500 tonnes contained sulphur).

*Obtained by multiplying H_2SO_4 tonnage by 0.327.

Canada consumption and trade

In 1977 Canadian consumption of sulphur in all forms, as reported by consumers, amounted to about 1.4 million tonnes.

Canada remains the largest exporter of elemental sulphur, having shipped 4 450 000 tonnes in 1977. From the outset the United States has been the principal destination for Canadian sulphur and presently accounts for about 30 per cent of Canadian exports. Sales to the United States were up 34 per cent from 1976, to a record 1.2 million tonnes. For the first time, sulphur was shipped from Vancouver to the United States east coast. Shipments to Europe, which had almost quadrupled between 1971 and 1974 largely as a result of major increases in Dutch, British and Italian purchases, were down 22 per cent from those of 1976, to an estimated 672 000 tonnes. This is almost entirely because of a more than 50 per cent decline in shipments to the Netherlands and Belgium. Asian sales increased 57 per cent to a record 805 000 tonnes, reflecting the return of the Peoples Republic of China to the market. Although Australasia's Canadian purchases totalling 569 000 tonnes were 53 per cent higher than those of 1976, this was well below the 685 000-tonne peak of 1974.

Sales to South America and Africa (mainly Brazil and South Africa) each rose to over 500 000 tonnes, together accounting for 25 per cent of total exports.

Table 5. Canada, sulphur production and trade, 1960, 1965, 1970, 1975-77

	Production				Imports	Exports	
	Pyrites[1]	In Smelter Gases	Elemental Sulphur	Total	Elemental Sulphur	Pyrites[2]	Elemental Sulphur
			(tonnes)			($)	(tonnes)
1960	397 157	262 739	248 894	908 790	298 251	1 259 151	129 764
1965	169 607[r]	403 478[r]	1 876 415[r]	2 449 500[r]	147 146[r]	978 828	1 358 915[r]
1970	159 222	640 360[r]	3 218 973[r]	4 018 555[r]	48 494[r]	1 226 000	2 711 069[r]
1975	10 560	694 666	4 078 780	4 784 006	14 335	170 000	3 284 246
1976	15 377	705 327	4 029 427	4 750 131	15 717	152 000	3 719 992
1977[p]	9 500	766 000	4 910 000	5 685 500	14 065	212 000	4 291 007

Source: Statistics Canada.
[1]See footnotes for Table 1. [2]Figures for quantities of pyrites exported not available.
[p]Preliminary; [r]Revised.

World review

World sulphur production has been virtually stagnant since 1974 as a result of reduced output from both voluntary and involuntary byproduct operations in the western world. The cutbacks were, in part, in response to reduced demand, but more permanent constraints to production among several major world suppliers have become manifest over the past few years. The effects of exhaustion of reserves, limited exploration success and prohibitive energy costs in established producing areas have been further magnified by slower-than-anticipated developments in new source areas.

Depressed market conditions affecting most industries continued through 1977. The fertilizer industry was an exception. Large increases in phosphate fertilizer prices in 1975 and weather conditions unfavourable to fertilizer consumption in 1976 had resulted in excessive inventories. However, recovery in late 1976 strengthened during 1977 and was the main component in a six per cent increase in sulphur consumption.

The USSR surpassed the United States to become the world's leading producer of sulphur in 1977 with an estimated output of 10.8 million tonnes. Production doubled during the last ten years as a result of strong growth in both the elemental sulphur and pyrite industries, a period during which pyrite output was declining elsewhere. Frasch and sour-gas sulphur projects have become important in the last few years and it is expected that these sources will account for most future growth in the USSR sulphur industry.

Development of the Frasch mining techniques in 1895 made large tonnages of low-cost sulphur available to world markets and established the United States as the world's foremost producer of sulphur, a position it held for over 50 years. In 1977 United States Frasch production fell for the third consecutive year, dropping to 5.91 million tonnes, the lowest output since 1965. Recovered elemental sulphur, principally from sour natural gas, increased 13 per cent to 3.59 million tonnes. Stocks decreased by 90 000 tonnes to 5.56 million tonnes. Exports in 1977 at 1.06 million tonnes were 10 per cent below that of the previous year, and the lowest export tonnage since 1946. Imports were up 14 per cent to 2.01 million tonnes. Domestic consumption increased 9 per cent to a record 10.58 million tonnes of elemental sulphur. Texasgulf Inc. closed the Fannett Frasch operation early in 1977, citing reserve depletion and high costs.

Table 6. Canadian export markets for sulphur, 1977

Country or Area	Exports	Per cent of total
	(million tonnes)	
United States	1.18	27.5
Europe	.66	15.3
South Africa	.37	8.7
Brazil	.37	8.6
Australia	.35	8.1
Italy	.26	6.0
People's Republic of China	.24	5.6
Taiwan	.23	5.3
Others	.63	14.9
Total	4.29	100.0

Source: Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.

Mexican elemental sulphur production decreased 20 per cent in 1977 to 1.6 million tonnes. Domestic shipments, which have tripled in six years in response to growth in the fertilizer industry, were an estimated 750 000 tonnes in 1977. Mexico's exports were 1.05

million tonnes, little changed from the previous year. This figure is 45 per cent less than for the peak year, 1974.

Production of elemental sulphur in 1977 from the Lacq sour natural gas field in France was 1.8 million tonnes, a production plateau first reached in 1969. Exports increased by 50 per cent to 1.04 million tonnes in 1977, returning to a level maintained for many years.

Elemental sulphur from sour gas in northern West Germany and from oil refineries increased an estimated 30 per cent to 790 000 tonnes.

Table 7. Canada sulphur consumption, 1960, 1965, 1970, 1975-77

	From Pyrites and Smelter Gases[e]	Sulphur[1,2]	Total
	(tonnes)		
1960	500 938	508 514	1 009 452
1965	445 225[r]	670 604[r]	1 115 829[r]
1970	693 952	763 661[r]	1 457 613[r]
1975	691 118	832 702[r]	1 523 820[r]
1976	710 992	653 723[p]	1 364 716[p]
1977[p]	765 278	. .	. .

Source: Statistics Canada.
[1]As reported by consumers. [2]Includes elemental (lump, powder, liquid, etc.) sulphur, and liquid sulphur dioxide (sulphur content only).
[e]Estimated by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa. [p]Preliminary; . . Not available; [r]Revised.

Polish production at 5.1 million tonnes was similar to 1976. Elemental sulphur output was 4.8 million tonnes. Exports expanded 13 per cent to nearly 4 million tonnes, almost entirely because of increased shipments to West Europe and North Africa.

Iraq became a significant producer of elemental sulphur in 1973. Capacity is reported to have reached 1 million tonnes a year, but no major expansion to the estimated 750 000-tonne output is expected until improved rail transport capability to the Persian Gulf port of Umm Qasr, 450 miles to the south, is completed. Shipments by truck for Mediterranean customers was begun in 1974 but political strife in Lebanon has stalled development of this transportation mode.

Outlook

Demand. The near-term outlook for sulphur is for a tightening of markets, despite the likelihood that recovery in world industrial demand will not be dramatic. This is based on the view that non-market constraints to supply, which have been developing over the past few years, are not amenable to quick resolution.

For the longer term, fertilizer manufacture, under the stimulus of world food requirements and the expansion of modern agricultural practice in Asia, Africa and Latin America, will continue to consume a growing portion of sulphur output. Many observers interpret growing substitution by hydrochloric and other acids in the important pigment, steel-pickling and oil-refining sectors as presaging an overall moderation of sulphur consumption growth. Such a view may be too pessimistic. Sulphur's role in the manufacture of substitute reagents must be taken into account; for example, the expected switch to hydrofluoric acid in petroleum refining could result in an increase in sulphur consumption, since three tonnes of H_2SO_4 are needed to produce one tonne of HF. Also, in addition to conventional fertilizer use, attention has been drawn in recent years to sulphur's important role as a plant nutrient and to sulphur deficiencies in the soil over broad areas throughout the world. An area of growth in the "other uses" category is that of uranium production. Uranium ore leaching requires 30 to 50 tonnes of sulphuric acid per tonne of uranium in the ore, plus additional acid indirectly in the manufacture of hydrofluoric acid and other chemicals used in processing. Demand for sulphur contained in acid for world uranium production in 1975 was an estimated 350 000 tons.

Table 8. Canada, consumption of sulphur[1] by industry

	1975	1976[p]
	(tonnes)	
Fertilizers	453 160	239 211
Pulp and paper	260 849	268 560[e]
Chemicals	98 252	105 448
Foundry	5 199	2 606
Rubber products	2 709	2 137[e]
Other industries[2]	12 533	35 761
Total	832 702	653 723

Source: Statistics Canada, Compiled by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
[1]Includes elemental (lump, powder, liquid, etc.) sulphur and liquid sulphur dioxide (sulphur content only). [2]Includes production of artificial abrasives, aluminum, explosives, food processing, glass and glass products, starch, sugar processing, and other minor uses.
[p]Preliminary; [e]Estimated.

By the year 2000, annual requirements are expected to exceed 2 million tons. Ore and tailings leaching in base-metal production, and anticipated developments in hydrometallurgy, are other consumption areas with high growth potential. Several new uses for elemental sulphur, based on attractive engineering properties, have been under development in recent years. Although some of these are fairly sensitive to sulphur prices, uses such as sulphur-asphalt road surfacing mixtures could become important. In summary, the future of a reagent so widely available, cheap, and versatile as sulphur, seems assured. It would appear that the historical sulphur demand growth of 4.5 per cent a year will be maintained over the medium- to long-term and, with fertilizer developments, could exceed the historical rate.

Supply. Supply is likely to be the most important factor in sulphur's fortunes. As one of the earth's most abundant elements, no ultimate shortage is foreseeable; however, an examination of likely rates of development of the various sources provides a less-assuring outlook.

Although Canada is the world's largest exporter of sulphur, with a 30 per cent share of total trade, its impact on world sulphur markets is expected to decline. Production of elemental sulphur from sour natural gas peaked in 1973 at 7.2 million tonnes and output in 1977 was 10 per cent less than this figure. Several of the major plants are recycling operations, i.e., sulphur is stripped from the gas and the gas returned to the reservoir. Output from these plants in now tapering off, and considering the reserve picture for the others, a reduction to about one-half of the peak output from existing plants is expected by 1985. Replacement of part of this lost production capability through new discoveries and reserve extensions will occur. Indeed, discoveries over the last year in the foothills are believed to be significant sour-gas fields. However, sulphur from these, starting in the early 1980s, is unlikely to reverse the decline in output from natural gas.

Table 9. Canada, sulphuric acid production, trade and apparent consumption, 1960, 1965, 1970, 1975-77

	Production	Imports	Exports	Apparent Consumption
	(tonnes — 100% acid)			
1960	1 518 000	8 642	39 399	1 487 243
1965	1 964 055	2 790	51 812	1 915 033
1970	2 475 070	9 948	129 327	2 355 691
1975	2 723 202	154 020	225 402	2 651 820
1976	2 842 431	39 537	349 826	2 532 142
1977[p]	3 140 340	6 634	287 304	2 859 670

Source: Statistics Canada.
[p] Preliminary.

Sulphur recovery from the Athabasca oil sands depends on the rate of exploitation of this source of oil. Current estimates in the order of 300 000 b/d by 1985 would yield about 500 000 tonnes of sulphur annually. Sulphur from metallic sulphides, produced largely in the form of sulphuric acid, is expected to increase by 50 per cent, equivalent to 400 000 tonnes of contained sulphur by 1985.

All told, Canada's output of sulphur from all sources is not expected to surpass the 1973 peak until beyond the next decade.

Table 10. World production of sulphur in all forms, 1976

	Elemental	Other[1]	Total[2]
	(thousands of tonnes)		
United States	9 553	2 028	11 581
U.S.S.R.	3 100	7 100	10 200
Canada	6 544	785	7 329
Poland	4 800	290	5 090
Japan	925	1 723	2 648
Mexico	2 147	98	2 245
France	1 850	143	1 993
West Germany	608	782	1 390
Spain	6	1 341	1 346
Italy	68	561	629
Finland	91	397	488
South Africa	27	401	428
Iran	399	—	399
East Germany	120	260	380
Sweden	10	263	273
Other countries	2 068	4 447	6 515
Total	32 316	20 619	52 934

Source: British Sulphur Corporation Limited, November/December 1977.
[1]Sulphur in other forms includes sulphur contained in pyrites and contained sulphur recovered from metallurgical waste gases mostly in the form of sulphuric acid. [2]Totals may not add due to rounding.
— Nil.

United States Frasch output in 1977 was 26 per cent below the high of 8.0 million tonnes in 1974. Although much of this reduction was in response to weak demand, two critical constraints are making themselves felt. Costs have more than doubled recently as a result of price increases for essential natural gas, and rising labour and material costs. At best, producers will have to face the problem of continued escalating costs of production, and fuel supply cuts remain a distinct possibility. Formerly, it was feasible to close high cost operations down temporarily to adjust to market demand. It would now appear that any closure is likely to be permanent. Also, notwithstanding the success of the Duval Corporation's mine in west Texas, which has a capacity of 2.4 million tonnes a year, and Texasgulf Inc.'s 500 000-tonne operation, which started up in 1976; there is little scope for growth in Frasch output. The closure of Freeport Minerals Company's Lake Pelto mine during 1975, Texasgulf's Spindletop mine in early 1976 and the latter company's Fannett mine in February 1977, is symptomatic of a net decline in reserves. Of 37 Frasch mines developed since the inception of the industry in 1895, only 11 remain in operation. More significantly, of 12 mines developed during the last 15 years, seven have closed down. It now seems optimistic to expect more than a 5-million-tonne Frasch output by 1985. Sulphur recovered from oil, gas, smelters, etc. could expand 75 per cent to 8.0 million tonnes by 1985, but this would be insufficient to alter the United States' recently developed position as a net importer of sulphur.

Although there may be scope for sulphur exploration and development in Mexico, present Frasch operations are experiencing technical difficulties, in addition to cost constraints similar to those affecting United States operators. Except for the all-time high of 2.3 million tonnes in 1974, production has varied between 1.2 and 1.8 million tonnes for much of its 24-year history. Mexico's oil and gas reserves, which are proving to be very large, appear to be the most likely source of expanded sulphur production in the country. However, overall sulphur output is not expected to become significant until after 1985.

Sulphur production in France from sour natural gas is expected to decline to 1.5 million tonnes by 1985.

Poland's Frasch production may reach 6 to 7 million tonnes, and the output from newly-emerging Middle East producers — sour gas and Iraqi Frasch — will likely rise to 3.0 million tonnes by 1985. However, rapid consumption growth in the communist bloc and in the Middle East will modify the effects of these additional supplies.

Despite the fact that pollution-abatement sulphur will become more important, its impact, for several reasons, is proving to be less dramatic than earlier predictions suggested. For sulphur removal from electric utility stack gases, the largest source of pollution-sulphur, economic and technologic considerations weigh in favour of a scrubbing process which will result in an impure gypsum waste product. Advances in acid-producing technology could result in a decision to install acid capacity where the net return to a plant covers the higher cost of acid production relative to limestone scrubbing. However, since costs of abatement, even using limestone scrubbing, exceed $100 per ton of H_2SO_4 equivalent for most plants; a third alternative, that of using clean coal, is likely to become attractive. A number of smelters are located in areas lacking adequate markets for sulphuric acid, which will likely result in neutralization and discard of some of this output. Moreover, in light of energy supply limitations, attention has been focussed on conservation, which will moderate growth in fossil fuel consumption, the major source of sulphur emissions.

Under the influence of the foregoing, a period of world tight supply appears imminent. Shipments from stocks in the United States and some remelting in Canada could ease the situation somewhat, but it is likely to endure until Polish elemental sulphur and European pyrite capacity can be increased.

Prices

A firming trend, which characterized prices a few years ago, was interrupted by the present recession. A resistance to price erosion despite sharply reduced sales was evident and, in fact, prices in the United States were raised from $45 to $55 for Gulf port in 1974 to $61.50 a tonne ($67.40 delivered to Tampa). This development is a reflection of Frasch production costs more than doubling in recent years. However, Canadian prices did slide from $25 a tonne fob Alberta to the $16 range. With tightening markets, there is little doubt that prices will rise during 1978. Although no general price increases have been negotiated, suppliers are reluctant to go beyond 6-month contracts. It is probable that prices will at least return to the $25 level, fob Alberta; and $45-$50, fob Vancouver, during the year.

Canadian sulphur prices quoted in Canadian Chemical Processing, November, 1977

	($)
Sulphur, elemental, fob works, contract, carload, per long ton	23.50
Sulphuric acid, fob plants East, 66° Be, tanks, per short ton	48.20

United States prices in U.S. currency, quoted in "Engineering and Mining Journal", January 1978

	($)
Sulphur elemental	
U.S. producers, term contracts fob vessel at Gulf ports, La. and Tex., per long ton (nominal)	
Bright	61.00-64.00
Dark	60.00-63.00
Export prices, ex terminal Holland	
Bright	66.00
Dark	65.00
Mexican export, fob vessel, per long ton	
Bright	63.00
Dark	63.00

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
92503-1	Sulphur of all kinds, other than sublimed sulphur, precipitated sulphur and colloidal sulphur	free	free	free	free
92802-1	Sulphur, sublimed or precipitated, colloidal sulphur	free	free	free	free
92807-1	Sulphur dioxide	free	free	free	free
92808-1	Sulphuric acid, oleum	10%	15%	25%	10%
92813-4	Sulphur trioxide	free	free	free	free

United States

Item No.		
418.90	Pyrites	free
415.45	Sulphur, elemental	free
416.35	Sulphuric acid	free
422.94	Sulphur dioxide	6% ad valorem

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. Tariff Schedules of the United States, Annotated (1978), T.C. Publication 843.

Talc, Soapstone and Pyrophyllite

G.H.K. PEARSE

Talc is a hydrous magnesium silicate $H_2Mg_3(SiO_3)_4$ formed by the alteration of rocks rich in magnesia (most commonly ultrabasic igneous rocks and sedimentary dolomite) within which it occurs as veinlets, tabular bodies, or irregular lenses. It is a soft, flaky mineral with a greasy feel or "slip", it is readily ground to a fine white or nearly white powder, has a high fusion point, low thermal and electrical conductivity and is relatively chemically inert. Most of the uses of talc depend on individual physical properties or combinations of these properties.

Talc is produced in various grades which are usually classified by end use; cosmetic, ceramic, pharmaceutical and paint. A special, high-quality block talc used in making ceramic insulators and other worked shapes is designated "steatite grade."

Soapstone is an impure talcose rock generally occurring in massive, compact deposits from which blocks can be sawn. Soapstone has been used since early times in many parts of the world for carving ornaments, pipes, cookware, lamps and other utensils. The art of carving this rock has survived among the Inuit people of Canada up to the present era. Present uses include metalworkers' crayons, refractory bricks, and blocks for sculpturing.

Pyrophyllite is a hydrous aluminum silicate $H_2Al_2(SiO_3)_4$ formed by hydrothermal alteration of acid igneous rocks, predominantly lavas which are andesitic to rhyolitic in composition. It resembles talc in physical properties and for this reason finds uses similar to talc, notably in ceramic bodies and as a filler in paints, rubber and other commodities.

In Canada, talc is produced in two provinces, Quebec and Ontario, while pyrophyllite is produced only in Newfoundland. The value of talc and soapstone shipments decreased from $1 386 000 in 1976 to $1 356 000 in 1977, according to official statistics. Indications from industry are that output actually increased. The value of pyrophyllite production increased from $447 082 in 1976 to $624 000 in 1977, a new record.

Production and developments in Canada

Talc, Soapstone. The earliest recorded production in Canada was in 1871-72 when 270 tonnes* of cut soapstone valued at $1 800 were shipped from a deposit in L 24, R 6 in Bolton Township, southern Quebec, by Slack and Whitney. In 1896 a deposit in Huntingdon Township, in the Madoc district of Ontario, was opened and over the next few years numerous deposits were discovered in this area and mined intermittently.

Several deposits in southern British Columbia and one in southwestern Alberta were discovered prior to 1920 and some of these were worked in a small way. At present, talc is mined by three companies — two in Quebec and one in Ontario.

Baker Talc Limited produces talc and soapstone from an underground mine in South Bolton, Quebec, 95 kilometres (km) southeast of Montreal. Ore from the mine is trucked 16 km south to the company's mill facilities at Highwater.

A modified flotation process is used to produce a high quality talc for use principally in the paper industry. A small quantity has been used as a filler in plastics and paints. Production of this high-quality material is around 5 000 tonnes a year and a somewhat larger tonnage of lower-grade talc, produced in a dry milling process, is shipped for a variety of uses. The company also sells soapstone blocks for sculpture to an art supplies dealer.

Shaft sinking to the 182-metre level was completed in 1976 and development and production at this level commenced in 1977. Mining is by open stoping, and access and ore-hoisting are by way of a 45° inclined shaft.

Broughton Soapstone & Quarry Company, Limited, quarries talc and soapstone from two deposits near Broughton Station in the Eastern Townships of

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Talc, soapstone and pyrophyllite production, trade and consumption, 1976-77

	1976		1977ᵖ	
	(tonnes)	($)	(tonnes)	($)
Production (shipments)				
Talc and soapstone				
Quebec[1]	. .	799 167	. .	781 000
Ontario[2]	. .	586 902	. .	575 000
Total	. .	1 386 069	. .	1 356 000
Pyrophyllite				
Newfoundland	. .	447 082	. .	624 000
Total Production	68 834	1 833 151	73 000	1 980 000
Imports (Talc)				
United States	46 240	2 874 000	33 567	2 819 000
Italy	148	21 000	163	25 000
Other countries	9	1 000	39	6 000
Total	46 397	2 896 000	33 769	2 850 000
	1975		1976ᵖ	
		(tonnes)		
Consumption[3] (ground talc available data)				
Paints and wall joint sealers	8 340		8 880ᵉ	
Gypsum products	6 414		7 121	
Roofing products	6 120		7 097	
Ceramic products	7 042		6 282	
Pulp and paper products	4 340		5 833	
Chemicals	2 437		1 972ᵉ	
Pharmaceutical preparations	1 514		1 784	
Rubber	1 392		1 566ᵉ	
Toilet preparations	755		534	
Other products[4]	2 178		2 526	
Total	40 532		43 595	

Source: Statistics Canada.
[1]Ground talc, soapstone, blocks and crayons. [2]Ground talc. [3]Breakdown by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa. [4]Adhesives, floor covering, insecticides and other miscellaneous uses.
ᵖPreliminary; . . Not available; ᵉEstimated.

Quebec, where the same geological conditions as in the South Bolton area are evident. Several low-priced grades of ground talc are produced, and soapstone is sawn to produce metalworkers' crayons and various sizes of blocks for sculpturing, and plates for etching. Much of the Inuit artists' soapstone requirements are supplied by this company and a certain volume is marketed elsewhere through an art supplies company.

Canada Talc Industries Limited produces talc from underground workings at Madoc, Ontario. The deposits at Madoc are extensive and were formed by the alteration of dolomitic marble. Tremolite and dolomite impurities in the deposit limit the use of some ground products. A high-quality product, suitable as a filler material in the paint and plastics industries and for pharmaceuticals, cosmetics and lens polishing, is produced. In the last few years, Canada Talc has more than doubled production of its high-quality talc to meet demand as a filler in automobile plastics. The company also produces dolomite terrazzo chips from the mine.

The talc ore is mined from drawpoints at 9-metre intervals along drifts flanking the ore zone. The mill circuit is comprised of a jaw crusher, Raymond mills and cyclones. Recent developments include a changeover from tracked haulage and hoisting of ore to rubber-wheeled transport to surface, via decline. The

Table 2. Production and trade, 1960, 1965, 1970, 1975-77

	Production[1]			
	Talc and Soapstone	Pyro phyllite[2]	Total[3]	Imports Talc
	(tonnes)			
1960	19 424	18 348	37 772	17 375
1965	20 596	27 337	47 933	25 272
1970	. .	. .	65 367	29 999
1975	. .	. .	66 029	30 428
1976	. .	. .	68 834	46 397
1977^p	. .	. .	73 000	33 769

Source: Statistics Canada.
[1]Producers' shipments. [2]Producers' shipments of pyrophyllite, all exported. [3]Since 1970, breakdown of producers' shipments not available for publication.
^{p}Preliminary;. . Not available.

deposit is being developed below the 167-metre level.

Canadian Johns-Manville Company, Limited brought its Penhorwood township deposit into production in July 1976 but closed both this operation and one in California in December, having apparently decided to get out of the talc business. About 1 000 tonnes was produced. Other interests are evaluating this deposit at the present time.

Numerous deposits of talc and soapstone occur in the producing areas and in other parts of Canada. A soapstone deposit on Pipestone Lake in Saskatchewan was worked by Indians for the manufacture of pipes and various utensils. Reserves are reported to be considerable. High quality "blue" talc was investigated in the Banff area of Alberta and British Columbia during the 1930s. In the Northwest Territories, a few occurrences of soapstone are known from which Eskimos obtained material for carving. Showings of minor importance occur at several localities in Nova Scotia and Newfoundland.

Pyrophyllite. Newfoundland Minerals Limited, a subsidiary of American Olean Tile Company, Inc. produces pyrophyllite from an open-pit mine near Manuels, 19 km southwest of St. John's, Newfoundland. Ore is crushed, sized and hand-cobbed at the mine site prior to being trucked a short distance to tidewater. Continuous chemical analyses and physical tests are run on all material delivered from the mine to the loading dock. Blended ore is shipped in bulk to the parent company's operation at Lansdale, Pennsylvania where it is used in the manufacture of ceramic tile. Annual production varies between 20 000 and 35 000 tonnes. The pyrophyllite deposit at Manuels appears to be a hydrothermal alteration of sheared rhyolite. Altered zones are associated for the most part with extensive fracturing near intrusive granite contacts. Reserves are extensive.

Table 3. World production of talc, soapstone, and pyrophyllite, 1975-77

	1975	1976^p	1977^e
	(tonnes)		
Japan	1 191 579	1 345 243	1 360 000
United States	841 458	963 229	956 000
Republic of Korea	415 874	496 468	. .
U.S.S.R.	420 000^e	440 000^e	. .
People's Republic of China	270 000^e	300 000^e	. .
France	241 130	253 680	272 000
India	200 474	241 728	. .
Brazil	220 671	225 000^e	. .
Italy	144 082	153 836	145 000
Finland	124 260	148 531	145 000
North Korea	130 000^e	130 000^e	. .
Austria	86 512	105 649	. .
Norway	104 993	100 000^e	. .
Australia	82 387	80 000	. .
Canada	66 029	68 834	73 000
Other countries	316 006	319 063	2 559 000
Total	4 855 455	5 371 261	5 510 000

Sources: U.S. Bureau of Mines, *Mineral Trade Notes*, Vol. 75, No. 2, February 1978. U.S. Bureau of Mines, *Mineral Commodity Summaries*, January 1978. Statistics Canada.
^{p}Preliminary; ^{e}Estimated; . . Not available.

Other known pyrophyllite deposits in Canada include an extensive area of impure pyrophyllite near Stroud's Pond in the southern part of Burin Peninsula, Newfoundland; a deposit near Ashcroft, British Columbia and three deposits on Vancouver Island, British Columbia, in the Kyuquot Sound area, 320 km northwest of Victoria. The Vancouver Island deposits were worked on a limited scale in the early part of this century.

Trade and markets

All pyrophyllite produced is exported, and, taken together with talc and soapstone, Canadian exports roughly equal imports of talc. Except for minor shipments to South Africa, exports go to the United States, where demand for good quality filler for automobile plastics has grown rapidly over the last few years, stimulating Canadian exports. Imported talc, most of it from the United States, is high-quality, high-value material suitable for use in the paint, ceramics, paper and cosmetic industries. It is anticipated that imported high-quality talc will be displaced to some extent in other industries by domestic product as capacity for producing these grades increases. Imports, nearly all from the United States, in 1977 amounted to 46 397 tonnes valued at $2 896 000, down 26 per cent in tonnage and 2 per cent in value compared with 1976. A decrease in housing starts in 1977 may account for the reduced imports of lower-value talc which would be required for roofing, floor tiles, wall board, wall joint sealer and the like. Average value of imports in 1977 was $84 a tonne, while domestic production sells in the range of $10 to $75 a tonne, depending upon quality.

Uses

Talc is used mostly in a fine-ground state; soapstone in massive or block form. There are many industrial applications for ground talc, but major consumption is limited to less than a dozen industries.

Talc is used as a filler material in the manufacture of high-quality paper where it aids in the dehydration of the pulp, improves sizing characteristics, reduces the tendency of papers to yellow and assures a well-bonded surface to promote ease of printing. For use in the paper industry, talc must be free of chemically active compounds such as carbonates, iron minerals and manganese; have a high reflectance, possess high retention characteristics in the pulp, and be free of abrasive impurities. Micronized material provides a high-gloss finish on coated papers.

The ceramic industry utilizes very finely ground talc to increase the translucence and toughness of the finished product and aid in promoting crack-free glazing. For use in ceramics, talc must be low in iron, manganese and other impurities which would discolour the fired product.

High-quality talc is used as an extender pigment in paints. Specifications for a talc pigment relate to the chemical composition, colour, particle size, oil absorption and consistency of, and dispersion in, a talc-vehicle. A low content of carbonates, a nearly white colour, a fine particle size with controlled particle size distribution and a specific oil absorption are important. However, because of the variety of paints, precise specifications for talc pigments are generally based on agreement between consumer and supplier. Paint characteristics influenced by the use of talc as an extender are gloss, adhesion, flow, hardness and hiding power.

Talc is well known for its use in pharmaceutical preparations and cosmetics. It is the major ingredient in face, baby and body powders. Finely ground, high-purity material is used as a filler in tablets and as an additive in medical pastes, creams and soaps. Material used for these purposes should be free of deleterious chemical compounds, abrasive impurities and fibrous minerals such as tremolite and asbestos, which are believed to be injurious to health when inhaled or ingested.

Lower-grade talc is used as a dusting agent for asphalt roofing and gypsum board, as a filler in drywall sealing compounds, as a filler material in floor tiles, in asphalt pipeline enamels, in auto-body patching compounds, as a carrier for insecticides and as a filler or dusting compound in the manufacture of rubber products.

Other applications for talc include use in cleaning compounds, polishes, electrical cable coating, plastic products, foundry facings, adhesives, linoleum, textiles and in the food industry.

Particle-size specifications for most uses require the talc to be minus 325 mesh. The paint industry demands from 99.8 to 100 per cent minus 325 mesh. For rubber, ceramics, insecticides and pipeline enamels, 95 per cent minus 325 mesh is usual. In the wall-tile industry, 90 per cent minus 325 mesh is generally required. For roofing grades the specification is about minus 80 mesh, with a maximum of 30 to 40 per cent minus 200 mesh.

Soapstone has now only very limited use as a refractory brick or block, but, because of its softness and resistance to heat, it is still used by metalworkers as marking crayons. The ease with which it can be carved makes it an excellent artistic medium.

Pyrophyllite can be ground and used in much the same way as talc, but at present the use of the Canadian material is confined to ceramic tile. It must be minus 325 mesh and contain a minimum of quartz and sericite, which are common impurities.

World review

Deposits of talc are widely distributed throughout the world, but have been developed commercially only in the more industrialized countries. Because talc is of relatively low unit value, only a verty small part of world production is traded internationally. The majority of international trade takes place within Europe, in the Far East between Japan, the People's Republic of China and Korea; and in North America between Canada and the United States. However, talc of exceptional purity is valuable enough to withstand the cost of transportation over much greater distances. For example, high-grade French, Italian, Indian and Chinese talcs are shipped throughout the world.

Prices

United States talc prices according to "Oil, Paint and Drug Reporter," December 26, 1977.

	($ per short ton)
Canadian	
Ground, bags, carlot fob mines	20.00-35.00
Vermont	
Domestic, ordinary, off-colour, ground, bags, carlot, fob works	22.25
California	
Domestic, ordinary off-colour, bags, carlot fob works	34.00-39.50
New York	
Domestic fibrous ground bags	35.50

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
		(%)	(%)	(%)	(%)
71100-3	Talc or soapstone	10	15		10
29655-1	Pyrophyllite	free	free	25	free
29646-1	Talc for use in manufacture of pottery or ceramic tile (expires Feb. 28, 1980)	free	free	25	free

United States

Talc, steatite, soapstone

Item No.		
523.31	Crude and not ground	0.02¢ per lb
523.33	Ground, washed, powdered, or pulverized	6% ad valorem
523.35	Cut or sawed, or in blanks, crayons, cubes, disks, or other forms	0.20¢ per lb
523.37	All other, not provided for	12% ad valorem

Sources: For Canada, The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States, Annotated (1978), TC Publication 843.

Using pneumatic equipment, a worker breaks the crust which has formed on the surface of the electrolyte bath of an aluminum reduction cell at the Arvida, Quebec plant of The Aluminum Company of Canada (Alcan). *Alcan photo*

Tin

G.S. BARRY

Tin is one of the few metals that Canada imports in large quantities. Domestic production is small and is exported in the form of concentrates to the United States, the United Kingdom and Mexico. Mine production is not sufficient to support a domestic smelter.

Canadian production of tin in concentrates and lead-tin alloy in 1977 was 317 tonnes*, valued at $4 073 000.

Canadian industrial requirements of tin are met mainly by imports, and these totalled 5 029 tonnes in 1977, valued at $56 527 000.

Canada also imports small quantities of tinplate (less than 1 per cent of domestic production), mainly from the United States. Tin metal scrap and tinplate scrap are mainly exported to the United States, as facilities for secondary metal processing in Canada are very limited. Tin-bearing secondary solders are recovered in a few plants; for example, Federated Genco Limited at its plant in Scarborough, Ontario. These are mainly melted away from products such as car radiators and pipes, and are reconstituted as solders. Statistics on the amounts recovered are not available.

Metal Recovery Industries Ltd. (formerly M & T Products of Canada Limited) Hamilton, Ontario recovers a secondary tin product by de-tinning industrial scrap. In 1977 American Can Company sold the chemicals business of M & T Chemicals (along with the name M & T) to Societe Nationale Elf Aquitaine of Paris, France. The metal recovery, or detinning, portion of M & T's former business was retained by American Can and re-named Metal Recovery Industries Ltd. In addition to detinning industrial scrap, this company is also processing small quantities of municipal scrap. The product, potassium stannate, contains 37.5 per cent tin, and is used directly in electroplating applications. An equivalent of 120 to 140 tonnes of tin is recovered annually in this way.

Traditionally, Malaysia was by far the main supplier of tin to Canada, but lately the United States has become the major source of tin imported by Canada. Large imports from the United States first occurred in 1974 and then again in 1976 and 1977, when they accounted for 78 per cent. Bolivia and Brazil have also recently become significant exporters to Canada. Tin consumption was not very buoyant in 1976, but picked up in 1977; this was reflected by a 19 per cent increase in imports.

Until the end of 1973, Cominco Ltd. was the only mine producer of tin, recovering cassiterite (SnO_2) as a byproduct from milling lead-zinc ores at Kimberley, British Columbia. In the past few years the company's annual output varied between 67 and 150 tonnes; in 1977, due to improved recoveries, production rose to 170 tonnes and is expected to remain above 160 tonnes in 1978. In addition to the tin concentrate recovered at Kimberley, Cominco recovers about 600 tonnes annually of a lead-tin alloy from treatment of lead bullion dross in the indium circuit of its Trail smelter. The tin content of this alloy is about 8 per cent. The company also produces, from purchased commercial-grade metal, small quantities of *Tadanac* brand high-purity tin (99.9999 per cent) and a special research grade (99.999 per cent) tin.

Texasgulf Canada Ltd., a subsidiary of Texasgulf Inc., completed construction of a tin-circuit at its base-metal concentrator at Timmins in the spring of 1974. This installation was planned to recover approximately 800 000 kilograms (kg) of tin annually, but recoveries have not reached design expectations and are below 10 per cent of the average tin content of the ore. During 1977, Texasgulf produced 169 tonnes of tin compared with 199 tonnes in 1976. Concentrates averaged about 37 per cent tin and were sent to the United Kingdom and Mexico for smelting.

Fine-grained cassiterite is a mineralogical component of sulphide ores at several Canadian mines, but its economic recovery is possible only at the Sullivan mine of Cominco and the Kidd Creek mine of Texasgulf. Ore grades at these mines are between 0.12 and 0.25 per cent SnO_2. Tin is present in small quantities in the zinc-lead orebodies of Brunswick Mining and Smelting Corporation Limited, New Brunswick, and in the South Bay, Ontario mine of Selco Mining Corporation Limited.

* The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Brunswick Tin Mines Limited, 89 per cent held by the Sullivan Mining Group Ltd., continued exploration and metallurgical testing on its multimineral deposit in southwestern New Brunswick. Reserves for the Fire Tower Zine (FTZ) reported in 1973 are 29.5 million tonnes, with an average grade of 0.20 per cent tungsten, 0.09 per cent molybdenum, 0.08 per cent bismuth, 0.04 per cent tin, 0.07 per cent copper, 0.35 per cent zinc, 0.08 per cent lead, 4 per cent fluorspar and about one ounce of indium a tonne. In addition, diamond drilling completed in 1974 and 1975 on the North Zone, a little more than half a mile north of the Fire Tower deposit, indicated 12 500 000 tonnes grading 0.241 per cent WO_3, 0.08 per cent MoS_2, 0.08 per cent bismuth and a small quantity of tin. Contained in the above tonnage, 2 300 000 tonnes graded 0.42 per cent tin, 0.077 per cent WO_3, 0.03 per cent MoS_2 and 0.06 per cent bismuth.

Some $1.4 million were spent during the 1975-76 fiscal year to evaluate the property. Favourable results were obtained from metallurgical tests conducted on ore from the Fire Tower Zone using gravity and flotation methods of concentration. The company continues to look for partners with capital to bring the property into production.

The principal use of tin in Canada, accounting for over 50 per cent of the total consumption, is the production of tinplate. There are two producers of electrolytic tinplate: Dominion Foundries and Steel,Limited (Dofasco) and The Steel Company of Canada, Limited (Stelco), both at Hamilton, Ontario. It is estimated that in 1977, 2 658.8 tonnes of tin were used to produce 533 300 tonnes of tinplate.

Dofasco and Stelco each operate three electrolytic tinplate lines. Stelco's third line, with a capacity of 175 000 tonnes of tinplate a year, was commissioned in November 1971. It can be converted to produce steel with other types of coatings, notably chrome-coated steel. Dofasco's third line is also dual purpose, and was commissioned in March 1972. It doubled the company's tinplate manufacturing capacity.

The second largest use for tin is the manufacture of solders, and 1 600 to 2 000 tonnes of tin are used annually for this product. Important Canadian users of tin for this application are The Canada Metal Company, Limited, Federated Genco Limited, Cramco Alloy Sales Limited, Kester Solder Company of Canada Limited, Tonolli Company of Canada Ltd., Toronto Refiners and Smelters Limited, and Metals & Alloys Company Limited.

Bronze, a copper-lead-tin alloy, is also produced in Canada, chiefly by Noranda Metal Industries Ltd., Anaconda Canada Limited, Federated Genco Limited, Metals & Alloys Company Limited, and The Ingot Metal Company Limited.

World developments

More than 75 per cent of the world's tin mine output is derived from mining alluvial deposits. The principal method used is bucket-line dredging, which can be used to a water depth of 50 meters (m). The suction dredge is also used, but in most places it is less efficient than the bucket-line. Other methods are gravel pumping, hydraulicking, and dulang washing. Tin is recovered as cassiterite (SnO_2) and at times is associated with other metals such as wolframite (tungsten).

A typical economic grade of a placer deposit is about 0.4 pounds of tin per cubic yard of sand (approx. 3 000 lbs.) or a tenor of only 0.013 per cent tin. Leading countries in this field of extraction are Malaysia, Thailand, Indonesia and Nigeria. This is a labour-intensive industry and some 150 000 people are employed in the four countries mentioned.

Lode mining is far less common than alluvial mining but still accounts for most of the tin output of Bolivia, Australia, Britain and South Africa. Countries of the communist and socialist blocks, notably The People's Republic of China and the U.S.S.R., are also important producers of tin. Lode deposits usually have a minimum tin content of 0.4 per cent and many mines in Bolivia, Australia and Britain have grades of about 1 per cent. Silver, tungsten and lead are common byproducts of lode mines. Cassiterite is the predominant tin-bearing mineral of lode deposits but stannite, a copper-tin-iron-bearing sulphide is of some importance.

Concentrating processes for alluvial and most lode tin are chiefly based on relatively simple gravity separation methods that produce concentrates containing 50 to 76 per cent tin. Lode mining companies in Australia, South Africa and Britain have recently installed flotation cells in their beneficiating plants to complement gravity separation and improve the recovery of tin and other metals.

Total non-communist world output of tin in concentrates in 1977 is estimated at 185 511 tonnes by the International Tin Council. This world output estimate includes some 7 500 tonnes of tin of unspecified origin which is being smuggled out of some producing countries, mainly to avoid taxes, and offered for processing to various custom smelters around the world.

World metal production in 1977 is estimated at 185 000 tonnes, compared to 179 700 tonnes in 1976. Consumption of primary tin metal is estimated at over 200 000 tonnes, leading to a significant gap in the supply-demand balance of about 15 000 tonnes. This estimate excludes tin released from noncommercial stocks. This statistical deficit for "new tin" may persist at least until 1980 and will exercise continuing strong upward pressure on prices. Prices could be moderated if there were to be substantial releases from the United States strategic General Services Administration (GSA) stockpile. During 1977 the U.S. sold 2 678 tonnes of tin from the GSA stockpile and only a few hundred tonnes remain that can be sold without authorization from Congress. At the end of 1977, some 204 176 tonnes remained in the stockpile and various bills calling for disposal of substantial additional quantities were being examined.

Table 1. Canada, tin production, imports and consumption 1976 and 1977

	1976		1977p	
	(tonnes)	($)	(tonnes)	($)
Production				
Tin content of tin concentrates and lead-tin alloys	274	1 881 735	317	4 073 000
Imports				
Blocks, pigs, bars				
United States	2 504	19 879 000	3 928	44 458 000
Bolivia	166	1 247 000	570	5 962 000
Brazil	198	1 078 000	419	4 762 000
Malaysia	94	667 000	65	755 000
Singapore	—	—	20	286 000
United Kingdom	19	136 000	25	282 000
Other countries	109	941 000	2	22 000
Australia	1 134	7 761 000	. . .	. . .
Total	4 224	31 709 000	5 029	56 527 000
Tinplate				
United States	1 377	741 000	1 651	980 000
United Kingdom	133	99 000	44	66 000
Other countries	2	1 000	5	3 000
Total	1 512	841 000	1 700	1 049 000
Tin, fabricated materials, nes				
United States	176	635 000	573	484 000
United Kingdom	14	45 000	35	70 000
West Germany	15	30 000	7	19 000
Other countries	. . .	3 000	8	22 000
Total	205	713 000	623	595 000
Exports				
Tin in ores, concentrates and scrap				
United Kingdom	499	1 053 000	759	2 661 000
Spain	110	410 000	45	251 000
United States	168	246 000	72	36 000
Total	777	1 709 000	876	2 948 000
Tinplate scrap				
United States	4 988	356 000	4 999	324 000
Peru	20	2 000	35	5 000
Thailand	—	—	15	3 000
Venezuela	82	14 000	—	—
Other countries	112	14 000	—	—
Total	5 202	386 000	5 049	332 000
Consumption				
Tinplate and tinning	2 524	. .	2 806	. .
Solder	1 829	. .	2 032	. .
Babbit	195	. .	182	. .
Bronze	117	. .	88	. .
Other uses (including collapsible containers, foil, etc.)	184	. .	177	. .
Total	4 849	. .	5 285	. .

Source: Statistics Canada.
p Preliminary; — Nil; nes Not elsewhere specified; . . Not available; . . . Figure too small to be expressed.

Table 2. Canada, tin production, exports, imports and consumption, 1960, 1965, 1970 and 1975-77

Year	Production[1]	Exports[2]	Imports[3]	Consumption[4]
		(tonnes)		
1960	282	. .	3 828	3 942
1965	171	219	5 073	4 970^r
1970	120	272^e	5 111	4 565^r
1975	319	370^e	4 487	4 315
1976	274	300^e	4 224	4 849
1977^p	323	372^e	5 028	5 285

Source: Statistics Canada.
[1]Tin content of tin concentrates shipped, plus tin content of lead-tin alloys produced. [2]Tin in ores, concentrates and tin scrap; and after 1969 also reexported primary tin. [3]Tin metal. [4]Current coverage exceeds 90 per cent, whereas until 1972, coverage was in the order of 80-85 per cent.
^{p}Preliminary; . . Not available; ^{r}Revised; ^{e}Estimate.

Table 3. Estimated world[1] production of tin-in-concentrates, 1967, 1976 and 1977

	1967	1976	1977
		(tonnes)	
Malaysia	73 278	63 401	58 073
Bolivia	27 721	28 122^p	32 000
Indonesia	13 819	23 418	25 100
Thailand	22 851	20 453	24 205^r
Australia	5 690	10 389	10 694
Nigeria	9 490	3 710	3 267
Republic of Zaire	7 126	4 000	3 607
Total including countries not listed	174 659	177 900	186 200

Source: International Tin Council, *Statistical Bulletin.*
[1]Excludes countries with centrally-planned economies, except Czechoslovakia, Poland and Hungary. The People's Republic of China and the U.S.S.R., are large tin producers.
^{p}Preliminary; ^{r}Revised.

Table 4. Estimated world[1] production of primary tin metal, 1967, 1976 and 1977

	1967	1976	1977
		(tonnes)	
Malaysia	77 553	78 017	66 305^r
Indonesia	1 505	23 322	24 005
Thailand	26 977	20 337	23 102
United Kingdom	23 691	9 848	11 458
Bolivia	1 076	9 790	13 300
Brazil	2 134	6 600	6 800
Australia	3 652	5 593	5 561
United States	3 098	5 733	6 724
Spain	1 547	5 369	5 626
Belgium	4 260	4 068	3 520
Nigeria	9 278	3 667	3 315
Republic of South Africa	670	2 400	2 400
West Germany	1 648	1 449	2 897
Total, including countries not listed	176 894	182 000	181 300

Source: International Tin Council, *Statistical Bulletin.*
[1]Excludes countries with centrally-planned economies, except Czechoslovakia, Poland and Hungary.
^{r} Revised.

The Fifth International Tin Agreement

The Fifth International Tin Agreement came into force on July 1, 1976 following a negotiating conference at Geneva in May 1975. Like the previous agreements it has a duration of five years, but now contains a provision that allows for renegotiation after two and a half years.

The Fifth Agreement is designed primarily to prevent excessive fluctuations in the price of tin, to help increase export earnings from tin, and to secure an adequate supply of tin at prices which will be fair to consumers and remunerative to producers. The participating countries also recognized that the agreement is in the spirit of the new international economic order.

The International Tin Council is the body formed to implement the agreement. The main objective of the International Tin Council is the consideration of short-term problems of supply and demand and pricing. Decisions that affect supply and price, however, are made with regard to long-term trends. Consumer and producer members form separate caucuses in the Council and have an equal number of votes in the governing body. Canada is a signatory to the Fifth Agreement and, in proportion to its consumption, had 30 out of the total of 1 000 votes allocated to consumers. The 22 consumer members and seven producer members accounted for 82.5 per cent of recorded world consumption of tin in 1977. The total does not include U.S.S.R. consumption, as data are not available even though the U.S.S.R. is a member country. The United States was the main nonmember country among Western consuming nations until July 1, 1976, when it decided to join the Fifth Agreement as a first-time member.

Producer members are Australia, Bolivia, Indonesia, Malaysia, Nigeria, Thailand and the Republic of Zaire. Together, producer and consumer members of the Council account for 88 per cent of the non-communist production of tin-in-concentrate, but the seven producer members alone account for 85 per cent.

The Fifth Agreement, like previous international tin agreements, incorporates two main operational mechanisms: the use of a buffer stock, and the application of export controls when necessary to adjust supply to demand. The operation of the buffer stock is related to a floor and ceiling price. The floor and ceiling price is to be expressed in Malaysian ringgit or in any other currency the International Tin Council may decide.

Contributions by producing countries to the buffer stock are required to be equivalent to 20 000 tonnes of tin either in the form of cash or tin metal, or a combination thereof as determined by the council. The equivalent of 7 500 tonnes is due upon entry into force of the agreement with the remainder due as determined by the council.

Under the Fifth Agreement contributions to the buffer stock made in cash after the entry into force of the agreement will be made at the floor price prevailing at that time and not, as under the Fourth Agreement, where contributions were based upon the floor price prevailing on the date of entry into force of the agreement. This will reduce any erosion of the authorized size of the buffer stock which might result from increases in the floor price during the life of the agreement.

The Fifth Agreement provides for additional contributions to the buffer stock over and above those required from producing countries. As in the Fourth Agreement, contributions may be made by any country invited to the conference; such voluntary contributions are made under the Fourth Agreement by France and the Netherlands. However, a major innovation in the Fifth Agreement is that an amount of up to the equivalent of 20 000 tonnes of tin metal is an implied overall target for contributions from the consuming countries participating in the agreement. After the agreement has been in operation for two and a half years, the council must review the results obtained in regard to these additional contributions. In the light of its review it may decide that a conference be convened within six months to renegotiate the agreement.

To date, the response for additional voluntary contributions by consumers has been good. In addition to the two countries mentioned, Belgium, Canada, Denmark and the United Kingdom have pledged to make contributions to the buffer stock, and the United States administration is proposing bills to Congress that would allow the country to make a voluntary contribution in the form of approximately 5 000 tonnes of tin from the GSA stockpile. This transfer may take place in late 1979.

The Fifth Agreement provides that the council may also borrow, for the purposes of the buffer stock, on the security of the tin it holds. Furthermore, in the event of any other financial resources becoming available to the council (for example, directly from international financial organizations), the council may modify the arrangements concerning the size and financing of the buffer stock.

The mandatory contributions by producers and the voluntary contributions by consumers are subject to a refund, plus or minus profits or losses, at the expiration of the five-year agreement. To date, all contributors recieved appreciable profits, since on principle, the buffer stock manager buys low and sells high.

Uses

The manufacture of tinplate represents the largest world market for tin, averaging about 35 per cent of world consumption. Approximately 85 per cent of tinplate is used by the can-making industry. Some 110 electrolytic tinning plants were in operation around the world in 1977. Typically, an efficient operation uses 5.0 kg of tin per tonne of tinplate produced. In 1977, 79 100 tonnes of tin were used for the production of 14.1 million tonnes of tinplate.

Solders are the second largest tonnage users of tin; estimated at 28.5 per cent of consumption in the United States, 32.6 per cent in Japan and 15.5 per cent in West Germany. Common solders used consist of 50 to 70 per cent tin. For soldering galvanized metal, solders with somewhat less than 60 per cent tin content possess the best "wetting" characteristics. Uses for tin solders (60-63 per cent tin) in the electronic industry are growing rapidly, but less solder is used per unit of manufactured product through the economics in printed circuitry and the use of "tailor-made" preforms. Soft solders are used to join side seams of cans (2-3 per cent tin) and as lead-rich, body-filling solders in the automotive industry. Automotive radiator cores are another important application for solders.

Tin is used with silver in low-temperature soldering applications.Comparisons of mechanical properties of solders containing 95 per cent tin-5 per cent silver with solders containing 80 per cent lead-20 per cent tin, show that both the ultimate tensile strength and the shear strength of the silver-tin solders are approxi-

Table 5. Monthly tin prices, 1977

	London Metal Exchange			New York			Penang		
	Highest	Lowest	Average	Highest	Lowest	Average	Highest	Lowest	Average
	Cash—£ per tonne			Prompt—¢ per lb.			Ex-works—$ M per picul		
Jan.	5 852.5	5 232.5	5 532.4	489.50	429.50	457.65	1 483.00	1 314.38	1 394.64
Feb.	6 137.5	5 665.0	5 979.4	516.50	470.75	504.14	1 561.00	1 428.00	1 525.47
Mar.	6 432.5	5 130.0	6 039.2	549.25	464.75	515.97	1 600.00	1 400.00	1 557.27
Apr.	5 712.5	5 335.0	5 574.0	491.50	463.00	478.31	1 477.00	1 390.00	1 434.73
May	5 812.5	5 567.5	5 720.6	490.00	481.75	485.31	1 475.00	1 448.00	1 458.13
June	5 732.5	5 367.5	5 603.7	485.25	471.50	478.90	1 458.00	1 416.00	1 440.37
July	6 347.5	5 692.5	6 039.2	543.25	484.25	516.54	1 616.00	1 448.00	1 543.32
Aug.	6 700.0	6 255.0	6 474.3	575.00	542.50	557.84	1 725.00	1 615.38	1 665.86
Sept.	6 795.0	6 110.0	6 383.6	593.25	533.00	558.47	1 770.00	1 580.00	1 659.78
Oct.	7 142.5	6 607.5	6 852.9	648.50	596.50	617.32	1 895.00	1 760.00	1 815.92
Nov.	7 175.0	6 765.0	6 952.5	647.50	603.25	624.43	1 880.00	1 735.00	1 804.71
Dec.	7 335.0	6 292.5	6 906.1	629.00	591.00	610.80	1 810.00	1 680.00	1 751.86

Source: International Tin Council, Monthly Statistical Bulletin.

mately twice that of lead-tin products. The solder is also 30 per cent harder.

The alloy applications of tin have a long tradition. Babbitt (usually 50 to 91 per cent tin) and white metal alloys (e.g., 10 to 15 per cent tin and 4 to 12 per cent antimony) are used in bearings, as are aluminum-tin alloys, which have a higher fatigue strength. Newer bearing materials include chromium- and beryllium-inoculated tin-base alloys offering markedly improved mechanical properties. Copper-tin alloys, such as bronze and gunmetal (up to 12 per cent Sn), have an average tin content of about 6 per cent and account for about 7 per cent of the world's primary tin consumption; or about 12 000 tonnes of primary tin, plus some 28 000 tonnes of secondary tin.

Titanium-tin alloys bearing 2 to 11 per cent tin are used increasingly in the aerospace industry, especially in supersonic jets (e.g., Concorde).

Terneplate, an alloy of 80-88 per cent lead and 12-20 per cent tin, has a three-century tradition as a most durable roofing material, and shows signs of revival in the United States. Other applications for terneplate are in automotive oil filters and some fixtures, and in critical body parts, for example the undersides of electric golf carts.

Pewter is gaining popularity as tableware and ornamental castings such as commemorative beakers and plates. Pewter is pure tin that has been hardened by the addition of copper and antimony, representative compositions range from 91 per cent tin, 2 per cent copper and 7 per cent antimony to 95 per cent tin, 1 per cent copper, and 4 per cent antimony. The usage of small amounts of lead is being discontinued. Total world consumption of tin for the manufacture of pewter is now estimated to be in excess of 5 000 tonnes a year.

Fusible alloys of tin, bismuth, lead, cadmium and sometimes indium, are used in safety devices such as heat fuses. Diecasting alloys of tin, antimony and copper have applications in the production of jewellery.

Lead-calcium-tin alloys are now being introduced in battery manufacturing, a market long served almost exclusively by antimonial lead. The tin content in this alloy is up to 1.3 per cent. There are forecasts that such maintenance-free, lead-acid batteries may capture up to one-third of the U.S. battery market by 1980.

A relatively new application is the use of small quantities of tin (approximately 0.1 per cent) in cast iron for engine blocks, crankshafts and rear-axle assemblies. Adding tin assures a uniformly hard, wear-resistant and thermally stable perlitic structure in the castings.

Pure tin is used in collapsible tubes, especially for pharmaceutical products. Tin is used in conjunction with the manufacture of glass, through the "float process", in which a continuous ribbon of glass floats along the surface of a bath of molten pure tin. (Pilkington Brothers process.)

Tin oxide is used for polishing applications and in the manufacture of conductive glass and glass resistors.

Tin is used widely in organic and inorganic tin compounds. The manufacture of chemicals account for the consumption of up to 10 000 tonnes, much of which comes from secondary tin. Growth potential from this modest base is excellent. The main use of organotins are as stabilizers and catalysts in the plastics and polyurethane foam industry, and in fungicides and disinfectants. The high-purity tin produced in Canada by Cominco, 59 grade (5-9's) (99.999 per cent) and 69 grade (6-9's) (99.99 per cent) is used mostly in metallic form in the electronics industry. Some is used to produce semiconductors, such as a tin-lead telluride for advanced solid-state radiation detection devices. Tin is reclaimed by M & T Products of Canada Limited in the form of potassium stannate and is used directly in electroplating.

The above is a short coverage of tin uses; the precedent, 1976 review has a much more extensive coverage and can be consulted accordingly.

Outlook

There has been a drastic decline in world mine production of tin between 1972 and 1976 from a peak of 195 300 tonnes to 178 000 tonnes. A noticeable improvement to approximately 184 000 tonnes was recorded in 1977, and a further increase to the 192 000 level is forecast for 1978. The increase in 1977 is mainly due to a significant increase in output from Bolivia, Indonesia and Thailand, but this gain was partially offset by a decline in output in Malaysia. (However, production in Malaysia may actually be 4 000 to 5 000 tonnes higher than stated, and is reported in world statistics as being of "unspecified origin".) The writer feels that the expected production of 192 000 tonnes in 1978 is too optimistic and that the level ultimately achieved will be between 185 000 and 190 000 tonnes.

World consumption of primary tin was approximately 192 000 tonnes in 1976, 191 000 tonnes in 1977, and is forecast to increase to 200 000 tonnes in 1978. The consumption level in 1977 is disappointing for producers since a year ago forecasts were in the range of 196 000 tonnes. A balance between supply and demand must take into account net trade with the Sino-Soviet countries which points to a net import by this bloc of some 3 000 tonnes for the years 1976 to 1978. Thus the statistical balance indicates the following deficits: 1976, 16 000 tonnes; 1977, 10 000 tonnes and 1978, 13 000 tonnes.

The total deficit of some 26 000 tonnes of tin for 1976 and 1977 was almost entirely moderated by the release of 19 200 tonnes from the International Tin Council Buffer stock in the latter part of 1976 and of 6 322 tonnes under the GSA disposal program. The deficit in 1978 may be taken up temporarily from consumers stocks in anticipation of further releases by the United States. The administration of the United States is already on record to favour a 5 000-tonne transfer to the International Tin Council buffer stock as a voluntary contribution; this requires approval by Congress during 1978. Further stockpile releases by the GSA over the next two or three years may be in the order of 30 000 to 45 000 tonnes, depending on the disposition of a number of stockpile-related legislative proposals that are currently at various stages of congressional consideration.

The combined result of continuing statistical deficits in the primary production-consumption balance and the possibility of noncommercial stockpile disposals, results in substantial price volatility. Generally, prices continued to be strong throughout 1977 and will continue to be very volatile in 1978 and 1979. As of time of writing, i.e., April 20, 1978, prices are consistently above the International Tin Councils buffer stock ceiling of 1,500 Malaysian dollars (ringgits) per picul (133.3 lbs.). It is probably salutary that prudent disposals of tin from the GSA stockpile could mitigate runaway prices. Higher prices would most certainly stimulate new developments in the mining industry, but significant results will not be evident until sometime after 1980. On the other hand, excessive prices in the 1978-79 period could trigger irreversible substitution, particularly in the tinplate industry, which in turn may lead to an oversupply of tin some time in the early 1980s.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
32900-1	Tin in ores and concentrates	free	free	free	free
33507-1	Tin oxides	free	15%	25%	free
33910-1	Collapsible tubes of tin or lead coated with tin	10%	17½%	30%	10%
34200-1	Phosphor tin	5%	7½%	10%	5%
34300-1	Tin in blocks, pigs, bars or granular form	free	free	free	free
34400-1	Tin strip waste and tin foil	free	free	free	free
38203-1	Sheet or strip, iron or steel, corrugated or not, coated with tin	10%	12½%	25%	8%
43220-1	Manufactures of tinplate	15%	17½%	30%	11½%

United States

Item No.		On or after January 1, 1975
601.48	Tin ore and black oxide of tin	free
608.91	Tinplate and tin-coated sheets, valued or not over 10c per pound	8%
608.92	Tinplate and tin-coated sheets, valued at over 10c per pound	0.8c per pound
622.02	Unwrought tin other than alloys of tin	free
622.04	Unwrought tin, alloys of tin	free
622.10	Tin waste and scrap	free
622.15	Tin plates, sheets and strips, not clad	6%
622.17	Tin plates, sheets and strips, clad	12%
622.20	Tin wire, not coated or plated with metal	6%
622.22	Tin wire, coated or plated with metal	6%
622.25	Tin bars, rods, angles, shapes and sections	6%
622.40	Tin pipes, tubes and blanks	6%
644.15	Tin foil	17.5%

Sources: For Canada, the Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1978) TC Publications 843.

Titanium and Titanium Dioxide

ALBERT BOUCHARD

Titanium is used principally in the oxide form, in the fabrication of a considerable number of products. In fact, the titanium dioxide (TiO_2) pigment industry consumes about 93 per cent of the world production of titanium minerals, virtually all the ilmenite and about 85 per cent of the rutile. The remainder of the production goes chiefly to the titanium metal industry and in some other less important areas. Ilmenite is the most important of the titanium minerals since it represents by itself alone, close to 90 per cent of the world production of titanium minerals. For 1977, the world production of ilmenite is estimated at 3 595 000 tonnes* principally from Australia, the United States, Canada and Norway, while rutile is estimated at 371 000 tonnes almost entirely from Australia.

Titanium dioxide (TiO_2) pigment may be obtained by two different processes, the sulphate or the chlorine process. Titanium metal is obtained through reduction of titanium tetrachloride ($TiCl_4$), which is an intermediate product of the chlorine process. At the present time, the majority of factories producing TiO_2 pigment use the sulphate process. The raw material used by these plants is ilmenite or titanium slag. The chlorine process is relatively recent and, the majority of TiO_2 pigment plants that have been constructed since the beginning of the 1960s, use this process. Rutile is the preferred raw material in the chlorine process. The most important difference between the two processes is the pollution resulting from the sulphate process. This process releases large quantities of liquid and solid wastes into the waterways as well as SO_2 emissions into the air. The treatment of these polluting agents is very expensive. It may, however, be reduced by using a raw material having a higher TiO_2 content. This is one of the main reasons for the considerable interest shown in titanium slag. The chlorine process is much cleaner by comparison, although it also produces some wastes. For this reason when new pigment plants are constructed a preference will be shown for the chlorine process, which uses rutile as a raw material. However, since the world reserves of natural rutile are limited, it has been necessary to find a new raw material having a TiO_2 content sufficiently high to be useable in the chlorine process. This has brought about the development of synthetic rutile, which requires ilmenite ore from which the iron has been removed through acid treatment. Synthetic rutile obtained in this way has a TiO_2 content greater than 90 per cent.

Canada

Quebec Iron and Titanium Corporation, which is two-thirds owned by Kennecott Copper Corporation and one third by New Jersey Zinc Company, is the only company that mines and processes ilmenite ore in Canada. This ore is taken from an open-pit mine in the Lac Tio region of eastern Quebec. After being crushed at the site to less than 7.5 centimetres diameter, the ore is shipped by rail to Havre St-Pierre where it is loaded on ore-carriers and transported via the St. Lawrence River to the Company's enrichment plant and foundry located at Sorel about 90 kilometres (km) north of Montreal. The ilmenite, which has an average combined content of iron and titanium oxide of about 86 per cent, is enriched to 93 per cent by various techniques such as heavy media separation, spirals and cyclones. The enriched product is then calcined in a rotary kiln to reduce the sulphur content. After cooling, the calcined product is mixed with powdered anthracite before melting in electric arc furnaces. The fusion products are a titanium slag, called Sorelslag, containing 70 to 72 per cent TiO_2 and pig iron with a low manganese content, called Sorelmetal, which is subsequently processed to meet consumer requirements. The titanium slag is used in the production of TiO_2 pigment by the sulphate process. The pig iron is principally used by manufacturers of ductile iron, but it is also used in powder metallurgy, or as a scrap iron substitute. A third product, Sorelflux, is also sold by the company. This unprocessed ilmenite ore, with a grain size between 6.4 and 38.0 millimetres, is used as

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

a metallurgical flux. Ilmenite ore from Quebec Iron and Titanium is also used as a heavy aggregate, although this represents a relatively low tonnage.

During the year the demand for titanium slag, which was produced by Quebec Iron and Titanium has been very strong. One of the principal reasons for this demand for Sorelslag on the international market is that TiO_2 pigments from titanium slag produces less pollution than the process that uses ilmenite as the raw material. In 1977 sales of titanium slag by Quebec Iron and Titanium were 711 000 tonnes compared to 816 000 tonnes in 1976. This drop of about 13 per cent resulted from a work slowdown followed by a five week strike by all the plant employees, which started at the beginning of June. The employees were protesting against the poor sanitary and safety conditions in the Sorel plant. The sales of Sorelmetal went from 467 400 tonnes in 1976 to 508 000 tonnes in 1977. This increase in sales of close to 9 per cent, in spite of the production stoppage at the plant, resulted from the company's accumulation of large quantities of pig iron during 1976 because of the poor demand for this product. The major part of the titanium slag produced by Quebec Iron and Titanium is exported, principally to the United Kingdom, western Europe and the United States. About 12 per cent of this slag production is sold on the Canadian market to two TiO_2 pigment producers; Canadian Titanium Pigments Limited of Varennes Que., a subsidiary of NL Industries, Inc. of the U.S., and Tioxide of Canada Limited, Tracy Que., a subsidiary of British Titan Products Company Limited of England. They have a combined

Table 1. Canada, titanium production and trade, 1976 and 1977

	1976		1977[p]	
	(tonnes)	($)	(tonnes)	($)
Production (shipments)				
Titanium dioxide slag	. .	73 121 342	. .	71 800 000
Imports				
Titanium dioxide pure				
United States	3 643	3 443 000	2 635	2 817 000
Belgium and Luxembourg	86	66 000	738	697 000
West Germany	589	598 000	582	577 000
United Kingdom	647	584 000	523	552 000
Total	4 965	4 691 000	4 478	4 643 000
Titanium dioxide extended				
United States	100	157 000	189	354 000
United Kingdom	112	124 000	161	185 000
West Germany	57	38 000	144	78 000
Czechoslovakia	2	6 000	2	6 000
Switzerland	5	21 000	—	—
Total	276	346 000	496	623 000
Titanium metal				
United States	430	5 894 000	289	4 039 000
United Kingdom	3	74 000	58	1 354 000
Belgium and Luxembourg	1	27 000	12	557 000
Other countries	5	81 000	13	96 000
Total	439	6 076 000	372	6 046 000
Exports[1] to the United States				
Titanium metal, unwrought including waste and scrap	199	290 997	173	392 607
Titanium metal, wrought	123	1 236 340	58	691 838
Titanium dioxide	10 237	8 538 544	14 185	12 246 274

Source: Statistics Canada, except where noted.
[1]U.S. Department of Commerce, U.S. General Imports, Report F.T. 135 is used as there are no identifiable classes available for Canadian export statistics.
[p]Preliminary; — Nil; . . Not available.

Table 2. Canadian production trade and consumption of titanium, 1968-77

	Production		Imports			Consumption	
	Ilmenite[1]	Titanium Dioxide Slag[2]	Titanium Dioxide Pure	Titanium Dioxide[3] Mixed	Total Titanium Dioxide Pigments	Titanium Dioxide Pigments	Ferro-titanium[4]
				(tonnes)			
1968	1 469 117	610 447	2 165	8 797	10 962	50 683	20
1969	1 654 852	679 742	2 272	7 848	10 120	54 983	31
1970	1 892 305	766 310	2 523	7 415	9 938	44 391	25
1971	1 893 321	773 829	5 390	5 193	10 583	51 452	19
1972	2 048 879	834 996	5 346	1 081	6 427	52 738	133
1973	2 082 206	855 215	4 304	380	4 684	60 808	14
1974	2 017 483	844 750	4 060	251	4 311	58 551	14
1975	1 825 042	749 850	2 467	241	2 708	50 152	25
1976	2 115 227	814 040	4 964	276	5 240	56 607	14
1977p	. .	692 341	4 478	496	4 974	. .	

Sources: Statistics Canada and Company annual reports.
[1]Ore shipped to Sorel; from company reports. [2]Slag with 70 to 72 per cent TiO_2; from company reports. [3]About 35 per cent TiO_2. [4]Ti content.
pPreliminary; . . Not available.

production of about 72 000 tonnes a year. The Canadian consumption of TiO_2 pigment is in the order of 60 000 tonnes a year, of which more than 90 per cent is of Canadian origin. This consumption is distributed between the paint industry (65 per cent), the paper industry (15 to 20 per cent) and others including rubber, plastics and textiles (15 to 20 per cent). In 1977, the demand for TiO_2 pigment was fairly good, and the two Canadian producers operated at close to full capacity.

At the present time, the two Canadian producers of titanium dioxide are actively concerned with problems arising from pollution. They have received notices from the government of Quebec directing them to limit, by 1980, the dumping of waste acids into the St. Lawrence River. Both of them produce TiO_2 pigment by the sulphate process from titanium slag obtained from Quebec Iron and Titanium. In this process the slag is digested in sulphuric acid, and subsequently the purified titanium sulphate is hydrolyzed to give titanium dioxide. This process generates dilute acid and solid wastes, which are released into the river. The Quebec authorities have requested that the two TiO_2 pigment plants process their wastes so as to control the pH and also to reduce the quantities of heavy metal ions and solids in suspension. The technique that will probably be used by Canadian Titanium Pigments and Tioxide of Canada to treat the wastes that are discharged into the St. Lawrence River will consist of neutralizing the waste acids with limestone. From this process they will obtain gypsum, which can be sold to the cement or wallboard industries. They will probably not realize a profit from the sale of this gypsum, but it will reduce their waste processing costs.

World Developments

The United States is one of the world's most important producers and consumers of ilmenite. In 1977 their ilmenite production is estimated at 490 000 tonnes; and their imports, including titanium slag from Canada, are estimated at 344 500 tonnes. The United States is also the most important rutile consumer. In 1977 their imports of natural and synthetic rutile ore are estimated at 85 300 and 48 000 tonnes respectively. Consumption of TiO_2 pigments is estimated at 711 000 tonnes. Imports of TiO_2 pigments increased considerably during the year largely because of the long strike that affected the NL Industries, Inc. plant at Sayreville, New Jersey, where production was not able to resume until the month of June. During the year Kerr-McGee Chemical Corporation began production of synthetic rutile at its new plant in Mobile, Ala. This plant has a production capacity of 100 000 tonnes a year. The plant constructed by E.I. DuPont de Nemours & Company Inc. at Delisle, Miss., should commence production of TiO_2 pigments at the rate of 136 000 tonnes a year in 1979. The Glidden Pigments Group, SCM Corporation, completed a major expansion of its TiO_2 pigments plant in Ashtabula, Ohio. This plant uses the chlorine process. In 1977, consumption of titanium metal in the form of sponge, ingots and scrap has increased substantially due in large part to the Cruse missile construction program. This program will certainly consume a great deal of titanium metal; but this consumption will, however, be less than that which it would have been if the B-1 Bomber construction program had not been cancelled. In early 1977, the Oregon Metallurgical Corporation (Oremet) recom-

Table 3. Production of iron and titanium slags, Quebec Iron and Titanium Corporation 1973-77

	Ore Smelted	Titanium Slag	Iron
		(tonnes)	
1973	1 768 240	855 215	588 300
1974	1 712 160	844 750	562 010
1975	1 543 490	749 850	501 930
1976	1 702 910	814 060	551 110
1977	1 442 290	692 341	459 260

Source: Quebec Iron and Titanium.

menced production of titanium sponge at its Albany, Oreg. plant. This plant had been closed in 1971 after only 10 months of operation because of high production costs. The production capacity of the plant is of the order of 2.3 to 2.7 million kilograms (kg) of titanium sponge a year.

In terms of world production, Australia is responsible for about 95 per cent of the production of rutile concentrate and 20 to 25 per cent of the ilmenite concentrate. In 1977, production of rutile concentrate is estimated at 353 800 tonnes and ilmenite concentrate at 916 000 tonnes. According to an Australian government study, the titanium mineral reserves are limited; and at the present production rate, known reserves of rutile would be exhausted in 10 years, and the likelihood of new deposits being discovered are at present considered poor. Tioxide Australia Pty. Ltd., a subsidiary of the Tioxide Ltd. group of the United Kingdom, and Westralian Sands Ltd. have now agreed to merge their two firms. If this merger occurs, the new company will be the most important producer of ilmenite concentrate in Australia with a capacity of 400 000 tonnes a year.

One of the most important projects related to the titanium industry is at Richards Bay in the Republic of

Table 4. Salient United States titanium statistics, 1976 and 1977

	Ilmenite		Rutile		Titanium[1]	
	1976	1977[e]	1976	1977[e]	1976	1977[e]
			(tonnes)			
Production	591 484	490 000	. .	. .	. .	. .
Imports	308 443[2]	345 000[2]	254 919	133 000	1 613	2 450
Consumption	930 772[2]	871 000[2]	255 826	200 000	12 079	14 500
Price/pound	. .	. .	. .	. .	$2.70	$2.98
Price/tonne	$55.00[3]	$55.00[3]	$510.00[4]	$360.00[4]	. .	. .

Source: United States Bureau of Mines, Commodity Data Summaries, January, 1977.
[1]Tonnes, of sponge metal. [2]Includes Titanium slag from Canada. [3]FOB Atlantic Ports, 54 per cent TiO_2 long ton. [4]FOB Atlantic and Great Lake Ports, short ton.
[e] Estimated; . . Not available or not applicable.

Table 5. Consumption of titanium concentrate in the United States, by products, 1976

	Ilmenite[1]		Titanium Slag		Rutile	
	Gross Weight	Estimated TiO_2 Content	Gross Weight	Estimated TiO_2 Content	Gross Weight	Estimated TiO_2 Content
			(tonnes)			
Pigments	736 611	445 287	185 033	131 094	188 186	176 856
Welding rod coating	. .	. .	. .	. .	7 396	7 018
Alloys and carbides	. .	. .	. .	. .	. .	. .
Miscellaneous[2]	9 329	6 648	. .	. .	20 072	18 984
Total	745 940	451 935	185 033	131 094	215 654	202 858

Source: U.S. Bureau of Mines, *Minerals Yearbook, 1977.*
[1]Includes mixed products containing rutile, leucoxene and ilmenite. [2]Includes ceramics, glass fibers and titanium metal.
. . Not available; — Nil.

South Africa. This project is being carried out jointly by Quebec Iron and Titanium (40 per cent) and three South African firms: Union Corporation Limited (30 per cent), Industrial Development Corporation of South Africa (20 per cent) and the S.A. Mutual Life Assurance Society (10 per cent). The Richards Bay project involves production of ilmenite, rutile and zircon from sand-dunes having more than 700 million tonnes of sand containing heavy minerals. The rutile and zircon are sold in the form of concentrate, while the ilmenite is processed in a foundry to convert it to slag with high titanium content and pig iron with low manganese content. The titanium slag obtained will have 85 per cent minimum TiO_2 content and may be used for TiO_2 pigment production by either the sulphate or chlorine process. Extraction of ores, which is carried out by Tisand (Pty) Ltd., commenced during 1977, and the first shipments of rutile and zircon were made towards the end of the year. The foundry operation, which is managed by Richards Bay Iron and Titanium (Pty) Ltd., should commence during 1978. When the project is operating at full capacity, in 1980, the estimated annual production will be 56 000 tonnes of rutile, 115 000 tonnes of zircon, 399 000 tonnes of titanium slag and 217 000 tonnes of pig iron with a low manganese content.

In Brazil, the anatase deposits at Tapira and Sâlitre in Minas Gerais province have been developed by the Mineracao Vale do Paranaiba (VALEP), a subsidiary of the Cia Vale do Rio Doce (CVRD), and the New Jersey Zinc Company. Preliminary studies have set reserves in the order of 344 million tonnes of ore with an average content of 22.4 per cent TiO_2. These studies also indicate a probable annual production of about 200 000 tonnes of anatase producing 150 000 tonnes of TiO_2 pigments and 6 000 tonnes of titanium metal. Also in Brazil, CVRD is planning the construction of a plant for production of TiO_2 pigments by the chlorine process. This plant, with an annual capacity of 60 000 tonnes, should begin production during 1980 and will at first use imported rutile as raw material and later probably the production from the deposits at Tapira and Salitre. Tibras Titanio do Brazil S.A., the most important producer of TiO_2 pigment in Brazil, commenced construction that will lead, in five years, to a doubling of its present capacity of 30 000 tonnes a year. This work will be carried out on the plant situated at Salvador in Bahia province.

In Italy the Mineraria Italiana SPA Co. is at present studying the possibility of mining new rutile deposits in the Ligurie region near Genoa. The proven reserves of this deposit are of the order of 150 million tonnes of ore, while probable reserves are of the order of 400 million tonnes. When the exploitation of this deposit is underway, Italy will become the most important producer of natural rutile in Europe.

In England, a new company, Willan-Wogen Ltd., which is owned in equal parts by Wogen Resources Ltd. and Aurora Holdings Ltd., commenced, during the year, production of ferrotitanium in the Sheffield region. Willan-Wogen Ltd., with a yearly production capacity of 3 500 tonnes, thus becomes the most important producer of this alloy in Europe.

In Malaysia, the Malaysian Titanium Corporation Sdn. Bhd., whose plant had been operating for only one year, ceased production of synthetic rutile giving as a reason an excessive drop in natural rutile prices on the world market.

Table 6. Production of ilmenite concentrates by countries, 1975-77

	1975	976	1977
	(000 tonnes)		
Canada	750	823	692
Australia	1030	1002	916
Norway	527	767	862
United States	651	592	490
Finland	123	123	—
Malaysia	112	180	—
Sri Lanka	64	56	—
India	82	82	91
Brazil	5	4	. .
Others	325	380	544
Total	3669	4009	3595

Sources: U.S. Bureau of Mines, *Minerals Yearbook, 1977. Commodity Data Summaries* (January, 1978), and *Mineral Industry Survey.*
[1]Titanium slag containing 70 to 72 per cent TiO_2.
[e]Estimated; . . Not available; — Nil.

Canadian minerals and deposits

Titanium is the ninth most abundant of the elements that make up the earth's crust. The two principal commercial titanium minerals are ilmenite ($FeTiO_3$),

Table 7. Production of rutile concentrate by countries, 1975-77

	1975	1976	1977[e]
	(tonnes)		
Australia	344 035	395 343	353 800
United States	. .	. .	. .
India	3 600	3 600	3 600
Sri Lanka	3 109	1 039	—
Brazil	104	105	—
Republic of South Africa	—	—	13 600
Total	377 848	427 087	371 000

Sources: U.S. Bureau of Mines, *Minerals Yearbook, 1977* and *Commodity Data Summaries*, January, 1978.
[e]Estimated; . . Not available; — Nil.

Table 8. United States titanium metal data, 1973-77

	1973	1974	1975	1976	1977[e]
			(tonnes)		
Sponge metal					
Imports for consumption	4 692	6 317	3 801	1 612	2 165
Industry stocks	1 760	3 467	5 161	3 281	3 217
Total inventory[1]	29 499	28 217	28 750	29 328	29 328
Consumption	18 301	24 399	15 990	12 079	14 729
Scrap metal consumption	9 106	9 615	7 544	8 356	9 878
Stocks	4 254	5 005	5 563	5 229	6 193
Ingot[2]					
Production	26 247	32 778	23 188	19 608	23 861
Consumption	23 051	28 633	22 213	19 055	22 898
Stocks	. .	. .	. .	1 661	1 722
Net shipments of mill products[3]	13 182	15 824	14 177	13 152	14 031

Source: U.S. Bureau of Mines, *Minerals Yearbook Preprint 1977.*
[1]Total inventory as of December 31 of each year. [2]Includes alloy constituents. [3]Bureau of the Census and Business Administration, Current Industrial Report Series BDCF-263.
[e] Estimated; . . Not available.

which contains between 45 and 55 per cent TiO_2, and rutile (TiO_2), which contains more than 95 per cent TiO_2. The other sources of titanium are leucoxene, which comes from ilmenite alteration and which has a higher TiO_2 content, and anatase, which is a rutile polymorph. Ilmenite and rutile are found in igneous, metamorphic and sedimentary rocks, as well as in placer and beach sand deposits, which have originated from erosion of primary rocks. Important deposits of ilmenite are of either primary or secondary origin, while the only economic rutile deposits are of secondary origin.

The Canadian Shield, in particular that part situated in the province of Quebec, contains numerous titanium-bearing deposits. At present, because of restrictions imposed by technology and economy, only ilmenite-hematite or ilmenite-magnetite deposits having a high TiO_2 content are of interest to investors. However, the deposits of titaniferous magnetite, whose TiO_2 content is relatively lower, provides an important potential, since the known reserves are of the order of several billion metric tonnes containing an average of 20 per cent iron and 5 per cent TiO_2. The only titanium deposit presently being worked in Canada is situated in the Lac Tio-Lac Allard region of northeast Quebec. This ilmenite deposit is worked by open pit mining and constitutes one of the most important deposits in the world with reserves exceeding 100 million tonnes with a content of 35 per cent TiO_2 and 40 per cent Fe.

The ilmenite-hematite deposit, having a high titanium content, situated near Saint-Urbain, 120 km northeast of Quebec City, was thoroughly studied under the joint sponsorship of Quebec Mining Exploration Company (SOQUEM) and Canadian Tiron Chemical Corporation. It has been judged too small to justify the investments necessary for production of synthetic rutile. Canadian Tiron has thus abandoned the project. This deposit has reserves estimated at 20 million tonnes with a content of 38 per cent TiO_2 and 40 per cent Fe. During 1977 this deposit was taken up by Houston Aggregate Co. of Canada Ltd., which intends to open a quarry for production of heavy aggregates. The operation should commence during 1978.

At present, certain deposits of titaniferous magnetite are under investigation. These, which include the deposits at Magpie situated about 200 km northeast of Sept Iles, contain more than a billion tonnes of titaniferous magnetite at 43 per cent Fe, 10.5 per cent TiO_2, 1.6 per cent Cr, and 0.19 per cent V_2O_5. A second deposit, which belonged to the Quebec Department of Natural Resources and which SOQUEM acquired during 1977, is situated in the Chibougamau region and has reserves of the order of 63 million tonnes at 31 per cent Fe, 10 per cent TiO_2, and 0.5 per cent V_2O_5. Another deposit belonging to Titan Iron Mines Limited, in the North Bay-Temagami region in eastern Ontario, has reserves of the order of 46 million tonnes at 39 per cent Fe, 19 per cent TiO_2 and 0.36 per cent V_2O_5. All of these deposits are considered as possible sources of several elements of which titanium is one.

In western Canada the various companies involved in exploitation of the tar sands as well as certain governmental organizations, are actively interested in recovery of the heavy minerals contained in these sands. Among others, studies made by Syncrude

Canada Ltd. have shown that it is possible to obtain zircon concentrate and titanium mineral concentrate from residues obtained from the centrifugation of the tar. These residues contain about 8 per cent Ti and 4 per cent Zr. Starting in 1978, Syncrude will produce about 78 000 tonnes a year of these residues and close to 700 000 tonnes when operating at full capacity in 1981. Assuming a recovery rate of 75 per cent for the two metals, Syncrude estimates that it will be able to produce 94 000 tonnes a year of titanium mineral concentrate and 41 000 tonnes a year of zircon concentrate when operating at full capacity.

Processing and uses

A high index of refraction gives titanium dioxide (TiO_2) an extreme whiteness and opacity. TiO_2 pigment may be obtained from two different processes, either the sulphate process, which uses ilmenite or slag as raw material, or the chlorine process, which uses natural or synthetic rutile as raw material. The sulphate process consists of digesting the raw material used in concentrated sulphuric acid. The solution that is obtained is clarified to take out heavy metals and materials in suspension. This solution is next cooled to precipitate the iron in the form of hydrated iron sulphate. After leaching and concentration, the liquid is hydrolyzed to form insoluble hydrated titanium dioxide, which precipitates after addition of seed crystals to the solution. The precipitate is washed and calcined to obtain titanium dioxide, which is then ready for final processing. The crystalline form obtained after calcination depends on the type of crystals that were added during the precipitation step. The chlorine process involves chlorinating the raw material used in the presence of carbon to obtain titanium tetrachloride. The tetrachloride is separated from the other chlorination products and is purified by distillation. Next it is vaporized and oxidized to produce titanium dioxide and chlorine. The chlorine is recovered and recycled.

Titanium minerals are used in the fabrication of various products such as TiO_2 pigment, titanium metal, welding rod coatings, ferrotitanium and other minor uses such as titanium carbide and chemical products containing titanium. The pigment industry is by far the most important consumer since it uses about 90 per cent of the world production of titanium ores. There are three different types of TiO_2 pigments on the market. Rutile and anastase are essentially pure titanium dioxide but differ in their indices of refraction and crystalline structure. The third type is mixed titanium pigment, which contains from 30 to 50 per cent TiO_2 and 50 to 70 per cent $CaSO_4$. More than one half of the production of TiO_2 pigment is consumed by the paint industry and nearly a quarter by the paper industry. The remainder of the production is consumed by various sectors such as plastics, rubbers, textiles, floor-coating, ceramics, inks, elastomers, etc. The strong demand for TiO_2 pigment arises from its large index of refraction, high degree of opacity, good resistance to chemical attack, good thermal stability, resistance to ultraviolet degradation and nontoxicity.

The second use of titanium minerals is in production of titanium metal, which consumes nearly all the remainder of the production of these minerals; since other uses, such as welding rod coating, ferrotitanium and others already mentioned, represent less than 1 per cent of total consumption. At the present time, the aerospace industry is the most important consumer of titanium metal, but the electric and chemical industries are using it more and more because of its properties: a large strength to weight ratio, high strength and good resistance to corrosion. Its high price is the only obstacle to a larger number of applications.

Outlook

Following the end of the labour unrest, Quebec Iron and Titanium has undertaken certain minor modifications with a view to improving the working conditions in its Sorel plant. These modifications will be spread over several years. Production has returned to its usual rate, and the company expects the 1978 production to be at essentially the same level as 1976.

Table 9. Chemical composition of titanium concentrates

	Ilmenite	Rutile	Titanium Slag
		(%)	
TiO_2	37.0 -65.0	94.0 -98.0	71.4
Fe ($FeO+Fe_2O_3$)	30.0 -55.0	0.2 - 1.5	16.3
SiO_2	0.5 - 3.0	0.2 - 2.0	3.8
Al_2O_3	0.2 - 1.5	0.2 - 0.5	4.6
CaO	0.1 - 1.0	0.02- 0.08	0.8
MgO	0.05- 4.0	0.02- 0.09	5.0
Cr_2O_3	0.01- 0.5	0.1 - 0.3	0.19
V_2O_5	0.05- 0.5	0.4 - 0.8	0.58
ZrO_2	0.1 - 2.0	0.04- 0.4	—

Source: Roskill Information Services Ltd.

After the slowdown brought on by the 1975 recession, consumption of TiO_2 pigments is at present undergoing a continuous growth. The rate of this growth is estimated at about 4 per cent a year for the next 20 years. This improvement in consumption is due principally to the fact that more than one half of TiO_2 pigment production is used in the paint industry, which depends for the most part on the construction and automobile industries. Recently these industries have shown some improvement, which should be maintained over a more or less long term.

It is very difficult to predict the demand for titanium metal since it is strongly dependent on the aerospace industry where production is extremely cyclic. This situation should, however, undergo some changes over a more or less long term since titanium metal is being used more and more by the chemical and electrical industries.

Prices of selected titanium commodities, in United States currency

	($)
Titanium ore, fob cars Atlantic and Great Lake ports[1]	
Rutile, 96%, per short ton, delivered within 12 months	360.00
Ilmenite, 54%, per long ton, shiploads	55.00
Slag, 70%, per long ton, fob Quebec	102.50
Titanium metal, sponge, per lb, max. 115 Brinell, 99.3%, 500-lb lots[1]	2.98
Mill products, per lb delivered, 4 000-lb lots[1]	
Billet, Ti — 6AL-4V (8in. diameter, rotating grade)	4.86
Bar, Ti-6AL-4V (2 in. diameter, random lengths)	7.48
Ferrotitanium[2]	
Low carbon, per lb Ti delivered, 25-40% Ti	1.35
Titanium dioxide, anatase, dry milled, Canadian prices[3]	
Bags, car lots, delivered East, per 100 lb	43.75
Bags, car lots, rutile, per 100 lb	48.50

[1]*Metals Week*, December 30, 1977. [2]*Engineering and Mining Journal*, last quoted June 1977. [3]*Canadian Chemical Processing*, December 1, 1977.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
			(%)		
32900-1	Titanium ore	free	free	free	free
34715-1	Sponge and sponge briquettes, ingots, blooms, slabs, billets, and castings in the rough, of titanium or titanium alloys for use in Canadian manufactures (expires June 30, 1980)	free	free	25	free
34735-1	Tubing of titanium or titanium alloys for use in Canadian manufactures (expires February 28, 1981)	free	free	25	free
34745-1	Sheet, strip or plate of titanium or titanium alloys, cold-rolled, for use in Canadian manufactures	free	free	25	free
37506-1	Ferrotitanium	free	5	5	free
92825-1	Titanium oxides	free	12½	25	free
93207-6	Titanium whites, not including pure titanium dioxide	free	12½	25	free

United States

Item No.		
422.30	Titanium compounds	7.5
473.70	Titanium dioxide	7.5
601.51	Titanium ore, including ilmenite, ilmenite sand, rutile and rutile sand	free
607.60	Ferrotitanium and ferrosilicon titanium	5
629.15[1]	Titanium metal, unwrought, waste and scrap	18
629.20	Titanium metal, wrought	18

Sources: For Canada, The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa; for the United States, Tariff Schedules of the United States annotated (1978) TC Publication 843.
[1]Suspension of duty on waste and scrap was extended until June 30, 1978.

Tungsten

D.G. LAW-WEST

Canada's single producer of tungsten concentrates, Canada Tungsten Mining Corporation Limited, reported an increase in production in 1977 to 2 284 409 kilograms (kg) of tungsten oxide (WO_3) in scheelite concentrate, an increase of nearly 5 per cent from 1976.

World tungsten prices increased rapidly in the first quarter of 1977 to above an average of $180 a metric ton unit* (mtu) cif European ports (London Metal Exchange (LME) Tungsten Ore Prices), and continued to remain high throughout the second quarter. In the third quarter they fell to near the beginning-of-the-year price of $142 mtu, and recovered somewhat in the fourth quarter, ending the year at $172 mtu.

Canadian developments

Canada Tungsten Mining Corporation Limited, the country's only tungsten producer, had a record year at its mine and mill complex in the Flat River Valley of the Northwest Territories. During 1977 the company mined and milled 168 400 tonnes** of ore grading 1.65 per cent tungstic trioxide (WO_3) to produce 228 441 mtu of WO_3, compared with the 1976 production of 171 398 tonnes of ore grading 1.55 per cent WO_3 and 216 815 mtu of WO_3. Although the company produced less ore, the grade was higher, and the mill recovery was improved. The company experienced three weeks of lost production in late August and early September through a wildcat strike by union members. At the end of 1977, mineable reserves were 3.8 million tonnes at 1.55 per cent WO_3.

In June 1977, Canada Tungsten began a major expansion program, which when completed in 1979 will double the mine and mill capacity in the Northwest Territories to 900 tonnes of ore a day. By year-end nearly $7 million of the estimated $12.3 million required for the project had been spent.

*A metric ton unit contains 10 kilograms, or 22.04 pounds.
**The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

The Sullivan Mining Group Ltd. signed a joint venture agreement through its subsidiary Brunswick Tin Mines Limited with Billiton Exploration Canada Limited. Under the agreement Billiton will carry out a feasibility study on the Mount Pleasant property in New Brunswick; cost of the study could be about $1.5 million. If the project does start, both companies will retain a 50 per cent interest in the property. The orebody is located about 64 kilometres (km) north of St. Andrews in Charlotte County, New Brunswick. There are two associated zones of mineralization, the Fire Tower Zone with an estimated 30 million tonnes of ore reserves and the North Zone with 12 million tonnes. The ore grade averages 0.2 per cent tungsten, 0.08 per cent molybdenum, 0.08 per cent bismuth, 5 per cent fluorite, 1.0 ounce a ton of indium, and minor amounts of copper, lead, zinc and tin. Considerable sampling and metallurgical testing have already been carried out. The envisaged production is around 1 350 tonnes of ore a day, which could lead to about 1 000 tonnes of tungsten a year.

AMAX Exploration, Inc. reported late in the year that its Tungsten Division had completed preliminary development of its 30-million-tonne (0.9 per cent WO_3) deposit located about 390 km northeast of Whitehorse on the Yukon-Northwest Territories border. There has been no announcement as to when further development may start.

There have been no further reports by Cordilleran Engineering Limited on a recent discovery of extensive tungsten mineralization in an area along the British Columbia-Yukon Territory border.

International developments

Austria. Wolfram-Bergbau-und Huttengesellschaft mbH. announced the completion of its scheelite ore processing plant at Mettersill, Austria. The company, owned 47.5 per cent by both Metallgesellschaft AG and Voest-Alpine Ab. and 5 per cent by Teledyne Inc., opened its scheelite mine in 1976. Wolfram-Bergbau is the first integrated tungsten producer in Europe. The

Table 1. Canada, tungsten production, imports and consumption, 1976 and 1977

	1976		1977[p]	
	(kilograms)	($)	(kilograms)	($)
Production[1] (WO_3)	2 168 153	. .	2 284 409	. .
Imports				
Tungsten in ores and concentrates				
United States	952	7 000	—	—
Total	952	7 000	—	—
Ferrotungsten[2]				
United Kingdom	75 000	865 000	90 000	1 557 000
United States	1 000	11 000	13 000	216 000
Others	1 000	15 000	—	—
Total	77 000	891 000	103 000	1 773 000
Metallic carbide tips or blanks				
United States	. .	359 000	. .	572 000
Sweden	. .	30 000	. .	7 000
Others	. .	71 000	. .	54 000
Total	. .	460 000	. .	633 000
Metallic carbide inserts				
United States	. .	2 170 000	. .	3 234 000
Sweden	. .	493 000	. .	826 000
Others	. .	825 000	. .	913 000
Total	. .	3 488 000	. .	4 973 000
Metallic carbides, nonagglomerated				
United States	234 235	3 568 000	633 000	6 328 000
Sweden	54 431	1 012 000	37 000	1 014 000
Others	2 086	40 000	3 000	70 000
Total	290 752	4 620 000	673 000	7 412 000
Consumption (W content)				
Tungsten metal and metal powder	226 803	. .	280 833	. .
Tungsten wire	8 335	. .	3 186	. .
Others[3]	102 207	. .	165 346	. .
Total	337 345	. .	449 365	. .

Source: Statistics Canada.
[1]Producers' shipments; [2]Gross weight; [3]Includes tungsten ore, tungsten carbide.
[p]Preliminary; . . Not available; — Nil.

mine and mill capacity is about 1 350 tonnes of contained tungsten in concentrate form. Eventually, an ammonium paratungstate (APT) plant and a tungsten carbide and metal powders plant are to be added. The ore reserves are in the area of 2.5 million tonnes, averaging 1.0 per cent WO_3.

Turkey. Etibank, the state-owned mining company, started production from the $45 million tungsten mine in the Uludag Mountain Range in northern Turkey. At full production, 2 400 tonnes a year of concentrate are expected.

Brazil. Tungsten producers and consumers have signed a special price formula for scheelite concentrate 70 per cent WO_3. The four producers and five consumers have agreed that the monthly domestic price will be based on weighted quotas of the previous month LME tungsten price with a ceiling of $180 per mtu. This will hold until September 1978 at which time

Table 2. Canada, tungsten production, trade and consumption, 1960, 1965, 1970, 1975-77

	Production[1] WO_3 content	Imports: Tungsten ore[2]	Imports: Ferro-tungsten[3]	Consumption W content
	(kilograms)			
1960	–	524 761	444 838	429 653
1965	1 734 837	162 114	160 572	398 079
1970	1 690 448	82 645	90 718	446 687
1975	1 477 731	953	45 359	534 958
1976	2 168 153	–	77 110	337 345
1977[p]	2 284 409	–	103 000	449 365

Source: Statistics Canada.
[1]Producer's shipments of scheelite (WO_3 content); [2]W content; [3]Gross weight.
[p]Preliminary; – Nil; . . Not available.

the producers will have to show their cost structures to the Interministerial Council on Prices, a government control agency. The consumers had asked the government to embargo scheelite exports.

Uses

The principal uses of tungsten are in carbides, tungsten-bearing steels, nonferrous alloys, mill products and chemicals.

Tungsten carbide (WC) is one of the hardest materials known. It is produced by chemical combination of tungsten metal powder and finely divided carbon. Cobalt is added as a binder, and the material is then compacted to the desired form and sintered to produce the cemented tungsten carbides. The largest end-use of cemented tungsten carbides is in cutting tools, which includes both mechanically-held and brazed-in-place inserts. Cutting tools are used in machining steel, cast iron and nonferrous metals and for shaping in the woodworking and plastics industries. Tantalum, titanium and columbium carbides are frequently added to tungsten carbide-cobalt mixtures to lower the coefficient of friction of the cemented carbides and, thereby, produce grades better suited to the machining of specific products, particularly steel. In the more-abrasive applications, such as dies for wire and tube drawing, punches and dies for metal forming, and bits and tools for drilling equipment and wear-resistant parts, a straight tungsten carbide-cobalt mixture is used almost exclusively. Other uses of tungsten carbide are in tire studs, studs in spikes for golf shoes, and armour-piercing projectiles.

Tungsten is added to steels either as ferrotungsten (80 per cent W), melting base (30 to 35 per cent W), scheelite ($CaWO_4$) or as tungsten-bearing scrap. The principal tungsten-bearing steels are tool steels, used in some of the applications of the carbides, but usually in applications where lower operating temperatures are encountered. Some tungsten is also consumed in certain stainless steels that are used in high-temperature environments. In addition, tungsten has been used in some magnet and die steels that have largely been supplanted by other products.

The most important tungsten-containing alloys are superalloys, used'in applications where high strength is

Table 3. Tungsten production in ores and concentrates, 1975-77

	1975	1976	1977[e]
	(tonnes of contained tungsten)		
Europe			
France	867	756	598
Portugal	1 467	1 285	997
Spain	351	328	327
U.S.S.R.	7 800	8 000	8 200
Total, Europe	11 088[e]	11 005[e]	11 362
North America			
Canada	1 172	1 719	1 863
United States	2 535[r]	2 644	3 175
Mexico	220	186	174
Total, North America	3 928	4 549	5 212
South America			
Bolivia	2 693	2 960	3 000
Brazil	1 395	1 096[e]	1 100
Peru	602[p]	519[p]	525
Total, South America	4 746	4 634	4 685
Africa	717[e]	769[e]	794
Asia			
People's Republic of China	8 980[e]	9 000[e]	9 100
North Korea	2 150[e]	2 150[e]	2 495
Japan	811	832	733
South Korea	2 533	2 423	2 493
Thailand	1 773	2 055	2 204
Total, Asia	16 717[e]	17 948[e]	18 544
Oceania, of which Australia	1 497	1 935	2 387
Total, Oceania	1 502	1 935	2 387
Grand Total[e]	38 600	40 800	43 000

Sources: UNCTAD Tungsten Statistics, April 1978; Statistics Canada; 1977 estimates by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
[e]Estimated; [p]Preliminary; [r]Revised.

required at high temperatures. The tungsten is usually added in the form of tungsten metal powder, although tungsten scrap can be used to satisfy part of the tungsten requirements. Superalloys can be classified into three principal types: nickel base, iron base and cobalt base. At present the principal usage of tungsten is in the cobalt-base or "Stellite" superalloys. The nickel- and iron-base superalloys currently contain little or no tungsten; however, several companies are developing new super alloys that contain several percentage units of tungsten and this should substantially increase the use of tungsten for this purpose. The expected rapid growth in usage of the superalloys, combined with a greater use of tungsten in them, should make this an important growth market for tungsten.

The most important properties of tungsten in its metallic form are its high melting point, low vapour pressure, high hardness, good electrical conductivity and low coefficient of thermal expansion. Tungsten mill products are made by compressing the tungsten metal powder into the desired shape and then sintering the compressed shape to produce a uniform product. The principal tungsten products produced are rods, wire and flat products.

Discs cut from tungsten rods are used as electrical contacts. In this application tungsten furnishes improved resistance to heat deformation where sparking and high temperatures occur at electrical contact points. Pure tungsten contacts have found their principal use in ignition circuits of automobiles and aircraft, but the trend to electronic ignition systems will decrease the use of tungsten in this application. Tungsten discs are also used as heat sinks in semiconductor applications. Tungsten is used in combination with other elements in electrical contacts and breakers for industrial applications.

Tungsten wire finds application for the filaments in incandescent lamps and for heating elements in fluorescent lamps and vacuum tubes. The use of vacuum tubes is declining, but tungsten usage overall should continue to grow as demand increases for different types of lamps. A minor new application is the use of tungsten wire in automobile windshields for deicing and defogging.

Flat products are used in fabricating parts of electron tubes and radiation shields and in parts for very high-temperature applications in reducing or inert atmospheres.

Among other uses of metallic tungsten, the most important is in heavy metals. Heavy metals are used in areas where counterweights or high-density material are required in limited spaces, e.g., in self-winding watches and in aircraft. Tungsten usage in heavy metals will grow at a slow rate because of the increasing availability and lower cost of depleted uranium, which has only a slightly lower density than tungsten. Steel tubes filled with tungsten carbide powder are used as electrodes in a welding method known as the Tungsten Inert Gas (TIG) method.

Tungsten compounds are used in small volume throughout the chemical industry. The principal end use is as sodium tungstate, phosphotungstate acid and phosphotungsmolybdic acid in dyes, toners, phosphors, chemical reagents and corrosion inhibitors. A minor and highly variable use is as petrochemical and chemical catalysts.

Price stabilization

When the Tenth Session of the United Nations Conference on Trade and Development (UNCTAD) Committee on Tungsten ended in an impasse in November 1976, the Trade and Development Board (TDB) was approached by some of the tungsten producing countries to form a negotiating conference. After considerable negotiating, a compromise resolution was agreed upon and the Ad Hoc Intergovernmental Group of Experts on Tungsten was convened for the first meeting from July 18 to 22, 1977. The Group of Experts was to "examine and assess proposals for the stabilization of the world tungsten market and, in particular, to undertake an in-depth examination of the UNCTAD Secretariat's proposal of September 1976, the proposals put forward by the tungsten-producing countries at the Tenth Session of the Committee on Tungsten in November 1976, and any other proposals put forward."

This first meeting of the Group of Experts ended with little real progress other than a compromise resolution on a future work program. The program involved studies to examine the legal, economic and administrative implications of proposals by the UNCTAD Secretariat, the producers, some consuming countries, as well as any others remaining before the Group. Most of these studies were examined at a second meeting of the Group of Experts from November 28 to December 2, 1977, but it too failed to make much progress.

The third and final meeting of the Group of Experts was held from February 20 to 24, 1978. While there was no consensus on what measures, if any, are necessary to stabilize world tungsten prices, the meetings revealed three broad proposals:

1. Commodity Agreement with binding economic provisions — Australia, Belgium, Bolivia, France, Netherlands, People's Republic of China, Portugal, Thailand, U.S.S.R. and Zaire.
2. Producer-Consumer Forum — West Germany, Japan, Sweden, United Kingdom and United States.
3. Commodity Arrangement without binding economic provisions — Canada.

The first two proposals are comprehensive — the commodity agreement seeks to impose an institutional structure on the market, while the producer-consumer forum seeks to define all the elements of the market. The Canadian proposal seeks to deal on a step-by-step basis to achieve greater market stability.

The pricing mechanism in tungsten is accepted by everyone to be a problem area, and from the Canadian viewpoint would seem to be the logical starting point. The Canadian proposal of an arrangement without binding economic provisions could lead to the formation of a group to establish a better price collection system or even suggest a price range for certain periods of time in order to try to improve the predictability of price. This type of approach would appear to offer just as much, or a greater, chance of success as the other, without the same degree of market intervention or the massive collection of statistical information on a country-specific basis.

The matter has been referred back to the UNCTAD Trade and Development Board to decide what can be done next, given the wide divergency in the views of the participating countries.

Prices

The *London Metal Bulletin (LMB)* price for tungsten concentrate rose sharply from $140 per mtu WO_3 at the beginning of the year to just over $180 an mtu by the end of February. The price remained high until the middle of July, when slackening consumer demand put downward presure on prices. By the end of September the price had fallen to near $140 an mtu WO_3. However, in response to new eastern European business and renewed demand from other consumers, by mid-October the price had rebounded to around $175 an mtu WO_3 where it remained until year end.

During 1977 *Metals Week* published its own tungsten price to reflect the price at which transactions took place in the United States. The tungsten price fluctuations in the U.S. almost perfectly reflected those in Europe.

Outlook

The outlook for 1978 is for much more stability in the price of tungsten concentrates as the supply and demand will almost balance during the year.

Looking further ahead, the tungsten market should remain fairly well balanced into the 1980s. However, the longer-term outlook is less certain since it will depend partially on the action of the UNCTAD Committee on Tungsten and the Primary Tungsten Association. Actions by either group will undoubtedly affect price, and through it consumption and production. Until such time as these situations become clarified, the future is uncertain.

Tungsten prices according to "Metals Week" for December 1976 and 1977

	1976	1977
	(U.S.$)	
Tungsten ore, 65% minimum WO_3 per stu of WO_3	effective Nov. 29, 1976	effective Oct. 28, 1977
G.S.A. Domestic, duty excluded	127.068	155.448
G.S.A. Export	127.000	154.750
L.M.B. ore quoted by *London Metal Bulletin*, cif Europe	effective Nov. 23, 1976 128.596-134.188	effective Dec. 8, 1977 150.595-159.666
Ferrotungsten, per pound W, fob shipping point, low-molybdenum	effective Nov. 1, 1976 9.250	effective Dec. 1, 1977 12.100
Tungsten metal, per pound, fob shipping point		
Carbon red, 98.8%, 1 000 pound lots	. .	. .
Hydrogen red, depending on Fisher No. range	effective Oct. 1, 1976 10.000-13.000	effective Dec. 1, 1977 13.900-15.500

. . Not available.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
			(%)		
32900-1	Tungsten ores and concentrates	free	free	free	free
34700-1	Tungsten metal in lumps, powder, ingots, blocks or bars and scrap of tungsten alloy metal, for alloying purposes	free	free	free	free
34710-1	Tungsten rod and tungsten wire	free	free	25	free
35120-1	Tungsten and alloys in powder, pellets, scrap, ingots, sheets, strips, plates, bars, rods, tubing, wire, for use in Canadian manufactures (expires June 30, 1979)	free	free	25	free
37506-1	Ferrotungsten	free	5	5	free
37520-1	Tungsten oxide in powder, lumps and briquettes, for use in the manufacture of iron and steel	free	free	5	free
82900-1	Tungsten carbide in metal tubes for use in Canadian manufactures	free	free	free	free

United States

Item No.		
422.40	Tungsten carbide, on W content	21¢ per lb + 12.5% ad val.
422.42	Other tungsten compounds, on W content	21¢ per lb + 10% ad val.
601.54	Tungsten ore, on W content	25c per lb
607.65	Ferrotungsten and ferrosilicon tungsten, on W content	21¢ per lb + 6% ad val.
629.25	Tungsten metal waste and scrap, not over 50% tungsten, on W content	21¢ per lb + 6% ad val.
629.26	Tungsten metal waste and scrap, over 50% tungsten, on W content	10.5% ad val.
629.28	Tungsten metal, unwrought, other than alloys: lumps, grains and powders, on W content	21¢ per lb + 12.5% ad val.
629.29	Tungsten metal, unwrought, other than alloys: ingots and shot	10.5% ad val.
629.30	Other unwrought tungsten metal	12.5% ad val.
629.32	Unwrought tungsten alloys, not over 50% tungsten, on W content	21¢ per lb + 6% ad val.
629.33	Unwrought tungsten alloys, over 50% tungsten	12.5% ad val.
629.35	Wrought tungsten metal	12.5% ad val.

Sources: For Canada, The Customs and Tariff Amendments, Department of National Revenue, Customs and Excise Division, Ottawa; for United States, Tariff Schedules of the United States Annotated (1978) TC Publication 843.

Uranium

R.M. WILLIAMS

Worldwide activity in the uranium industry attained high levels in 1977. Exploration programs were reported in more than 80 countries, with major activities being concentrated in the United States, Canada and in Africa, south of the Sahara. Development and expansion programs were underway in several countries which, if completed, could see world uranium production capability double by 1980. Despite this relatively high level of activity, however, there continued to be some uncertainty about the future of the industry, which events of 1977 did little to dispel.

Although in August 1977 the Australian government made known its decision to permit the development of uranium projects in its Northern Territory, implementation of its new development policies was expected to take some time, and the consequent order and timing of new production remained unclear. Concern about the environmental impact of new uranium developments, which had focussed on Australia in 1976, was focussed on North America where inquiries and licensing delays were affecting the timetables of several major development projects. Also of concern on the supply side were events in southern Africa where, in addition to political uncertainties, the largest new uranium mine in the world, that of Rossing Uranium Limited in Southwest Africa (Namibia), was experiencing technical difficulties reaching design capacity. All of these issues were unfortunately complicated by a proliferation of investigations and legal actions, either directly or indirectly related to the "Westinghouse affair" (see Markets).

The nuclear safeguards issue was also the focus of attention in 1977, as the United States and Australia followed Canada's earlier lead in an attempt to strengthen their safeguards requirements governing exports of nuclear materials, equipment and technology. Canadian producers were directly affected when, in January 1977, the Canadian government placed an embargo on the export of uranium to countries which had not yet completed negotiating revised nuclear safeguards agreements with Canada. By the end of 1977, however, agreements had been completed with all affected countries except Switzerland and Japan, and shipments had either resumed or were due to be resumed early in 1978.

Late in 1977 it was announced that Ontario Hydro had reached agreement with one Canadian producer and was near agreement with two other companies, all at Elliot Lake, relative to its projected uranium supplies into the next century. These major long-term contracts should see a doubling of the work force at Elliot Lake, Ontario over the next few years.

Production and development

Production of uranium in 1977 amounted to about 5 794 tonnes of uranium (U)*, compared with 4 850 tonnes U in 1976, the increase being attributable to expanded output from several producers. In addition, one new operation, that of Agnew Lake Mines Limited, began production in mid-1977 bringing to a total of six the number of Canadian uranium producers. Shipments of uranium from these six producers in 1977 were reported by Statistics Canada at 5 787 tonnes U, valued at $349.2 million. Some 63 per cent of these shipments were attributable to the four Ontario producers, the remainder coming from the two producers in Saskatchewan.

Mine production at Denison Mines Limited's Elliot Lake, Ontario operation increased gradually throughout the year to accommodate the recently expanded 6 440 tonne per day mill. Some 1 867 893 tonnes of ore were milled with an average grade of 0.878 kilogram (kg) U per tonne to produce 1 539 tonnes U. Significant elements of the expansion program completed during 1977 were the commissioning of the new "C" axis conveyorway and the reopening of the No. 1 shaft. The former will service new production centres in eastern portions of the Denison orebody, while the latter will provide access to good-grade pillars and for the development of three higher

*One metric ton of elemental uranium (tonne U) = 1.2999 short tons of uranium oxide (U_3O_8).

uranium-bearing "reefs," the mining of which may start in 1979. Additional expansion of the mill to some 10 900 tonnes per day was planned by 1982, followed by the reopening of the company's Stanrock and Can-Met workings, which adjoin to the east of the main property, and the reactivation of the Stanrock mill (2 720 tonnes per day) by 1985.

Rio Algom Limited's Quirke mill operated in excess of its nominal capacity, at an average of 4 330 tonnes of ore per day during 1977, treating 1 520 440 tonnes of ore with an average recovered grade of 1.102 kg U per tonne; average mill recovery was 94.1 per cent and production totalled 1 664 tonnes U. Some 2 037 tonnes U were delivered to domestic and export customers from production and inventory.

The major expansion of Rio Algom's Elliot Lake operations continued on schedule and within budget. Phase 1 of the program involves the expansion of the Quirke mill from 4 080 to 6 350 tonnes per day, together with the development of a new highly mechanized production centre in a uranium-bearing "reef" to the west of the New Quirke shaft, adjoining the old Quirke mine. This $76 million project was scheduled for completion in early 1978. Phase 2 of the expansion involves the reactivation of the company's Panel mine and 2 990 tonne per day mill, also located on the north limb of the Quirke Lake syncline, east of the new Quirke mine. Work on the $134 million project commenced in mid-1977, and completion was scheduled for 1980.

Table 1. Uranium production in Canada, by province, 1976 and 1977

	1976		1977	
	(tonnes)	($000)	(tonnes)	($000)
Production				
(Uranium (U) shipments)[1]				
Ontario	3 766	186 439	3 628	250 689
Saskatchewan	1 672	55 390	2 159	98 530
Total	5 438	241 829	5 787	349 219

Source: Statistics Canada.
[1]One metric ton of elemental uranium (tonne U) = 1.2999 short tons of uranium oxide (U_3O_8).

Subsequent phases of Rio Algom's expansion would be dependent on additional sales contracts and would involve the reactivation of the company's Milliken, Lacnor and Nordic properties on the south limb of the Quirke Lake syncline. Late in 1977, an affiliated company, Preston Mines Limited, announced that it was negotiating an agreement with Ontario Hydro with regard to reopening its Stanleigh property, which adjoins the latter three Rio Algom properties; Rio Algom would be engaged to construct and manage this project on behalf of Preston.

Output from Madawaska Mines Limited's Faraday operation, near Bancroft, Ontario, totalled 170 tonnes U in 1977, which was short of expectations due primarily to difficulties in providing sufficient ore of good grade to the 1 360 tonne per day mill. Considerable progress was made during the year, however, by way of increasing the number of workplaces in the mine, expanding the work force and improving productivity, such that capacity production was expected to be achieved in 1978.

Operations at Canada's newest producer, Agnew Lake Mines Limited, commenced in June 1977, when the mill began processing solutions from its surface stockpile. By year-end some 27 tonnes U had been recovered. The project, located 90 kilometres (km) east of Elliot Lake, Ontario, employs an underground and surface heap-leaching technique, whereby (during 1977) broken ore was "percolation-leached" in the stopes and the uranium-bearing solutions brought to surface for treatment by ion-exchange. Some 30 per cent of the ore, however, was also brought to surface (due to the increase in volume upon breaking) where it was heap-leached. Due to commissioning difficulties experienced both with the plant and with the ore development program, planned output of some 380 tonnes U per year was not expected to be attained until the second quarter of 1978.

Near Uranium City, Saskatchewan, Eldorado Nuclear Limited continued with its expansion program which was expected to result in an output of some 690 tonnes U per year by 1979. Key elements in this program include mine development in the lower Fay orebody, the rehabilitation of the Verna mine, which adjoins the Fay to the east, and the renovation of the mill to its original capacity of 1 630 tonnes per day. Considerable progress was made on all fronts during 1977; increased tonnages were provided to the mill mostly from the Fay mine but also as a result of the Verna rehabilitation and exploitation of the Eagle open pit, north of the main complex. A total of some 231 896 tonnes of ore were mined, with an average grade of 0.21 per cent U, to produce 456 tonnes U.

The Gulf Minerals Canada Limited-Uranerz Canada Limited joint venture at Rabbit Lake, Saskatchewan, operated in excess of its nominal capacity during 1977, following startup difficulties in 1976, which were largely solved by the addition of a primary crusher to the mill. Although the open-pit mine and 1 500 tonne per day mill is designed to produce some 1 730 tonnes U per year, over 1 939 tonnes U were produced during the year. Gulf continued its evaluation of three nearby deposits, one at Collins Bay about 11 km north of Rabbit Lake, and the Raven and Horseshoe deposits some 5.5 km southwest of Rabbit Lake, which eventually should contribute to the extension of the Rabbit Lake operation.

Table 2. Uranium production by major-producing countries, 1960, 1965, 1970 and 1975-77

	United States	Canada	France[1]	South Africa	Namibia	Australia	Other[2]	Total[3]
				(tonnes U)				
1960	13 663	9 807	1 061	4 930	—	1 000	1 116	31 577
1965	8 033	3 418	1 700	2 263	—	285	138	15 837
1970	9 822	3 157	1 694	3 169	—	254	232	18 328
1975	8 924	4 679	4 061	2 488	—	—	368	20 520
1976	9 770	5 438	4 193	2 759	593	359	464	23 576
1977^p	11 385	5 787	4 630	3 360	2 340	356	491	28 349

Sources: Statistics Canada; United States Bureau of Mines Minerals Yearbooks; USBM Mineral Trade Notes, September 1978; South African Chamber of Mines, Analysis of Working Results; 1977 Annual Reports of Commissariat a l'Energie Atomique and Rio Tinto Zinc Corporation Limited.
[1]Includes Gabon, Malagasy Republic (1960 and 1965) and Niger (from 1970). [2]Includes Argentina, Congo (1960), Finland (1960), Portugal, Spain and Sweden. [3]Totals are of listed figures only.
^{p}Preliminary; — Nil.

Late in 1976 the government of Saskatchewan announced that it would conduct an inquiry into the environmental, health and safety aspects of Amok Ltd.'s Cluff Lake project as well as the overall implications of further uranium developments in the province. In early 1977 Amok decided to await the outcome of the inquiry and suspended further activity on its property. A 1 500 tonne U per year operation had been envisaged for startup in 1979, to be built in two phases at a total cost of $133 million. Phase 1 would involve the exploitation of the rich "D" orebody by open-pit methods utilizing a small 80 tonne per day mill. Subsequently it was envisaged that beginning in 1981 or 1982 the mill would be expanded to some 1 090 to 1 360 tonnes per day to exploit the Claude and "N" orebodies. As a result of the inquiry however, it was expected that the project would be delayed by at least one year.

Saskatchewan's other major new development will be at Key Lake, some 160 km southwest of Rabbit Lake on the rim of the Athabasca Basin. Two deposits, discovered in 1975 and 1976 respectively, were being evaluated by Uranerz Exploration and Mining Limited jointly with the Saskatchewan Mining Development Corporation (SMDC) and Inexco Mining Company (Canada) Ltd. Late in 1977 it was announced that the Gaertner deposit contained 20 349 tonnes U and 22 520 tonnes nickel (Ni) in ore averaging 2.42 per cent U and 2.67 per cent Ni, respectively; the Deilmann deposit contained 19 122 tonnes U and 11 115 tonnes Ni in ore with average grades of 1.79 per cent U and 1.00 per cent Ni, respectively. Although Uranerz envisaged a 1 150 tonne U per year, $200 million operation beginning in 1983, it was expected that the timing, size and cost of the project could be altered both by the outcome of the Cluff Lake Board of Inquiry, and as engineering and development studies proceeded.

Also affected by the Cluff Lake Board of Inquiry was Cenex Limited's* project near Uranium City, Saskatchewan. The company, which had acquired the past-producing Lake Cinch uranium property from Eldorado in late 1976, planned to redevelop the property, hopefully for production commencing in the latter half of 1978. A milling contract had been arranged with Eldorado providing for the treatment of 360 tonnes of ore per day for four years, with an option for an additional two years. Despite the delays due to the Board of Inquiry, site preparations were underway by the end of 1977.

Two other potential Canadian development projects were those of British Newfoundland Exploration Limited (Brinex) in eastern Labrador, and Consolidated Rexspar Minerals & Chemicals Limited in the Birch Island area of British Columbia. A study of the feasibility of exploiting Brinex's Michelin and Kitts deposits near Kaipokok Bay was completed in mid-1977 and further drilling was subsequently initiated in an effort to boost reserves; Urangesellschaft Canada Limited is a partner (40 per cent) in the project. Late in 1977 Rexspar proposed that its Birch Island deposits be exploited by open-pit methods at a rate of 6 350 tonnes of ore per week which would yield about half a tonne U per day. Although known uranium reserves are sufficient for only 4.5 years of production, a nearby fluorite deposit could extend the life of the operation by some 4 years and additional potential exists for additions to uranium reserves; the capital cost of the project was estimated at $27 million. Considerable local opposition to the project had surfaced by year-end so that the outcome of the proposal was uncertain.

One of the principal constraints on the current expansion of Canada's uranium industry is the provi-

*Name changed August 1977 from New Joburke Explorations Limited.

sion of adequate skilled manpower. Companies have taken several steps in an effort to alleviate this problem including the institution of miner-training programs, the use of an air-commuter service in the case of the Gulf-Uranerz project, and major home-building programs in the case of Denison, Rio Algom and Eldorado. Illustrative of the magnitude of the latter type of effort was Rio Algom's program to provide some 1 000 housing units at a cost of $50 million by the end of 1978, and Eldorado's program to provide some 110 new units and renovate existing units at a cost of $18 million by the end of 1978.

Exploration

Results of a Department of Energy, Mines and Resources survey of uranium exploration activity in Canada indicated that levels of activity increased appreciably in 1977. Of more than 300 companies polled, 120 companies responded to the survey reporting some $72 million of exploration expenditures in 1977, representing a 10-fold increase over levels of activity in 1971 and 1972. The same survey indicated that 294 000 metres (m) of exploration drilling were completed during the year. Activity was reported in all provinces, as well as in the Yukon and Northwest Territories, with an increasing number of new areas receiving attention. Almost half the total expenditures and more than 60 per cent of the drilling were in Saskatchewan.

Major multi-project, multi-million dollar programs were reported by a number of companies, several of which were receiving financial assistance from domestic and/or foreign utilities. Much of the foreign involvement in Canada's uranium exploration activity was either directly or indirectly supported by foreign governments, often through joint ventures with Eldorado Nuclear Limited and/or provincial government Crown Corporations. Britain, West Germany, France, Italy, Spain and Japan all had such involvement, reflecting their need to satisfy the nuclear fuel requirements of their major nuclear power programs.

As in 1976, northern Saskatchewan was the scene of the most intensive activity, spurred by the Key Lake discoveries in 1975 and 1976 as well as by the earlier successes of Amok Ltd. and Gulf Minerals. The year 1977 saw three more potential prospects, all associated with the edge of the Athabasca Basin. In another joint Uranerz-Inexco-SMDC project, a uranium deposit was discovered at Maurice Bay, west of Uranium City, on the north shore of Lake Athabasca. In August it was reported *(Northern Miner Press)* that the zone extended some 343 m in length and 55 m in width, with an average depth of 17 m. Mineralization had been detected in some 68 holes, with grades averaging from 0.20 to 2.8 per cent U over thicknesses of a few metres to 18 m in several of these. Drilling was continuing at year-end to further define the deposit.

The view that the southeast edge of the Athabasca Basin, between Rabbit Lake and Key Lake, would be particularly promising was strengthened in 1977 with reports of two exploration successes. Gulf Minerals, in a joint venture with Noranda Exploration Company, Limited and SMDC, located a uranium-nickel occurrence, known as the West Bear project, some 40 km southwest of Rabbit Lake. Drilling of the zone, which occurs in the base of the Athabasca Formation, was continuing at year-end. In the same general area, Conwest Exploration Company Limited reported that drilling had located uranium mineralization on its Geikie River East property which could be important. The project is one of several held by The Conwest Canadian Uranium Exploration Joint Venture, which includes Conwest, Eldorado, Empresa Nacional del Uranio, S.A., Electrowatt Limited, and the Central Electricity Generating Board.

Numerous other areas in Canada were also receiving much attention. Projects were underway over the length and breadth of Nova Scotia. Exploration continued in the Makkovik-Moran Lake area, Labrador, and several areas in Quebec were active, including the Mont Laurier and Sakami Lake areas, the Johan Beetz area and portions of the Labrador trough. Activity continued in the Bancroft area of Ontario, as well as in Elliot Lake and the area north and west of Thunder Bay. In Manitoba, projects were reported in the areas of Seal River (65 km west of Churchill) and Kasmere Lake, and in Alberta the northeastern corner of the province was the focus of attention.

The Kelowna-Beaverdell area of British Columbia saw increased activity in 1977. Over 20 companies were exploring in the area in the wake of encouraging results of drilling by Noranda on the property of Tyee Lake Resources Ltd. and Peregrine Petroleum Ltd. and the earlier success of Japan's Power Reactor and Nuclear Fuel Development Corporation (PNC). In 1977 Norcen Energy Resources Limited, in a joint venture with Campbell Chibougamau Mines Ltd. and E & B Explorations Ltd. reported encouraging results of a drilling program on its Blizzard property in the same area; the property had been farmed out from Lacana Mining Corporation, which retains a 30 per cent interest. Activity in British Columbia was generally encouraged early in the year when the provincial government revised its mineral royalty scheme and instituted new tax incentives to stimulate exploration.

Activity was reported in several districts of the Yukon and Northwest Territories including the Fairchild Lake area of the Y.T., the Dismal Lake, Ennadai Lake, Amer Lake, Yathkyed Lake and Cape Dorset areas of the N.W.T. Of particular significance, however, was the decision in April 1977 of the Minister of Indian and Northern Affairs to limit exploration in the Baker Lake area for approximately one year, pending the results of a study of the influence of exploration activity on the grazing habits of the caribou herds. Several companies had been very active in the area prior to the suspension.

A total of $4.8 million was spent on Canada's uranium reconnaissance program during 1977 by the

Table 3. 1976 estimates of Canada's recoverable uranium resources

Resource Category	Mineable at prices up to $104/kg U ($40/lb. U_3O_8)[1]	$156/kg U ($60/lb. U_3O_8)[2]
	(tonnes U)	
(1) Measured	79 000	83 000
(2) Indicated	88 000	99 000
(1)+ (2) = Reasonably Assured[3]	*167 000*	*182 000*
(3) Inferred	238 000	307 000
(4) Prognosticated	154 000	349 000
(3)+ (4) = Estimated Additional[3]	*392 000*	*656 000*

Source: Department of Energy, Mines and Resources, Ottawa. [1]$104/kg U was the estimated "world price" in September 1976, at the commencement of the assessment. [2]Includes resources mineable up to $104/kg U. [3]International resource terms employed by Nuclear Energy Agency of OECD and the International Atomic Energy Agency.

federal government and the participating provinces. Some 527 200 km² were covered by airborne gamma ray spectrometry and 251 000 km² by regional geochemistry, in areas of seven provinces as well as both the Yukon and Northwest Territories. During the year, maps were released with respect to 523 100 km² of airborne work and 210 880 km² of regional geochemistry performed during 1976. Late in 1977 a new 2.5 year, $1 061 000 project was announced under the program which would cover 166 000 km² of Newfoundland and Labrador.

Uranium resources

In June 1977 the Department of Energy, Mines and Resources released its third annual assessment of Canada's uranium supply and demand,* prepared by the Department's Uranium Resource Appraisal Group (URAG). The 1976 assessment estimated resources in four categories of reliability and in two categories of price, as shown in the accompanying table.

For purposes of allocating responsibility for domestic requirements amongst Canadian producers only resources in the measured, indicated and inferred categories are considered. After deducting 1976 production of 4 850 tonnes U, the total in these three resource categories showed an increase of 14.3 per cent over comparable figures one year earlier. This increase was largely a reflection of initial successes as a result of increased levels of uranium exploration in Canada. Estimates of prognosticated resources increased only slightly over the comparable 1975 figures.

URAG also made a projection of uranium production which could be supported by these resources, assuming adequate availability of manpower, equipment, capital financing and the existence of base-load contracts. Barring such constraints, it was estimated that 1977 production could reach 6 100 tonnes U, rising to 7 950 and 12 500 tonnes U per year in 1980 and 1985, respectively, then declining slightly to 11 250 tonnes U by 1990, due to depletion of certain deposits and the mining of lower grade material in others. As outlined earlier, actual 1977 production fell short of expectations by some 5 per cent.

Canada's relative position with respect to the world's total uranium resources (excluding the USSR, Eastern Europe and China) can be seen in the accompanying figure, taken from a recent Canadian study prepared for the Conservation Commission of the World Energy Conference (WEC)*. Canada together with the United States accounts for some 38 per cent of the world's Reasonably Assured Resources, recoverable at costs up to $130 per kg U, and some 79 per cent of the world's Estimated Additional Resources in the same cost category.** Comparable annual world production capability figures taken from the WEC study are 33 330 tonnes U in 1977, rising to 55 130, 91 260 and 108 880 tonnes U in 1980, 1985 and 1990, respectively.

Government affairs

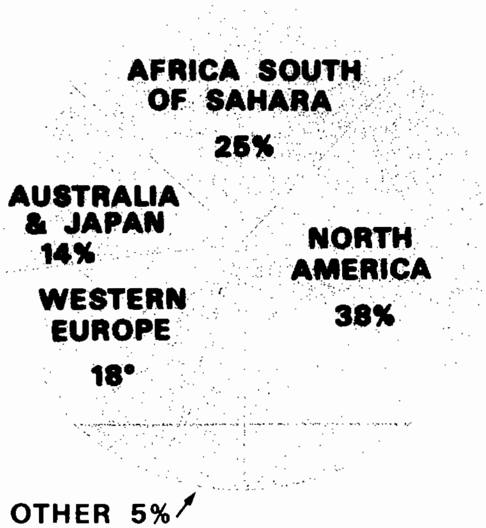
In February 1977 the government of Saskatchewan appointed a three-member Board, under the chairmanship of Mr. Justice E.D. Bayda, to inquire into the implications of Amok Ltd.'s Cluff Lake development project. Hearings were held throughout 1977 and the Board's report was awaited at year-end. The province of Ontario's Environmental Assessment Board also held public hearings during the year to assess the environmental impact of the expansion of uranium operations in the Elliot Lake area. The Board was expected to submit its findings to Ontario's Minister of the Environment early in 1978. The recommendations

*See EMR Report EP 77-3, June 1977, *1976 Assessment of Canada's Uranium Supply and Demand*, for details.

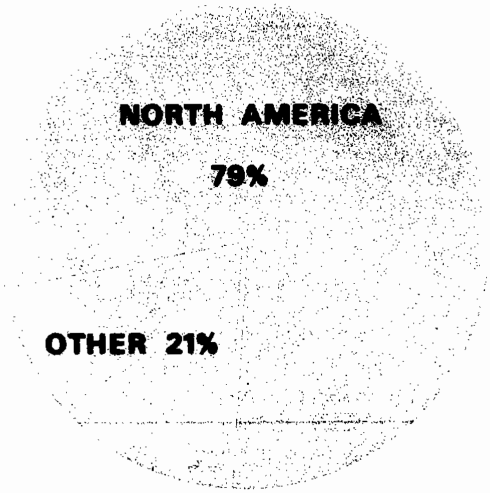
**The Contribution of Nuclear Power to World Energy Supply, 1975 to 2020*, August 1977 (revised to November 1, 1977). This report was presented at the WEC's 10th World Energy Conference, Istanbul, September 19 to 23, 1977; it was published in July 1978 together with several other studies carried out for the WEC's Conservation Commission as part of its investigation of world energy supply problems to the year 2020.

**For purposes of international comparison Canada compares its $104 and $156 per kg U "price" categories to the NEA/IAEA's $80 and $130 per kg U "cost" categories.

ESTIMATED WORLD RESOURCES OF URANIUM RECOVERABLE AT COSTS UP TO $130/KG U AS OF JANUARY 1977



REASONABLY ASSURED RESOURCES



ESTIMATED ADDITIONAL RESOURCES

(tonnes uranium)	World Region	(tonnes uranium)
825 000	North America	1 709 000
389 300	Western Europe	95 400
303 700	Australia, N.Z. & Japan	49 000
64 800	Latin America	56 200
32 100	Middle East & N. Africa	69 600
544 000	Africa S. of Sahara	162 900
3 000	East Asia	400
29 800	South Asia	23 700
2 191 700	Total World	2 176 200

of both Boards could have a profound effect on the nature of future developments in these two provinces.

In October 1977 the Minister of Energy, Mines and Resources (EMR) released publicly seven general Directions dealing with uranium prices and quotas that were issued between 1972 and 1975 to the Atomic Energy Control Board (AECB). Release of the documents was accompanied by a review of various efforts on the part of the Canadian government to seek, in cooperation with consumer nations, possible solutions to the deteriorating world uranium market situation of the early 1970s. It was the failure of these efforts which led, in 1972, to the international uranium marketing arrangements in which Canadian producers participated. Minimum prices contained in the AECB Directions ranged from $14.04 per kg U ($5.40 per lb. U_3O_8) to $21.32 per kg U ($8.20 per lb. U_3O_8) for immediate delivery in 1972 and 1974, respectively. Restrictions as to quotas and prices were revoked by the Minister in January and March 1975, respectively.

In March 1977, Canadian producers were informed by the Minister of EMR of a decision taken by the federal government that "with regard to all contracts not yet approved by the AECB, and all future contracts, the government will expect that terms of sale will provide for an annual renegotiation of price based on then existing world prices, giving consideration to such factors as term and size of contract and any special financing arrangements." He noted further that "provision should also be made for an escalating floor price which will protect investment in production facilities." Finally, he encouraged producers to renegotiate their older contracts in cases "where production costs have increased to the extent that prices are too low to provide a reasonable return."

In October 1977 the Minister of EMR amended the *Uranium Information Security Regulations* to limit their scope to information relating to the export from Canada, or marketing for use outside Canada, of uranium or its derivatives and to persons associated with uranium producers and the federal government. The Regulations do not preclude discussions by others of documents already in the public domain. The Regulations were initially approved under the Atomic Energy Control Act in September 1976 for the purpose of preventing documentation on Canadian uranium marketing arrangements from being released to United States courts. The more limited restrictions continue to ensure that Canadian sovereignty in this regard is adequately protected. Discussions were underway at year-end between Canada and the United States, directed at finding a solution to the type of extraterritorial legal conflict which necessitated these Regulations.

In October 1977, several members of Canada's federal Progressive Conservative opposition party challenged the validity of the Uranium Information Security Regulations in the Ontario Supreme Court. While Chief Justice Gregory Evans concluded that the Regulations were valid, he ruled that the subsection which gave the Minister of EMR authority to consent to the release of documents coming within the Regulations, was invalid.

In November 1977 the Minister of EMR tabled the *Nuclear Control and Administration Act* (Bill C14) in the House of Commons. The new act, which was intended to replace the more than 30-year old Atomic Energy Control Act, had as its objective the separation of responsibilities for health, safety, security and environmental matters from those dealing with the commercial and promotional aspects of nuclear energy. The former responsibilities would be administered by the Atomic Energy Control Board (AECB) to be renamed the Nuclear Control Board (NCB), which would report to Parliament through the Minister of State for Science and Technology. The Minister of EMR would retain the responsibility for commercial and promotional matters, which would be administered by EMR.

Importantly, the new act would provide the NCB with a mandate to hold public hearings on applications to construct major nuclear facilities and to make public, information on nuclear licence applications. The NCB would also have the power to assume responsibility for clean-up, if necessary, of radioactive wastes, the cost to be borne by a fund to be built up from prescribed payments of licensees. Provisions in the new act relative to the commercial and promotional aspects of the development of nuclear energy would remain substantially the same as they were in the Atomic Energy Control Act, except that, as a result of the split in regulatory responsibility, the new act included provisions which would authorize the Minister of EMR to regulate and engage in such commercial and promotional activities; to issue and/or revoke licences for such activities; and to set terms and conditions for those licences. The role of Crown corporations set up under the act would also be further clarified.

In January 1977 the Canadian government embargoed the export of Canadian nuclear materials and technology to all countries which had not completed negotiations of revised nuclear safeguards agreements with Canada. The revised agreements were necessary as a result of Canada's two-stage effort to strengthen its export requirements with respect to safeguards. The first of these steps, announced in December 1974, stipulated that the then existing contracts be covered by binding assurances that Canadian exports not be used to produce a nuclear explosive device; the second step, announced in December 1976, requires that shipments to non-nuclear weapon states under future contracts be restricted to countries which have ratified the Non-Proliferation Treaty (NPT) or otherwise accept international safeguards over their entire nuclear program.

Shipments of Canadian uranium to a number of countries were affected, principally Japan, countries of the European Economic Community (EEC), Switzerland and the United States. An interim agreement with the United States was reached in November 1977, and negotiations had been successfully completed with the EEC by the end of 1977. Agreements had been reached earlier with Argentina, Finland, Romania, South Korea, Spain and Sweden, although in the case of Argentina and Spain only the 1974 requirements had been met; since neither country is a signatory to the NPT, an additional agreement would be required to cover any new export contracts. At year-end agreements were outstanding with Japan and Switzerland, although negotiations with Japan were concluded early in 1978.

Markets

In December 1977 Denison and Ontario Hydro jointly announced that, subject to the issuance of an approving order-in-council by the Ontario government by February 28, 1978, they had reached an agreement whereby Denison will provide Ontario Hydro with some 48 465 tonnes U over the period 1980 to 2011. Prices will be determined from time to time according to a formula which takes into account the cost of production, an agreed margin and world price; the contract also provides for adjustments in the amount of uranium to be delivered if requirements should diminish. Prepayments will be made by Ontario Hydro to assist Denison with the required expansion of its operation and the development of certain specified mining areas which have been reserved for the fulfillment of the contract.

A number of other smaller sales were announced in late 1976 and early 1977. In December 1976, a contract was announced between Agnew Lake Mines and four northeastern United States utilities* for delivery of 423 tonnes U over the period 1977 to 1980. Subsequently, in February 1977, Agnew Lake announced the sale of 673 tonnes U to the Swedish Nuclear Fuel Supply Co. for delivery between 1977 and 1981. Initial deliveries under these and an earlier sale to the Korea Electric Company were made with the help of a uranium loan from Eldorado. Also in December 1976, Cenex Limited reportedly had negotiated a contract with Atomic Energy of Canada Limited (AECL) for the delivery of 84 tonnes U between October 1978 and June 1979, with reported prices beginning at \$123.50 per kg U (\$47.50 per lb. U_3O_8) and escalating to \$133.90 per kg U (\$51.50 per lb. U_3O_8). Finally, in June 1977, Madawaska Mines signed a contract with Hydro-Quebec for the delivery of some 39 tonnes U for delivery in 1978 at a reported price of \$111.02 per kg U (\$42.70 per lb. U_3O_8).

In late 1977 the AECB released information with respect to 29 contracts for the export of uranium which had been approved since September 1974. By comparison with similar data published earlier, it can be seen that contracts for only 1 840 tonnes U were approved during 1976 and 1977. The approved exports indicated in the accompanying table represent commitments made by Gulf Minerals, Uranerz Canada, Rio Algom, Eldorado, Agnew Lake, Amok, Madawaska and Denison. As of December 1977, total outstanding export commitments of all Canadian producers were estimated at some 68 000 tonnes U.

*Yankee Atomic Electric Company; Vermont Yankee Nuclear Power Corporation; Maine Yankee Atomic Power Company and the Public Service Company of New Hampshire.

Table 4. Uranium exports approved by Atomic Energy Control Board since September 5, 1974

	(short tons U_3O_8)	(tonnes U)
Italy	1 800	1 390
United Kingdom	10 000	7 690
Japan	21 500	16 540
Spain	6 250	4 810
West Germany	7 800	6 000
Finland	2 300	1 770
Belgium	1 100	840
Switzerland	650	500
United States	23 300	17 930
South Korea	300	230
Sweden	875	670
Total	75 875	58 370

Source: Atomic Energy Control Board.

A number of different court actions were in progress in the United States during 1977, relating to international uranium marketing activities during the period 1972 to 1975. In a suit brought against Westinghouse Electric Corporation by a number of electric utilities, Westinghouse was charged with failure to honour contracts to deliver some 25 000 tonnes U at prices averaging \$26 per kg U (\$10 per lb. U_3O_8). In its defence, Westinghouse claimed that participants in the 1972-1975 international uranium-marketing arrangement (see Government affairs) were mainly responsible for the rise in uranium prices which made it commercially impracticable for Westinghouse to honour its uranium supply contracts. Westinghouse also relied on the activities of the uranium-marketing arrangement as the basis for its treble-damage suit against uranium producers, both domestic and foreign. In another action, United Nuclear Corporation (UNC) sued General Atomic Co., whose Canadian affiliate Gulf Minerals Canada Limited was a participant in the marketing arrangement, on the grounds that Gulf's participation in the arrangement had put General Atomic in a position of artificially holding down the price for uranium purchased from UNC. In a countersuit, General Atomic denied UNC's allegations and asked that UNC

Table 5. Exports of uranium concentrates from Canada, 1960, 1965, 1970 and 1975-77

	United States[1]	Britain	Japan	West Germany	Others	Total
			($000)			
1960	236 594	25 905	147	294	601	263 541
1965	17 140	39 573	179	426	1 941	59 259
1970	20 148	9 482	266	103	3 982	33 981
1975	97 725	23 096	1 773	304	10 578	133 476
1976	198 277	24 327	1 068	288	29 128	253 088
1977[p]	224 717	2 946	288	384	8 268	236 603

Source: Statistics Canada, exports of radioactive ores and concentrates and radioactive elements and isotopes which cleared customs.
[1]For years 1967 to 1976 exports to the United States are almost entirely destined for a third country, primarily West Germany and Japan, following enrichment. Beginning in 1977, as a result of the phased removal of the United States restriction on enrichment of foreign uranium for domestic use, a growing proportion of these exports will be destined for the United States domestic market.
[p]Preliminary.

fulfill its 10 400 tonne U contract. Late in 1977, the Tennessee Valley Authority filed a civil anti-trust suit against 13 uranium producers, five of whom are based in Canada, and all of whom were alleged participants in the marketing arrangement. Australian participants in the arrangement were noticeably absent from the latter list.

The international uranium marketing arrangement was also being investigated by the United States Department of Justice and at least two State legislatures, to determine if the participants might have been guilty of violations of U.S. anti-trust laws and if their collective actions were responsible for increased nuclear energy costs to U.S. consumers. Faced with various attempts to gain access to information on Canadian uranium marketing activity as evidence for these various actions and investigations, the Canadian government took steps (see Government affairs) to prevent the release or disclosure of such material. The government also decided in October 1977 to conduct a formal domestic inquiry to determine if the 1972-1975 international uranium-marketing arrangement violated Canada's Combines Investigation Act. At year-end, while there had been some minor out-of-court settlements between Westinghouse and certain of its reactor customers, the outcome of these various lawsuits and investigations was uncertain. It was expected that some of the proceedings would not be concluded for some time.

In a separate matter, late in 1977, AGIP Nucleare SpA began an action against the Canadian government in the Federal Court, in which it raised several issues relating to the determination of prices for 1977 deliveries under AGIP's contract with Madawaska Mines. Named in the action were Madawaska, the Ministers of Industry, Trade and Commerce, and Energy, Mines and Resources, the Secretary of State for External Affairs, and the Atomic Energy Control Board.

Refining and enrichment

Output of uranium hexafluoride (UF_6)* at Eldorado's Port Hope, Ontario refinery increased by 16 per cent in 1977 to 3 867 tonnes U as UF_6. The program to expand the UF_6 circuit to 5 440 tonnes U a year continued, with completion expected during 1978. As one of five commercial uranium refiners in the world, Eldorado converts uranium concentrates to UF_6 for a variety of customers in Europe, Japan and the United States. Deliveries of UF_6 to customers in EEC countries and Japan were placed in inventory during 1977, pending successful negotiation of revised nuclear safeguards agreements between Canada and the EEC, and Canada and Japan (see Government affairs).

Output of Eldorado's other principal product, natural ceramic-grade uranium dioxide (UO_2), increased by 63 per cent in 1977, to some 841 tonnes U as UO_2. Natural UO_2 powder is subsequently pelletized at Canada's two fuel-fabricating facilities (Westinghouse Canada Limited at Port Hope, Ontario and Canadian General Electric Company Limited at Peterborough, Ontario) for fabrication into fuel elements for Canada's nuclear power program, as well as for first cores for CANDU exports. In anticipation of the increased UO_2 requirements of Canadian utilities forecasted for the mid-1980s, Eldorado proceeded with plans for the construction of an additional processing circuit, to be installed, probably in 1979.

Both the UO_2 and the UF_6 circuits are fed by a solvent extraction circuit which converts mine con-

*Uranium hexafluoride is the required feed material for the uranium enrichment process.

centrates to nuclear-pure uranium trioxide (UO_3). Expansion of Eldorado's UO_3 plant, which had begun in 1974, continued throughout 1977 with the objective of increasing its nominal capacity from 4 540 tonnes U a year to some 6 800 tonnes U a year by 1979.

During 1976 Eldorado completed preliminary examinations of 17 potential Ontario sites for a new 9 070-tonne-U-a-year UF_6 plant. On January 7, 1977 the company announced that a site at Port Granby, 14.5 km west of Port Hope, was its preferred choice; the site includes the company's current residue management area. A detailed environmental impact assessment of the project was subsequently prepared and submitted to a federal environmental assessment review panel, which held a series of public hearings beginning in September. It was expected that the panel would make its recommendations early in 1978. The company was also conducting feasibility studies on the possibility of locating an additional refinery at Warman, near Saskatoon, Saskatchewan, in the 1980s.

There have been two study projects undertaken in Canada to examine the possibility of establishing a domestic uranium enrichment facility. In 1970, Brinco Limited began studying the possibility of establishing a plant based on United States gaseous diffusion technology although this did not lead to a firm proposal. Numerous other alternatives were examined by the company, using gas centrifuge technology, until the program was phased out in late 1975. In early 1974, a second study was undertaken jointly by James Bay Development Corporation, SERU Nuclear (Canada) Limited (subsidiary of the French Commissariat à l'Energie Atomique (CEA)*), Canadian Pacific Investments Limited and Cominco Ltd., to examine the possibility of utilizing power from Quebec's James Bay hydroelectric power project to operate a plant based on French gaseous diffusion technology; a joint company CANADIF was formed to carry out the study. In late 1975, however, Canadian Pacific and Cominco withdrew from the project, following completion of the first phase of the study, largely because the required investment had a much larger payback time than their normal business investments.

Due to the CANADIF project and various other developments in the energy and uranium enrichment fields, the Government of Canada undertook a review, beginning in late 1975, to determine if it should revise its policy on uranium enrichment enunciated in August 1973. This policy resulted from an earlier study made by the federal government in 1971, which concluded that no clear case could be made either for or against uranium enrichment in Canada. The policy statement reflected this view in that the stand adopted was essentially one of "benevolent neutrality."

*In January 1976, all assets in the nuclear fuel cycle controlled by the CEA were transferred to the State company, Compagnie générale des matières nucléaires (COGEMA).

The latest review was completed in mid-1976 and a report, entitled "1976 Review of Uranium Enrichment Prospects in Canada," was released in July 1977. The review found that uranium enrichment plants existing or committed in the world at that time would have sufficient capacity to meet projected world demand for enrichment services until 1990. Moreover, the review indicated that the cost of separative work in a new commercial plant of a type proposed by CANADIF would be higher than the-then current prices charged by the United States Energy Research and Development Administration (ERDA). Economic analyses were conducted, which suggested that there would be a net economic loss to Canada from the export of uranium enriched in a 9 000 000 separative work unit (SWU)* a year gaseous diffusion plant, principally by virtue of the implicit subsidy on the heavy electrical input and the lower than average benefits accruing to individuals other than investors. The implicit subsidy resulted from the fact that, among other things, Canada's public utilities realize a lower than average return on investment. For Canada to realize positive economic benefits from such a plant, additional return to the economy of approximately 20 per cent of sales would need to be obtained.

The report indicated that taking all things into consideration, the construction of an enrichment plant in Canada to supply the export market was less attractive in 1976 than when the possibility was first examined in 1971. It recommended that no change should be made to the 1973 federal government policy regarding uranium enrichment. It noted, however, that there was potential for such a business in the future owing to development of new enrichment technologies such as the laser and the ultracentrifuge methods, both of which are much less energy intensive than the gaseous diffusion method.

Nuclear power developments

As of late 1977, over 80 000 electrical megawatts (MWe) of nuclear power capacity was operating throughout the world (excluding China, USSR and Eastern Europe). It was projected that some 270 000 MWe would be in operation by 1985 and over 1 000 000 MWe by the year 2000. Within Canada, nine CANDU reactors with an aggregate capacity of 4 028 MWe were operating by the end of 1977 and a further 16 reactors with an aggregate capacity of some 11 300 MWe were either under construction, committed or planned.

*A measure of effort expended to separate a quantity of uranium of a given assay into two components, one having a higher percentage of U^{235}, and one having a lower percentage. Separative work is generally expressed in kilogram units to give it the same dimensions as material quantities, i.e., kilograms or metric tons of uranium. It is common practice to refer to a kilogram separative work unit simply as a separative work unit or a SWU.

Table 6. Nuclear power plants in Canada, 1977

Reactors	Owner	Net Output (MWe)	In-Service Dates
Operating			
Nuclear Power Demonstration	Atomic Energy of Canada Ltd.	22	1962
Douglas Point	Atomic Energy of Canada Ltd.	208	1967
Gentilly 1	Atomic Energy of Canada Ltd.	250	1971
Pickering 1 to 4	Ontario Hydro	2 056	1971-1973
Bruce 1 and 2	Ontario Hydro	1 492	1976
Subtotal		4 028	—
Under Construction or Committed			
Bruce 3 and 4	Ontario Hydro	1 492	1978-1979
Pickering 5 to 8	Ontario Hydro	2 064	1981-1983
Gentilly 2	The Quebec Hydro-Electric Commission	637	1980
Point Lepreau	New Brunswick Electric Power Commission	630	1981
Bruce 5 to 8	Ontario Hydro	3 076	1983-1986
Subtotal		7 899	—
Planned			
Darlington 1 to 4	Ontario Hydro	3 400	1985-88
Subtotal		3 400	—
Grand Total		15 327	—

Sources: *1976 Assessment of Canada's Uranium Supply and Demand,* Department of Energy, Mines and Resources, Ottawa. Report EP77-3, June 1977; Atomic Energy of Canada Limited, Annual Report 1977-78.

The principal event of 1977 was the startup of the third unit of Ontario Hydro's Bruce 'A' Generating Station. The unit started up on November 28, 1977 and produced its first electricity by December 12, 1977; it was declared in service on February 1, 1978. Units 1 and 2 operated with an average capacity factor of 65.1 per cent during 1977. The Atomic Energy Control Board had authorized the operation of all three units at 88 per cent of reactor power, thus allowing them to produce their full electrical output; a portion of Bruce 'A's steam output was to be provided to Ontario Hydro's heavy water production plants. Meanwhile, construction of Unit 4 proceeded satisfactorily, with completion expected by the end of 1978.

Perhaps the other most noteworthy accomplishment in nuclear power in Canada in 1977 was the continued remarkable performance of Ontario Hydro's Pickering 'A' Generating Station. Some 28 per cent of

Ontario's electricity was attributed to nuclear power in 1977, most of which was generated at Pickering. The 4-unit station operated during 1977 with an average capacity factor of 91 per cent with total unit energy costs of 9.3 mills per kilowatt hour (kWh), approximately half the cost of operating the coal-fired Lambton Generating Station, if it were run on base load operations.

The Douglas Point Generating Station, which provides some 65 per cent of its output to the Bruce Heavy Water Production Plant, operated with an availability factor of 89 per cent during 1977, despite the development of a small heavy water leak in mid-year. By the end of 1977 the Nuclear Power Demonstration Generating Station (NPD) had completed 16 years of successful operation, during which time it provided nearly two billion kWh to the Ontario Hydro grid; the plant's main purpose is as a training facility in nuclear power plant operations. AECL's Gentilly 1 station (a CANDU-Boiling Light Water prototype)* remained inoperative throughout 1977, while studies were carried out to assess its economic viability and to determine its future role in the Canadian nuclear power program. Modifications were also underway in line with the plan for Gentilly 1 to act as the source of steam for the La Prade Heavy Water Production Plant. This conversion work was suspended in January 1978, however, with the signing of an agreement with Hydro-Quebec for Gentilly 2 to perform this role.

Construction of Pickering 'B' (a duplicate of Pickering 'A'), Gentilly 2 and Point Lepreau generating stations continued more or less on schedule. Engineering work continued during the year for Bruce 'B' (a duplicate of Bruce 'A' with certain changes), orders for major nuclear components were placed and construction commenced on the site. Authorization by Ontario Hydro for the design and construction phase of the Darlington Generating Station to be located near Bowmanville, Ontario, was received in January 1978. AECL completed a design report on a 1 250 MWe CANDU reactor for Ontario Hydro's next generation of stations. Detailed design studies were to continue with a view to having a completed design by 1980.

In November 1977, the Minister of EMR released a report entitled "The Management of Canada's Nuclear Wastes,"** prepared by an independent panel which was asked by the Minister to examine the issues in an effort to promote public discussion. The report examined several aspects of the nuclear waste management problem including the nature of nuclear wastes, current methods of nuclear waste management, related environmental and health impacts, possible final nuclear waste disposal methods, current Canadian and international programs for developing methodes for storage and disposal of nuclear wastes, possible institutional responsibilities and opportunities for public discussion. The overall conclusion of the report was that good prospects for safe, permanent disposal of nuclear reactor wastes exist and that the disposal problem should not delay Canada's nuclear power program, provided that work is begun on a national nuclear waste disposal plan immediately.

*Gentilly 2 will use a conventional CANDU-Pressurized Heavy Water reactor.

***The Management of Canada's Nuclear Wastes,* A.M. Aitken, J.M. Harrison and F.K. Hare (chairman), Department of Energy, Mines and Resources, Ottawa. Report EP77-6, August 31, 1977.

Outlook

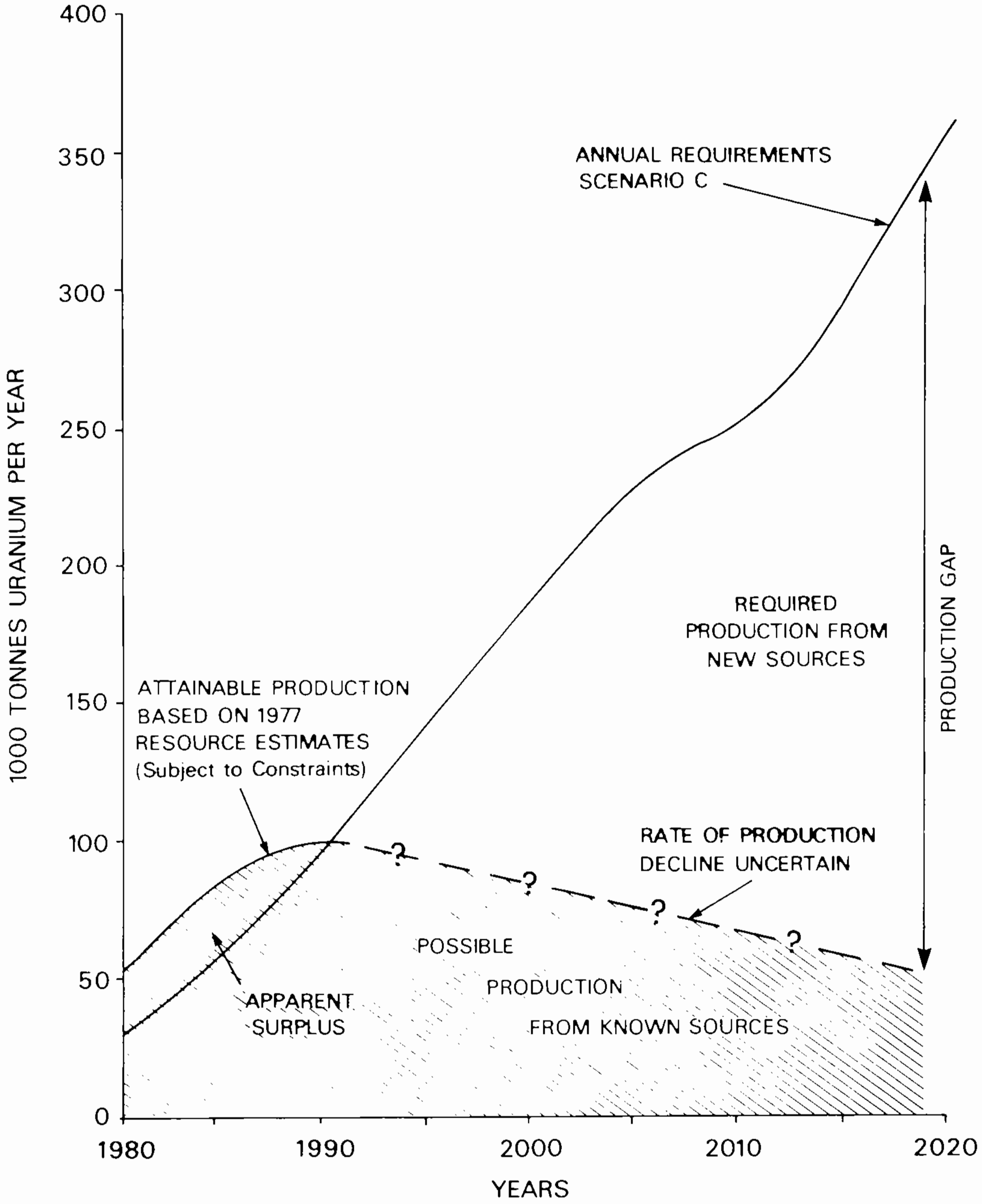
In the study recently prepared for the Conservation Commission of the WEC (see Uranium resources) several nuclear energy growth scenarios were presented in order to illustrate the nature of the uranium supply problem over the next few decades. Under all but the most conservative cases it was predicted that world* uranium requirements would increase ten-fold to about 200 000 tonnes U per year by the year 2000. If currently envisaged breeder reactors are introduced successfully prior to the end of the century, requirements would still grow to some 350 000 tonnes U per year by the year 2020 (see accompanying figure). Should breeder reactors and plutonium recycling not be introduced, however, requirements would grow to some 600 000 tonnes U per year by the year 2020, presenting a uranium supply challenge that the study inferred could not likely be met. The inescapable conclusion was that use of advanced nuclear fuel cycles was essential and that, if nuclear energy was to play its expected role, unprecedented levels of international cooperation would be required.

In April 1977, however, a new nuclear policy was unveiled in the United States, which left the future use of advanced fuel cycles in some doubt. Briefly, President Carter called for an indefinite deferral of the commercial reprocessing and recycling of plutonium produced in U.S. power programs, a deferral of the commercial use of breeder reactors in the U.S., a redirection of U.S. research and development programs into alternative nuclear fuel cycles which do not involve direct access to materials useable in nuclear weapons, and an expansion of U.S. capacity to enrich uranium to provide adequate and timely supply for both domestic and foreign needs. The overall objective of these new directions is to reduce the worldwide spread of nuclear explosive capability, while ensuring that all nations are able to achieve their overall energy objectives.

In line with the latter aspect of President Carter's new policy, the organizing conference of the International Nuclear Fuel Cycle Evaluation (INFCE) met in Washington in October 1977. Conceived at the London summit of principal western world leaders in mid-1977, INFCE was to examine the pros, cons and alternatives

*Excluding the USSR, Eastern Europe and China.

SCHEMATIC ILLUSTRATION OF WORLD URANIUM SUPPLY PROBLEM, 1980 TO 2020



to a world "plutonium economy," in an attempt to arrive at an internationally acceptable system to combat nuclear weapons proliferation. At year-end more than 40 countries had indicated their intention of participating in the study which would be carried out by eight-working groups over a two-year period. Canada was to provide the cochairmen, together with Egypt and India, for working group 1 which would examine the question of fuel and heavy water availability to the year 2025. It was hoped that the outcome of INFCE would remove many of the uncertainties about the future trend of nuclear power growth, thus clarifying the nature of the supply challenge facing the uranium industry.

Despite a significant decline in uranium requirement projections during recent years, due largely to reductions in projections for overall energy demand, the task of discovering, developing and exploiting the required uranium on a timely scale remains large. The magnitude of the problem increases markedly in the post-2000 period, when the developing countries will experience their major nuclear power growth expansion. While the recent WEC study concluded that the problem would not likely be one of existence of resources, it did identify a number of physical, technical, economic and political constraints which would make it difficult to make these resources available on the required timescale. Among the more important of these constraints were the lengthening lead times associated with uranium development projects, as a result of environmental impact inquiries and more complex regulatory procedures, and restrictions on exploration in some areas of the world where additional uranium resources can be expected to be discovered. Hopefully, some of these factors can be mitigated thus permitting the uranium supply industry to build up the required momentum to enable the world's nuclear power programs to reach their full potential.

Zinc

D.H. BROWN

There was no growth in the world's consumption of zinc during 1977, but despite this, world mine and metal production increased. Zinc inventories rose to record levels and prices declined.

Canadian developments were no exception to this general trend. Mine and metal production both increased while exports declined. Domestic inventories and prices likewise followed world trends. Canada's zinc industry is over 90 per cent reliant upon foreign markets, and in turn, 25 per cent of all zinc consumed in the western world originates from mines in Canada. Canada has sufficient refining capacity to process 50 per cent of its domestic mine production, but this potential has not been reached in recent years due to recessionary world market conditions. These same factors have caused Canada's exports of zinc-in-concentrate to decline by 36 per cent during the past four years.

Mine production in Canada

In 1977, there were 28 mining enterprises operating 30 mills that produced zinc concentrate in Canada. The zinc content of this production was 1 300 228 tonnes* compared to 1 145 407 tonnes in 1976. This increase in production is accounted for by the fact that Brunswick Mining and Smelting Corporation Limited and Cyprus Anvil Mining Corporation recovered from severe labour strikes in 1976 and Nanisivik Mines Ltd., which started production in late 1976, turned in a full year of capacity production in 1977.

Mine closures during the year reduced the daily mill capacity of Canada's zinc-producing mines by 3 800 tonnes to 91 850 tonnes. Average utilization of this mill capacity was 83.9 per cent compared to 73.9 per cent in 1976. The average tenor of zinc-in-ore processed during the year declined to 4.82 per cent from 5.3 per cent in 1976 and the average zinc recovery from these ores to zinc concentrate declined to 82.6 per cent from 83.7 per cent in 1976.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Zinc-producing mines that closed during the year were the Cupra Division of the Sullivan Mining Group Ltd., the Manitouwadge Division of Willroy Mines Limited, and Nigadoo River Mines Limited. Collectively, these mines produced 18 000 tonnes of zinc-in-concentrate in 1976. Earlier, Ruth Vermont Mine Ltd. closed effective year-end 1976.

The only zinc-producing mine to come into production during 1977 was the Westarm copper-zinc mine owned by Hudson Bay Mining and Smelting Co., Limited. The mine will produce about 1 000 tonnes of zinc-in-concentrate annually.

Newfoundland. Zinc production at the Buchans mine operated by ASARCO Incorporated declined from 18 674 tonnes to 17 338 tonnes. Declining ore reserves will only permit the mine to continue operating for another two years at most.

Newfoundland Zinc Mines Limited operates the only pure zinc mine in Canada at Daniels' Harbour and has increased its zinc output to 45 270 tonnes from 37 998 tonnes by increasing both the mill throughput and the grade of ore treated.

New Brunswick. Zinc mine production at Brunswick Mining and Smelting Corporation Limited recovered from the strike-bound year of 1976 but poor zinc markets forced the company to reduce employment as well as scale down and defer the $53 million expansion program at the No. 12 mine. The new No. 3 mine shaft will now only be bottomed at the 1 127 metre (m) level and production will be deferred one year to 1980. The No. 6 mine ceased open-pit operations in 1977 but underground operations there should continue for about another four years, when ore reserves will be exhausted. Zinc-in-concentrate production was 210 097 tonnes compared to 120 707 tonnes the year before.

Nigadoo River Mines Limited ceased operations on August 26, 1977 due to exhaustion of ore reserves.

Heath Steele Mines Limited reduced zinc production in 1977 due to a reduction in the tenor of ore treated. Zinc-in-concentrate output was 35 474 tonnes compared to 37 818 tonnes in 1976.

Table 1. Western world primary zinc statistics, 1975-77

	1975	1976	1977^p
	(000 tonnes zinc content)		
Mine production	4 547	4 548	4 852
Metal production	3 769	4 135	4 268
Metal consumption	3 531	4 127	4 129
Refinery capacity^e	5 180	5 329	5 548
Refinery operating rate	69%	79%	76%

Source: International Lead and Zinc Study Group.
^{e} Estimated by the Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa; ^{p}Preliminary.

Nova Scotia. Imperial Oil Limited decided to develop the Gays River lead-zinc deposit, at a cost of $27 million, into a producing mine by the fourth quarter of 1979. The mine will operate at a rate of 1 360 tonnes a day and produce about 18 000 tonnes of zinc a year.

Quebec. The Lake Dufault division of Falconbridge Copper Limited decreased zinc production from 12 529 tonnes to 11 650 tonnes in 1977 as a result of a reduced throughput of ore. The nearby Corbet mine will furnish replacement ore reserves for declining reserves at the Millenbach mine; diamond drilling at this property was completed in 1977. Indicated reserves are 2.3 million tonnes of ore grading 2.26 per cent zinc, 3.47 per cent copper, 21.15 grams (g) of silver per tonne, and 1.03 of gold per tonne.

Lemoine Mines Limited increased zinc production to 8 685 tonnes in 1977 from 6 955 tonnes in 1976 due to increased ore treatment. Zinc production by the Louvem Mining Company Inc. increased from 15 110 tonnes in 1976 to 16 120 tonnes in 1977 for the same reason.

The Sullivan Mining Group Ltd. closed down the Cupra and D'Estrie mines on January 31, 1977 as had been previously announced.

Zinc output by Mattagami Lake Mines Limited at its zinc-copper Matagami mine declined from 74 900 tonnes to 58 518 tonnes in 1977 as both the quantity and grade of ore declined during the year.

Orchan Mines Limited increased zinc output to 28 259 tonnes in 1977 from 24 818 tonnes in 1976; however, because of depressed zinc prices and mounting inventories all mining operations ceased temporarily on December 2, 1977 for about one month. At the same time, development of the P.D. Division's open-pit mine was suspended pending improved economic conditions.

Ontario. Willroy Mines Limited closed down its lead-zinc mine at Manitouwadge on May 31, 1977 due to ore exhaustion.

The Sturgeon Lake mine, which is a joint venture operated by Falconbridge Copper Limited, increased zinc output in 1977 to 30 755 tonnes from 24 064 tonnes in 1976 due to increased ore throughput, higher zinc grades and improved recoveries.

Zinc output at Mattabi Mines Limited increased to 72 443 tonnes from 69 016 tonnes. Due to declining reserves, the Mattabi mill will process ore from the adjacent Lyon Lake Division, which is owned by its parent company Mattagami Lake Mines Limited, when the new mine starts regular production in 1978.

Table 2. Canada, primary zinc statistics, 1975-77

	1975	1976	1977^p
	(000 tonnes zinc content)		
Mine production	1 229	1 145	1 300
Metal production	427	472	495
Metal consumption	125	119	125
Refinery capacity	563	633	633
Refinery operating rate	76%	74%	78%
Exported mine production (A)	705	644	556
Exported metal production (B)	247	351	295
Export processing index (B+(A+B) X 100)	26%	35%	35%

Sources: Statistics Canada. Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
^{p} Preliminary.

Table 3. Canada, zinc production, trade and consumption, 1976 and 1977

	1976		1977p	
	(tonnes)	($)	(tonnes)	($)
Production				
All forms[1]				
Ontario	317 194	263 101 933	291 923	225 452 000
Northwest Territories	147 610	122 438 035	164 963	127 401 000
New Brunswick	134 733	111 756 241	161 809	124 965 000
British Columbia	106 500	88 337 884	110 743	85 527 000
Quebec	117 768	97 684 826	107 608	83 106 000
Yukon	47 300	39 233 926	105 071	81 147 000
Manitoba	60 563	50 234 883	57 354	44 295 000
Newfoundland	42 498	35 251 008	47 164	36 425 000
Saskatchewan	7 891	6 545 359	7 893	6 095 000
Total	982 057	814 584 095	1 054 528	814 413 000
Mine output[2]	1 145 013		1 300 228	
Refined[3]	472 316		494 888	
Exports				
Zinc blocks, pigs and slabs				
United States	274 449	211 653 000	207 377	159 232 000
United Kingdom	40 601	29 427 000	44 512	32 904 000
Pakistan	2 795	2 083 000	7 870	5 485 000
Venezuela	6 347	4 239 000	4 949	3 488 000
West Germany	1 245	902 000	2 693	1 992 000
Singapore	4 029	2 924 000	2 730	1 854 000
France	506	419 000	2 152	1 694 000
Turkey	2 077	1 461 000	1 743	1 196 000
Taiwan	1 583	1 073 000	1 799	1 138 000
Israel	—	—	1 442	1 108 000
Thailand	1 586	1 117 000	1 594	1 067 000
Other countries	15 635	10 878 000	16 503	11 408 000
Total	350 853	266 176 000	295 364	222 566 000
Zinc contained in ores and concentrates				
Belgium and Luxembourg	246 844	91 899 000	260 004	96 812 000
Japan	108 351	45 155 000	113 022	43 709 000
United States	48 868	18 808 000	58 242	21 261 000
West Germany	111 625	38 629 000	44 062	13 426 000
U.S.S.R.	—	—	15 741	5 707 000
France	7 124	2 935 000	10 636	3 845 000
United Kingdom	9 149	3 332 000	11 101	3 810 000
Poland	21 192	7 616 000	8 028	3 130 000
India	23 785	6 990 000	9 791	2 626 000
Algeria	—	—	6 456	2 467 000
Other countries	67 156	22 941 000	18 552	4 921 000
Total	644 094	238 305 000	555 635	201 714 000
Zinc alloy scrap, dross and ash[4]				
United States	10 872	1 805 000	14 934	2 682 000
United Kingdom	1 977	505 000	2 728	780 000
Spain	307	167 000	282	164 000
Belgium and Luxembourg	320	75 000	577	56 000
Taiwan	19	7 000	108	49 000

Table 3. (concl'd)

	1976		1977p	
	(tonnes)	($)	(tonnes)	($)
Exports (concl'd)				
West Germany	1 546	282 000	414	41 000
Other countries	1 145	311 000	93	28 000
Total	16 186	3 152 000	19 136	3 800 000
Zinc dust and granules				
United States	3 295	3 344 000	3 419	3 614 000
Venezuela	—	—	94	105 000
Nicaragua	5	7 000	8	11 000
Turkey	261	298 000	—	—
Other countries	19	5 000	—	—
Total	3 580	3 654 000	3 521	3 730 000
Zinc fabricated material nes				
United States	4 371	3 831 000	1 788	1 782 000
Hong Kong	—	—	149	104 000
Belgium and Luxembourg	—	—	73	60 000
United Kingdom	32	37 000	12	30 000
Mexico	2	6 000	2	4 000
Other countries	131	75 000	. . .	2 000
Total	4 536	3 949 000	2 024	1 982 000
Imports				
In ores, concentrates and scrap	3 449	1 486 000	6 048	2 822 000
Dust and granules	185	231 000	156	181 000
Slabs, blocks, pigs and anodes	12 518	9 856 000	3 328	2 386 000
Bars, rods, plates, strip and sheet	262	405 000	433	759 000
Zinc oxide	1 808	1 454 000	4 037	1 848 000
Zinc sulphate	1 776	578 000	1 509	562 000
Zinc fabricated materials nes	1 173	2 599 000	1 139	2 747 000
Total	21 171	16 609 000	16 650	11 305 000

	1976			1977p		
	Primary	Secondary	Total	Primary	Secondary	Total
Consumption[5]			(tonnes)			
Zinc used for, or in the manufacture of:						
Copper alloys (brass,bronze, etc.)	11 184			11 410		
Galvanizing: electro	1 107	637	68 501	1 174	520	74 851
hot dip	55 573			61 747		
Zinc die-cast alloy	8 116	—	8 116	11 686	—	11 686
Other products (including rolled and ribbon zinc, zinc oxide)	20 291	1 989	22 280	16 902	1 973	18 875
Total	96 271	2 626	98 897	102 919	2 493	105 412
Consumer stocks on hand at end of year	11 223	675	11 898	8 512	846	9 358

Source: Statistics Canada.
[1]New refined zinc produced from domestic primary materials (concentrates, slags, residues, etc.) plus estimated recoverable zinc in ores and concentrates shipped for export. [2]Zinc content of ores and concentrates produced. [3]Refined zinc produced from domestic and imported ores. [4]Gross weight [5]Consumer survey does not represent 100 per cent of Canadian consumption and is therefore consistently less than apparent consumption.
p Preliminary; — Nil; . . . Less than one tonne; nes Not elsewhere specified.

Table 4. Canada, mine output, zinc, 1976 and 1977

	1976	1977
	(tonnes)	
Newfoundland	55 107	60 977
New Brunswick	160 221	232 102
Quebec	135 893	123 920
Ontario	373 003	351 958
Manitoba-Saskatchewan	80 481	82 328
British Columbia	109 493	109 242
Yukon Territory	66 409	122 678
Northwest Territories	164 406	217 023
Total	1 145 013	1 300 228

Source: Statistics Canada.

The Geco Division of Noranda Mines Limited also increased its zinc production modestly to 37 981 tonnes from 35 193 tonnes in 1976.

Zinc output from the South Bay mine, owned by Selco Mining Corporation Limited, remained unchanged from the prior year at 15 073 tonnes in 1977. Completion of underground development at the company's Detour River copper-zinc property in Quebec is scheduled for completion by year-end 1978; construction of an all-weather access road to the property was finished in 1977.

Texasgulf Canada Ltd. maintained zinc-in-concentrate production at its Kidd Creek mine at the prior year's level of 222 145 tonnes, even though the mine was shut down for the entire month of July. The company also announced deferred expansion of the No. 2 underground mine. As of April 19, 1977 the open pit was closed and all subsequent ore production came from the underground mine.

Manitoba. Zinc output at the Hudson Bay Mining and Smelting Co., Limited increased in 1977 to 35 844 tonnes from 31 191 tonnes in 1976, due to increased ore production. The new ore production came from the Centennial and Westarm mines and replaced ore from the Schist Lake and Dickstone mines, which were closed the year before. Construction of a new concentrator to process ore from the Snow Lake area mines began in 1977 and is expected to cost $26 million at completion in 1979. Capacity of the new plant will be 3 450 tonnes a day and the company expects significant transportation savings will be realized since the ore will no longer be trucked to Flin Flon for processing.

Sherritt Gordon Mines Limited commenced underground development of the Ruttan mine in 1977 and the open pit is scheduled to close down in 1982. Zinc output at Ruttan declined 6 791 tonnes to 37 664 tonnes, but at the Fox mine, output increased 2 814 tonnes to 13 162 tonnes.

British Columbia. Zinc output at the Sullivan and H.B. Mines of Cominco Ltd. remained unchanged from 1976 at 77 594 tonnes and 12 716 tonnes respectively. This was also the case for Western Mines Limited, which produced 18 608 tonnes of zinc in 1977.

Yukon Territory. Cyprus Anvil Mining Corporation produced 128 276 tonnes of zinc in 1977 compared to 72 890 tonnes in 1976. This output came from both zinc and bulk concentrates; the large increase in 1977 is due to the fact that the company suffered severe labour strikes the year prior.

Northwest Territories. Pine Point Mines Limited operated seven pits in 1977, with two new pits being opened during the year and one closed down. Additionally, development of the M.40 underground test mine was suspended during the year due to the depressed market for zinc. Zinc output during the year

Table 5. Canada, zinc production, exports and domestic shipments, 1960, 1965, 1970, 1975, 1976 and 1977

	Production		Exports			Producers' domestic shipments
	All Forms[1]	Refined[2]	In ores and concentrates	Refined	Total	
			(tonnes)			
1960	371 831	236 746	154 125	187 870	341 995	48 495
1965	745 738	325 224	442 203	239 678	681 881	94 892
1970	1 135 714	413 196	809 248	318 834	1 128 082	106 405
1975	1 055 151	426 902	705 088[r]	247 280	952 368[r]	149 214
1976	982 057	472 316	644 094	350 853	994 947	133 561
1977[p]	1 054 528	494 888	555 635	295 364	850 999	130 641

Source: Statistics Canada.
[1]New refined zinc produced from domestic primary materials (concentrates, slags, residues, etc.) plus estimated recoverable zinc in ores and concentrates shipped for export. [2]Refined zinc produced from domestic and imported ores.
[p]Preliminary; [r]Revised.

Table 6. Principal zinc mines in Canada, 1977 and (1976)

Company and Location	Daily mill capacity	Zinc	Lead	Copper	Silver	Ore Produced	Zinc Concentrates Produced	Zinc Concentrates Zinc Grade	Zinc Content of all concentrates	Destination of Zinc concentrate
	(tonnes ore)	(%)	(%)	(%)	(grams/ tonne)	(tonnes)	(tonnes)	(%)	(tonnes)	
Newfoundland										
ASARCO Incorporated,	1 150	10.76	6.12	0.99	107.0	174 180	26 232	55.81	17 338	6,11
Buchans	(1 150)	(10.69)	(6.03)	(0.96)	(105.6)	(188 694)	(29 134)	(55.6)	(18 674)	(6,8,9,11)
Newfoundland Zinc										
Mines Limited,	1 350	9.4	—	—	—	492 552	71 291	62.6	45 270	3,6
Daniel's Harbour	(1 350)	(8.1)	(—)	(—)	(—)	(474 199)	(61 213)	(62.0)	(37 998)	(3,6)
New Brunswick										
Brunswick Mining and										
Smelting Corporation										
Limited,	8 950	7.83	3.12	0.37	84.8	3 134 419	354 135	51.91	210 097	3,7,9,10
Bathurst	(8 950)	(7.01)	(2.80)	(0.37)	(84.3)	(2 247 212)	(231 839)	(52.04)	(120 707)	(9)
Heath Steele Mines										
Limited,	3 650	3.90	1.53	1.22	68.2	1 150 338	69 181	47.78	35 474	8,10,12
Newcastle	(3 650)	(4.53)	(1.85)	(0.99)	(77.8)	(1 052 568)	(72 422)	(48.34)	(37 818)	(8,9,12)
Nigadoo River Mines										
Limited,	1 050	2.54	2.39	0.15	85.7	179 458	5 960	. .	. .	. .
Bathurst	(1 050)	(2.63)	(2.43)	(0.16)	(93.9)	(198 698)	(8 970)	(45.30)	(4 063)	(9)
Quebec										
Falconbridge Copper										
Limited,	1 400	3.74	—	3.27	38.7	389 967	22 152	52.59	11 650	12
Lake Dufault Division,	(1 400)	(3.44)	(—)	(3.09)	(41.5)	(458 447)	(23 523)	(52.82)	(12 529)	(8)
Noranda										
Lemoine Mines Limited,	350	10.6	—	4.67	100.8	110 306	16 516	52.84	8 685	12
Lemoine Mine,	(350)	(10.4)	(—)	(4.35)	(87.7)	(88 239)	(13 067)	(53.22)	(6 955)	(8)
Chibougamau										

Louvem Mining										
Company Inc.,	900	5.95	. .	. .	41.82	277 837	30 334	53.14	16 120	12
Louvem Division,	(–)	(5.99)	(. .)	(–)	(56.22)	(258 534)	(28 380)	(54.57)	(15 110)	(12)
Barvue Division*	(1 450)	(3.13)	(0.51)	(–)	(97.0)	(96 836)	(. .)	(. .)	(2 616)	(6)
Val d'Or										
Mattagami Lake Mines										
Limited,	3 500	6.6	–	0.52	30.9	946 343	108 518	53.33	58 518	3,6
Matagami	(3 500)	(7.3)	(0.10)	(0.55)	(31.9)	(1 112 156)	(140 513)	(52.7)	(74 900)	(3,12)
Orchan Mines Limited,	1 700	6.35	–	0.54	29.1	508 273	54 787	51.53	28 259	3
Orchan and Garon										
Lake mines,	(1 700)	(6.74)	(–)	(0.78)	(31.9)	(424 260)	(48 064)	(51.64)	(24 818)	(3)
Matagami										
Sullivan Mining Group										
Ltd.,	1 300	2.15	0.47	2.88	49.0	10 307	415	58.0	241	6
Stratford Centre,	(1 300)	(2.32)	(0.51)	(2.54)	(38.3)	(207 485)	(. .)	(. .)	(3 877)	(6)
Cupra Division										
Ontario										
Falconbridge Copper										
Limited,	1 100	10.44	1.26	3.46	206.4	383 883	57 805	53.22	30 755	12
Sturgeon Lake Joint										
Venture,	(1 100)	(9.57)	(1.23)	(2.15)	(183.8)	(377 257)	(46 019)	(52.29)	(24 064)	(12)
Sturgeon Lake										
Mattabi Mines Limited,	2 700	8.40	0.84	1.01	121.7	938 427	127 707	54.88	72.443	3
Sturgeon Lake	(2 700)	(8.13)	(0.76)	(1.23)	(121.0)	(966 797)	(126 185)	(54.36)	(69 016)	(3,12)
Noranda Mines Limited,	4 550	2.62	0.11	1.94	41.8	1 591 682	60 309	51.93	37 981	3,12
Geco Division,	(4 550)	(2.55)	(0.12)	(1.69)	(44.2)	(1 529 781)	(56 584)	(52.07)	(35 193)	(3)
Manitouwadge										
Selco Mining Corporation										
Limited,	500	9.87	–	1.68	76.8	164 792	27 442	53.62	15 073	3,6,12
South Bay Division,	(450)	(10.38)	(–)	(1.73)	(79.9)	(163 482)	(29 181)	(53.66)	(15 658)	(6)
Uchi Lake										
Texasgulf Canada Ltd.,	9 050	7.26	0.22	1.84	104.0	3 299 033	395 782	52.59	22 145	6,7,12
Kidd Creek	(9 050)	(8.05)	(0.30)	(1.73)	(119.7)	(3 242 279)	(429 099)	(51.98)	(224 955)	(7,12)
Willroy Mines Limited,	1 450	4.06	0.14	0.95	73.0	57 442	. .	. .	. .	. .
Manitouwadge										
Division,	(1 450)	(3.67)	(0.17)	(0.56)	(54.5)	(311 430)	(20 482)	(51.58)	(10.503)	(6)
Manitouwadge										

Table 6. (concl'd)

Company and Location	Daily mill capacity	Zinc	Lead	Copper	Silver	Ore Produced	Zinc Concentrates Produced	Zinc Concentrates Zinc Grade	Zinc Content of all concentrates	Destination of Zinc concentrate
	(tonnes ore)	(%)	(%)	(%)	(grams/ tonne)	(tonnes)	(tonnes)	(%)	(tonnes)	
Manitoba and Saskatchewan										
Hudson Bay Mining and Smelting Co., Limited,										
Western	–	1.44	–	3.45	14.4	74 833				
Centennial	–	2.44	–	1.57	17.1	150 789				
Flin Flon	7 700	2.23	–	1.60	23.7	587 593				
Osborne Lake		2.00		2.49	7.2	218 366				
Stall Lake	–	0.18	–	4.36	7.2	239 180				
White Lake	–	3.17	–	1.93	19.2	11 038				
Ghost Lake	–	9.72	–	1.47	38.1	26 930				
Anderson Lake	–	0.18	–	2.88	7.9	124 423				
Chisel Lake	–	9.24	–	0.74	40.1	219 767				
Total (or average)	7 700	2.80	0.2	2.20	20.6	1 652 919	63 764	47.8	35 844	2
	(7 700)	(1.68)	(0.2)	(2.30)	(20.6)	(1 417 442)	(50 039)	(47.7)	(31 191)	(2)
Sherritt Gordon Mines Limited,										
Fox mine	2 700	1.93	–	1.46	. .	807 688	22 051	51.10	13 162	2
Lynn Lake	(2 700)	(1.68)	(–)	(1.56)	(. .)	(755 123)	(17 354)	(49.41)	(10 348)	(2)
Ruttan Lake	9 100	1.95	–	1.13	. .	2 261 227	70 244	50.63	37 664	2,7
Ruttan Lake	(9 050)	(2.14)	(–)	(1.08)	(. .)	(2 413 868)	(83 523)	(50.56)	(44 455)	(2,6,7)
British Columbia										
Cominco Ltd.,	9 050	3.8	3.8	–	47.6	2 198 840	150 420	48.6	77 594	1
Sullivan mine, Kimberley	(9 050)	(3.95)	(4.0)	(–)	(45.9)	(2 124 892)	(150 648)	(48.1)	(77 007)	(1)
H.B. Mine,	1 100	3.86	0.67	–	. .	357 258	22 561	54.2	12 716	1
Salmo	(1 100)	(3.82)	(0.69)	(–)	(. .)	(374 803)	(23 261)	(53.8)	(12 877)	(1)
Silvana Mines Inc.,	100	6.04	7.15	–	594.0	15 877	1 405	49.78	892	6
Silmonac mine, Sandon	(100)	(4.86)	(5.3)	(–)	(457.7)	(16 694)	(1 240)	(49.54)	(744)	(1)

Northair Mines Ltd.,										
Alta Lake,	250	2.03	1.54	–	126.5	92 167	2 347	53.9	1 265	1
Brandywine area	(250)	(1.81)	(0.86)	(–)	(111.8)	(47 554)	(846)	(48.5)	(411)	(2)
Teck Corporation										
Limited,	100	0.41	0.36	–	353.1	34 434	245	32.5	154	1
Beaverdell mine,	(100)	(0.54)	(0.43)	(–)	(336.3)	(34 448)	(298)	(39.1)	(186)	(1)
Beaverdell										
Western Mines Limited,	1 100	7.58	1.34	1.14	147.1	269 071	31 247	52.67	18 608	6,12
Lynx and Myra Falls	(1 000)	(7.73)	(1.42)	(1.19)	(169.4)	(269 294)	(32 299)	(52.85)	(18 987)	(12)
Yukon Territory										
Cyprus Anvil Mining										
Corporation,	9 050	4.9	2.7	0.17	22.5	3 116 035	220 831	50.29	128 276	7,12
Faro	(9 050)	(5.48)	(2.66)	(–)	(16.5)	(1 519 881)	(114 868)	(51.36)	(72 890)	(7,8)
United Keno Hill Mines										
Limited	450	1.12	4.57	–	1 216.8	82 995	454	. .	676	2
Elsa	(450)	(1.17)	(4.02)	(–)	(1 216.8)	(68 506)	(586)	(48.0)	(282)	(2)
Northwest Territories										
Pine Point Mines Limited	9 050	5.3	2.1	–	–	3 123 307	264 801	56.66	152 574	1,8,11,12
Pine Point	(9 050)	(5.3)	(1.7)	(–)	(–)	(3 422 833)	(295 711)	(57.37)	(171 277)	(1,6,7,8,9,12)
Nanisivik Mines Ltd.	1 350	13.3	2.0	–	50	546 000	116 500	57.6	67 000	12
Baffin Island	(1 350)	(14.5)	(2.9)	(–)	(. .)	(70 762)	(14 756)	(49.0)	(7 230)	(12)

Sources: Company reports in response to survey by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.
Destination of concentrates: (1) Trail; (2) Flin Flon; (3) Valleyfield; (4) Belledune; (5) Timmins; (6) United States; (7) Japan; (8) Germany; (9) Belgium; (10) France; (11) Britain; (12) Unspecified and other countries.
– Nil; . . Not available; *Merged with Manitou-Barvue Mines Limited in August, 1976.

Table 7. Canada's producers' zinc ore reserves at December 31, 1977

Company and Province	Ore reserves	Per Cent zinc	Zinc in ore
	(000 tonnes)		(000 tonnes)
Newfoundland			
ASARCO Incorporated	468.1	11.74	55.0
Newfoundland Zinc Mines Limited	2 794.2	8.66	242.0
	3 262.3	9.10	297.0
Nova Scotia			
Esso Minerals Canada	5 443.2	4.00	217.7
New Brunswick			
Brunswick Mining and Smelting Corporation Limited	110 747.5	8.29	9 176.5
Heath Steele Mines Limited	19 365.9	4.56	882.4
	130 113.4	7.73	10 058.9
Quebec			
Falconbridge Copper Limited	3 615.2	2.85	103.0
Lemoine Mines Limited	387.4	10.04	38.9
Louvem Mining Company Inc.	1 062.0	6.15	65.3
Mattagami Lake Mines Limited	7 796.9	7.20	561.4
Orchan Mines Limited	3 417.8	5.37	183.4
	16 279.3	5.85	952.0
Ontario			
Mattabi Mines Limited	4 626.7	7.19	332.7
Mattagami Lake Mines Limited	3 656.0	6.66	243.5
Noranda Mines Limited	23 587.0	3.73	879.8
Selco Mining Corporation Limited	459.3	10.86	49.9
Sturgeon Lake Mines Limited	819.7	9.15	75.0
Texasgulf Canada Ltd.	74 043.2	6.71	4 966.8
	107 191.9	6.11	6 547.7
Manitoba			
Hudson Bay Mining and Smelting Co., Limited	12 616.0	3.06	385.9
Sherritt Gordon Mines Limited	34 376.3	1.44	494.6
	46 992.3	1.87	880.5
Saskatchewan			
Hudson Bay Mining and Smelting Co., Limited	2 035.2	1.40	28.5
British Columbia			
Cominco Ltd.	50 117.6	6.10	3 054.7
Silvana Mines Inc.	9.1	5.00	0.5
Northair Mines Ltd.	220.4	2.68	5.9
Teck Corporation Limited	134.3	0.40	0.5
Western Mines Limited	1 324.4	7.50	99.3
	51 805.8	6.10	3 160.9
Yukon Territory			
Cyprus Anvil Mining Corporation	37 502.1	5.60	2 100.1
United Keno Hill Mines Limited	114.3	1.05	1.2
	37 616.4	5.59	2 101.3

Table 7. (concl'd)

Company and Province	Ore reserves	Per Cent zinc	Zinc in ore
	(000 tonnes)		(000 tonnes)
Northwest Territories			
Nanisivik Mines Ltd.	6 394.1	13.48	861.9
Pine Point Mines Limited	33 986.2	5.30	1 801.3
	40 380.3	6.60	2 663.2
Canada	441 120.1	6.10	26 907.7

Source: MR178, *Canadian Reserves of Copper, Nickel, Lead, Zinc, Molybdenum, Silver, and Gold as of January 1, 1977;* Department of Energy, Mines and Resources, Ottawa, 1978.

Table 8. Canada's zinc-bearing deposits considered most promising for future production

Company and Province	Deposit Name	Indicated Tonnage	Per Cent Zinc	Zinc Content
New Brunswick				
Canex Placer Limited and	Restigouche	2 721.6	6.00	163.3
Gowganda Silver Mines Limited	Murray Brook	21 479.8	1.95	418.9
Caribou-Chaleur Bay Mines Ltd.	Caribou	44 815.4	4.48	2 007.7
Cominco Ltd.	Stratmat 61	2 041.2	6.29	128.4
Key Anacon Mines Limited	Key Anacon	851.9	5.98	50.9
	Key Anacon	917.2	5.78	53.0
Texasgulf Inc. and Bay Copper Mines Limited	Halfmile Lake	6 168.9	6.80	419.5
		78 996.0	4.10	3 241.7
Quebec				
Noranda Mines Limited	Magusi	1 378.9	4.80	66.2
	West MacDonald	2 502.0	4.50	112.6
Selco Mining Corporation Limited	Detour Al	32 114.7	2.30	738.6
	Detour B	3 061.8	0.80	24.5
Giant Yellowknife Mines Limited	Low Pyrite	4 008.4	3.97	159.1
— Emington and Vermillion Mines	High Pyrite	8 199.5	3.82	313.2
		51 265.3	2.76	1 414.2
Manitoba				
Dickstone Copper Mines Limited		304.4	4.50	13.7
Falconbridge Nickel Mines Limited — Stall Lake Mines Limited	Stall Lake	610.2	2.28	13.9
Hudson Bay Mining and	Rail Lake	294.8	0.70	2.1
Smelting Co., Limited	Spruce Point	453.6	4.50	20.4
		1 663.0	3.01	50.1

Table 8. (concl'd)

Company and Province	Deposit Name	Indicated Tonnage	Per Cent Zinc	Zinc Content
British Columbia				
Liard Copper Mines Ltd.	Schaft Creek	272 158.2	0.19	517.1
Noranda Mines Limited	Goldstream	3 628.8	2.60	94.3
		275 787.0	0.22	611.4
Yukon Territory				
Hudson Bay Mining and Smelting Co., Limited	Tom	7 842.7	8.40	658.8
Kerr Addison Mines Limited and	Grum	26 081.8	6.40	1 669.2
Canadian Natural Resources Ltd.	Swim Lake	4 536.0	5.50	249.5
— Vangorda Mines Limited	Vangorda	8 527.6	4.96	423.0
Placer Development Limited and United States Steel Corporation	Howards Pass[1]	272 158.2	6.40	17 418.1
Sovereign Metals Corporation	Mel Property	3 628.8	5.20	188.7
		322 775.1	8.15	20 607.3
Northwest Territories				
Arvik Mines Ltd.	Polaris	22 679.9	14.10	3 197.9
	Eclipse	907.2	12.43	112.8
Bathurst Norsemines Ltd.	Cleaver Lake	3 628.8	7.07	256.6
and Cominco Ltd.	Boot Lake	4 536.0	5.86	265.8
	Main A Group	3 628.8	8.50	308.4
Cadillac Explorations Limited	Prairie Creek	1 814.4	15.50	281.2
Texasgulf Canada Ltd.	Izok Lake	11 022.4	13.77	1 517.8
	Hood River 10	453.6	3.50	15.9
	Hood River 41	290.3	3.20	9.3
Western Mines Limited, Du Pont of Canada Exploration Limited, and Philipp Brothers (Canada) Ltd.	X-25	3 447.3	9.10	313.7
		52 408.7	11.98	6 279.4
Canada		782 895.1	5.46	32 204.1

Source: MR178 *Canadian Reserves of Copper, Nickel, Lead, Zinc, Molybdenum, Silver, and Gold, as of January 1, 1977;* Department of Energy, Mines and Resources, Ottawa, 1978.
[1]MR 178 indicates ore reserves at Howard's Pass exceed 272.2 million tonnes with an average grade of 6-12% combined lead-zinc. Data in above table compiled using a lead to zinc ratio of about 1.0/2.5 applied to an average grade of 9% combined lead and zinc based upon minimum ore reserves.

Table 9. Canada, primary zinc metal production 1977

	Refined Zinc Production	Annual Rated Capacity	Per cent Utilization
	(tonnes)	(tonnes)	
Canadian Electrolytic Zinc Limited Valleyfield, Quebec	141 110	205 000	68.8
Cominco Ltd. Trail, British Columbia	202 300	245 000	82.6
Hudson Bay Mining and Smelting Co., Ltd. Flin Flon, Manitoba	68 860	74 400	92.6
Texasgulf Canada Ltd. Hoyle, Ontario	82 640	108 900	75.9
Total	494 910	633 300	78.1

Sources: 1977 Company annual reports. *Metallurgical Works in Canada. Nonferrous and Precious Metals,* Operators List 3, January 1977. Department of Energy, Mines and Resources.

declined to 152 574 tonnes from 171 277 tonnes in 1976. The new 30-yard walking dragline will be operational in 1979 and increased stripping efficiencies will permit the mining of smaller and deeper orebodies.

Nanisivik Mines Ltd. turned in its first full year of production and produced 67 000 tonnes of zinc-in-concentrate compared to 7 230 tonnes in 1976. The mine started production in October 1976.

Metal production in Canada

Production of refined primary zinc metal in Canada during 1977 was 494 888 tonnes compared to 472 316 tonnes in 1976. Collectively, Canada's four electrolytic zinc producers operated at 78.1 per cent of their 633 300 tonnes of annual capacity during the year due to the continuing depressed market for zinc. Not all of this production was sold, as metal stocks increased from 112 000 tonnes to a record level of 189 000 tonnes at year-end; equivalent to about 5.5 months deliveries. Table 9 shows this production on a plant by plant basis.

In response to the depressed market for zinc, Texasgulf shut down its refinery for the month of August and operated it at 65 per cent of capacity thereafter. Much of the expanded capacity at Canadian Electrolytic Zinc Limited, which came on stream in 1976, continued to remain idle. The plant was closed for 13 days commencing December 21, 1977. Cominco Ltd. also found it necessary to curtail production in the second half of the year for inventory control purposes.

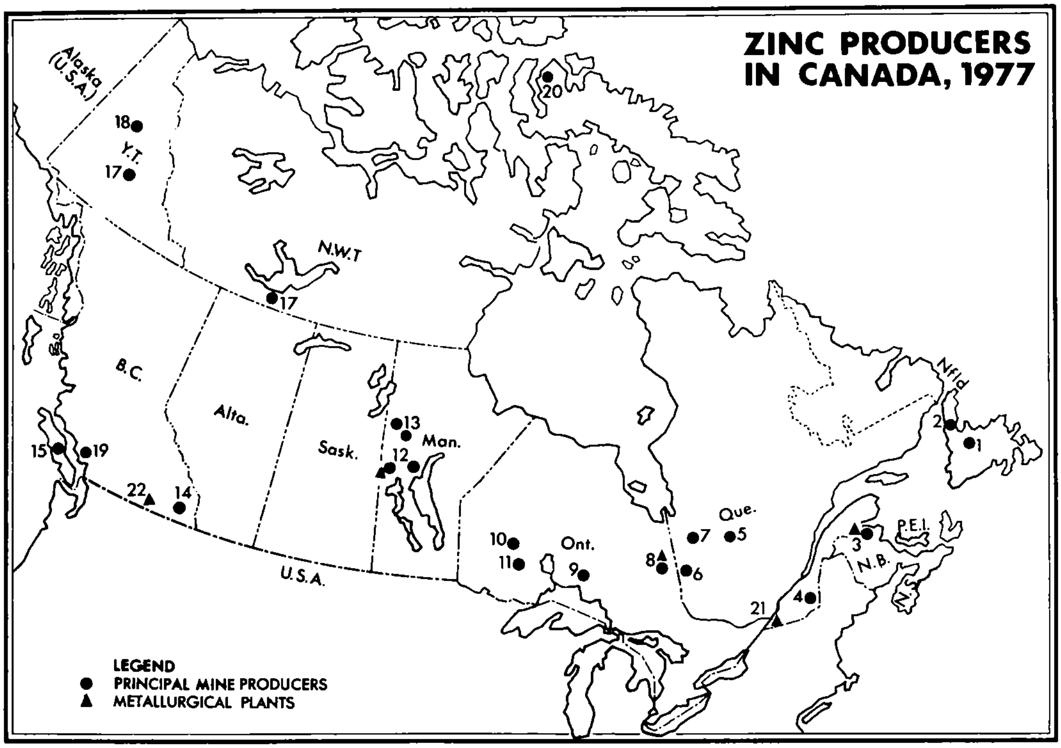
After twenty years of basic research, Sherritt Gordon Mines Limited has concluded a successful pilot scale-process for the pressure-leaching of zinc concentrates. The Sherritt Process produces elemental sulphur and eliminates atmospheric emissions of sulphur-dioxide gas. In addition, the process can achieve extractions as high as 98 per cent eliminating the need for residue treatment. In 1977, Cominco Ltd. and Sherritt conducted a joint venture pilot-plant program to further develop the process. The favourable results of the program indicate high potential for commercial application. Cominco Ltd. is currently evaluating the feasibility of incorporating the process into its modernization program at Trail, B.C. which will eventually expand the plant's capacity by 25 000 tonnes a year. Additionally, the Province of New Brunswick is hopeful that either this process or a sulphation-roast process developed by the Research and Productivity Council of New Brunswick will provide economic incentive to the mining and refining of fine-grained lead-zinc ores in that province.

The availability in Canada of zinc-in-scrap has traditionally been modest and until last year, small

Table 10. Canada, producers' domestic shipments of refined zinc, 1975, 1976, 1977.

	1975	1976	1977^p
		(tonnes)	
1st Quarter	23 898	30 656	33 606
2nd Quarter	40 903	40 251	35 845
3rd Quarter	47 688	31 858	28 640
4th Quarter	36 725	30 796	32 550
Total	149 214	133 561	130 641

Source: Statistics Canada.
^{p} Preliminary.



Principal Producers

(numbers refer to numbers on map above)

1. ASARCO Incorporated (Buchans Unit)
2. Newfoundland Zinc Mines Limited
3. Brunswick Mining and Smelting Corporation Limited
   Heath Steele Mines Limited
   Nigadoo River Mines Limited
4. Sullivan Mining Group Ltd.
5. Lemoine Mines Limited
6. Falconbridge Copper Limited, Lake Dufault Division
   Louvem Mining Company Inc.
7. Mattagami Lake Mines Limited
   Orchan Mines Limited
8. Texasgulf Canada Ltd.
9. Noranda Mines Limited (Geco Division)
   Willroy Mines Limited
10. Selco Mining Corporation Limited
11. Mattabi Mines Limited
    Falconbridge Copper Limited (Sturgeon Lake Joint Venture)
12. Hudson Bay Mining and Smelting Co., Limited (Chisel Lake, Osborne Lake, Stall Lake, Ghost Lake, Anderson Lake, Westarm, Flin Flon, White Lake, Centennial)
13. Sherritt Gordon Mines Limited (Fox Lake mine and Ruttan mine)
14. Cominco Ltd. (Sullivan mine and H.B. mine)
    Teck Corporation Limited (Beaverdell mine)
    Silvana Mines Inc. (Silmonac mine)
15. Western Mines Limited
16. Pine Point Mines Limited
17. Cyprus Anvil Mining Corporation
18. United Keno Hill Mines Limited
19. Northair Mines Ltd.
20. Nanisivik Mines Ltd.

Metallurgical Plants

8. Texasgulf Canada Ltd., Hoyle
12. Hudson Bay Mining and Smelting Co. Limited, Flin Flon
21. Canadian Electrolytic Zinc Limited, Valleyfield
22. Cominco Ltd., Trail

quantities of about 5 000 tonnes were consumed directly in the manufacture of copper alloys, zinc oxides and dusts. In late 1977, Fers et Métaux Recyclés Ltée started up its Auto-Metal Reclamation System which currently recovers about 5 000 tonnes a year of zinc diecast alloy from shredded automobiles. The plant's capacity to process the nonferrous portion of scrapped automobiles currently exceeds the automotive scrapping rate in Canada and accordingly, further units are not likely to be built in Canada in the near future, given the small size of our domestic market. The system was developed and constructed in Canada and is Canada's first heavy-media-separation metal-recycling plant. The recovered alloy contains about 92 per cent zinc and is sold to Canadian consumers to produce zinc dust for the paint industry.

Metal consumption in Canada

Canadian consumption of primary zinc is estimated to be 125 000 tonnes in 1977 compared with 119 000 tonnes in 1976. Typically, usage is broken down into protective coatings, 49 per cent; alloy for diecast parts, 21 per cent; brass, 12 per cent; and a general category, including zinc oxide as the major component, 18 per cent.

During 1977 the Zinc Institute Inc. conducted a survey of 53 Canadian diecasters to determine end usage of diecast parts. The survey indicated market breakdown as: automotive components, 44.5 per cent, most of which are exported to the United States; builders' hardware, 28.3 per cent; electrical components, 10.5 per cent; domestic appliances, 7.1 per cent; industrial-agricultural-commercial machinery, 5.4 per cent; sound and television equipment, 0.6 per cent; sporting goods and toys, 0.5 per cent; and scientific and professional equipment, 0.5 per cent. Automotive and electrical components and builders' hardware accounted for over 80 per cent of all diecast parts produced in Canada. The major diecasting companies were Hudson Bay Diecastings Limited, Doehler Canada Limited, Albright Platers Ltd. and National Hardware Specialties Limited. The protective coatings market, represented primarily by 41 galvanizing companies, includes the largest industrial consumers of zinc in Canada: The Steel Company of Canada, Limited and Dominion Foundries and Steel, Limited both have continuous lines for the galvanizing of sheet steel. Of the 135 foundries in Canada that produced brass and other copper alloys, the four major companies that consumed zinc metal were Noranda Manufacturing Ltd., The Canada Metal Company, Limited, Anaconda Copper and Brass Co. and Radcliff (Canada) Ltd. The main producers of zinc oxide were Zochem Limited, Pigment and Chemical Company, Limited and G.H. Chemicals Ltd.

Characteristics and uses

The wide use of zinc stems from its chemical and metallurgical properties. Its major areas of application are in galvanizing, zinc-alloy casting, rolled zinc, brass-making, as the major additive to copper; and in zinc chemicals used in manufacturing rubber, paints and pharmaceuticals. In many instances the cost of zinc is not a significant factor in end-product production costs.

In certain applications, especially automotive, where competition with aluminum and plastics and reduced unit-consumption of zinc, e.g., thin-wall zinc diecasting, has occurred, zinc has lost ground. In the future, the weight factor may be an important constraint in zinc diecasting for the automotive industry.

The largest use of zinc is in galvanizing iron and steel products. It provides a corrosion-resistant coating which can be readily finished with electroplated metal coatings or organic coatings.

Galvanizing is done by batch or continuous hot dip or electrolytic processes, with the main product categories being sheet and strip metal, tube and pipe, and wire and wire rope. The market for galvanized sheet and strip steel is of major importance, both in size and growth. These products are used primarily by the construction, automobile and building industries for roofing, siding, appliance casings, office equipment, decking to support concrete floors, heating and ventilation ducts, automobile door panels, and underbody parts.

The ability to control zinc thicknesses on steel by electrolytic processes has resulted in new products such as prepainted galvanized steel clapboard siding for residential and industrial buildings. The introduction of single-sided galvanized sheet with improved weldability in auto body manufacture is expected to increase consumption in the sheet and strip line.

Aluminum is an alternative coating for sheet and strip steel; however, its usage is marginal at present because of higher costs, and its inability to provide sacrificial protection to substrate metal when scratched, as zinc does. The tube, pipe, wire and wire rope coatings markets have declined in recent years with the substitution of copper and plastic products for usages such as residential plumbing systems and plastic-coated residential fencing.

In Australia a new zinc-aluminum alloy coating known as *Zincalume,* which provides twice the longevity of zinc corrosion protection on sheet steel at about the same cost, has been successfully introduced. The alloy consists of 55 per cent aluminum, 43.4 per cent zinc and 1.6 per cent silicon and is applied in a standard coating of 150-200 grams per square metre (g/m^2), compared with 300-430 g/m^2 for zinc. The new product is used currently in sheet steel roofing and wall cladding applications and may eventually capture the majority of the domestic market, estimated to be about 150 000 tonnes a year.

Overall substitution by alternative materials does not appear to pose a serious threat to the protective-coating market for zinc; of greater concern is obsolescence through the possible development of low-cost corrosion-resistant steels.

Zinc diecast parts, the second largest use of zinc, are used as trim pieces, grills, door and window handles, carburetors, pumps, door locks, and other mechanical components in automobiles. In the United States, the automobile industry uses approximately two-thirds of the total production of zinc diecastings. Diecastings are also used in small appliances, business equipment and light engineering industries.

Possible substitutes for zinc in diecasting are magnesium, aluminum and plastics, the last mentioned as a result of the development of metal-on-plastic plating techniques. The most significant factor in North America affecting zinc diecast parts is the trend to produce smaller and lighter cars. Weight is an important consideration in the automotive industry and some industry officials forecast a decline in zinc diecast consumption per automobile from the level of about 40 pounds in 1976 to about 25 to 30 pounds by 1980. By comparison, the average consumption of aluminum per vehicle is expected to increase from 87 pounds in 1976 to 150-200 pounds in 1980. Likewise, plastics are expected to increase from 160 pounds in 1976 to 300 pounds in 1980. At the same time, oil-based energy considerations may well provide a significant new market for nickel-zinc batteries associated with the development of electric vehicles during the next decade.

Increasing acceptance of thin-wall zinc diecast parts will preserve some automotive applications and possibly obtain others, but unit consumption per car will decline, although the decline will likely be partially offset by automobile production growth and increased usage in corrosion protection.

The manufacture of brass is the third major area of zinc consumption. Brass is used in a variety of applications from decorative hardware to plumbing and heat exchange units. It combines good physical, electrical, thermal and corrosion-resistant qualities with an ability to be formed by a wide variety of processes. Brass is an alloy consisting essentially of zinc and copper with the amount of zinc ranging from 5 to 40 per cent. The low-to-medium zinc content brasses are used for cold working, e.g., deep drawing and pressing, and the higher zinc content brasses are used for hot working, e.g., extrusion, hot stamping, and casting. Additions of lead, up to 3.7 per cent, are made to higher zinc content brasses when the product requires high-speed machining.

During periods of high copper and zinc prices a wide variety of other metals and plastics can substitute for brass.

Rolled zinc is used for dry battery production, photo engraving, lithographic printing plates, roof coverings and flashings, and rain water gutters and pipes. Roofing applications are generally confined to Europe where zinc has the tradition of being a building material. For these applications zinc is generally alloyed with a small quantity of copper and titanium.

Over one-half of the zinc oxide produced is used in the manufacture of rubber. Up to 5 per cent of the product weight consists of zinc oxide which is used as a catalyst in the vulcanization of natural and synthetic rubber. Zinc oxide is used as a white pigment in paint, and serves a variety of purposes in applications such as photocopy paper, agricultural products, cosmetics and medicinal products.

Zinc dust, which is a finely divided form of zinc metal, is used in the printing and dyeing of textiles, in zinc-rich paints, in purifying fats, and precipitating gold and silver from cyanide solutions. The more important industrial compounds of zinc are zinc sulphide, which in combination with barium sulphate forms the pigment lithopone; zinc sulphate, used in rayon fibre manufacture; and zinc chloride, a wood preservative.

Weather-resistant paints based on zinc oxide and zinc dust provide one of the most effective and durable protective coatings on outside surfaces, especially metallic ones. A new application is a two-coat paint system known as *Zincrometal* that can be hot-rolled on coiled steel. It is applied on a chromium-base coating. This system is reported to have corrosion resistant properties similar to galvanized steel, and could replace it in some applications. It has, however, important limitations, since tests show that it gives little if any sacrificial protection on scratched surfaces or cut edges. It is estimated that about 617 000 tonnes of *Zincrometal* was produced in the United States in 1976, with installed capacity capable of producing about 900 000 tonnes.

The International Lead Zinc Research Organization, Inc. (ILZRO) is the main body assisting industry to find new uses for lead and zinc. Promotion and advertising of new zinc products and processes is carried on by the Zinc Institute, Inc. which opened a branch office in Toronto in 1968. The development of thin-walled diecastings and improved zinc-based diecasting alloys has done much to expand the use of zinc as a diecasting metal in competition with alternative materials such as aluminum and plastics.

International developments

The United States' stockpile objective for zinc, which was set at just under 1.2 million tonnes by the Ford administration, was confirmed in 1977 by the Carter administration. Existing stocks are deficient by about 0.8 million tonnes, but authorization to commence purchases still awaits approval by Congress. Attaining the new objective is expected to occur over an extended period of time.

On a smaller scale, the government of Japan began stockpiling zinc in fiscal 1975 with the acquisition of 12 000 tonnes. In addition, a second stockpiling program was initiated which assisted the domestic producers by stockpiling 51 000 tonnes in 1977 and an estimated 82 000 tonnes to be acquired in 1978. At present, Japan's policy concerning national stockpiles appears directed towards temporary relief to the domestic industry and not long-term strategic-economic purposes as is the case for the United States.

On December 20, 1977 the Lead-Zinc Producers

Committee in the United States filed a petition with the International Trade Commission requesting the establishment of quotas and tariffs under Section 201 of the Trade Act of 1974 to restrict zinc metal imports to the United States for the 1978-82 period. The petition requests an annual import quota for zinc of 317 500 tonnes, with a special tariff of 7 cents a pound levied against imports above the quota. The petition could have an adverse effect on the orderly rehabilitation of the zinc industry in the rest of the world. Canada, which has traditionally been the leading supplier of concentrates and metal to the United States, accounting for about 50 per cent of its import requirements, could face the greatest degree of restricted access. There is also the unfavourable impact the petition would have on the multinational trade negotiations in Geneva which are now in the final stages. Public hearings will be held in March, after which the Commission must recommend a course of action to President Carter no later than mid-year.

Price developments

World prices for zinc declined in 1977. The market forces which brought about this decline began with the 1 000 000-tonne decline in 1975 consumption which resulted in large supply surpluses. At the end of 1977 world consumption had not recovered to prior levels, and for the third consecutive year, refineries operated below capacity. Unused capacity grew from 300 000 tonnes in 1973 to 1 300 000 tonnes throughout the 1975-77 period. During that period, suppliers' metal stocks increased from about 300 000 tonnes to 800 000 tonnes despite production restraints which kept world capacity utilization of zinc refineries in the 73 to 76 per cent range. Under these conditions, the practice of discounting from producers' list prices became prevalent; but it was not until May 1977 that these list prices outside North America were dropped. Since zinc refineries overseas pay for zinc-in-concentrate at the list price, commonly known as the Overseas Producers Price, the discounts by overseas refineries represented a severe erosion in their profitability, until the May 1977 decline in the list price, the mines supplying zinc concentrate to these refineries had been isolated from the effects of the discounted price levels. The reduced list price for zinc from $U.S. 795 a tonne to $U.S. 700 a tonne overseas which became effective May 18, 1977 enabled metal producers to continue the discounting practice at still lower levels and resulted in a second reduction in the Overseas Producers Price to $U.S. 600 a tonne on November 2, 1977. Producer prices in North America followed the decline in price overseas, but at year-end remained above the U.S. 27.2-cent-a-pound level overseas. In the United States, the equivalent price at year-end 1977 was U.S. 30.5 cents a pound and in Canada 32.5 cents a pound, which in part, reflected the devaluation of the Canadian dollar. Overall, overseas producer prices for zinc have declined 30 per cent since 1974. It remains to be seen whether North American prices will drop to these levels.

Table 11. International zinc metal prices, 1976 and 1977

Month	Producers Canada	Producers U.S.A.	Producers Outside North America	London Metal Exchange Prompt
	c/lb	c/lb	$US/ tonne	£/tonne
January	36.3	37.0	795.0	403.6
February	36.3	37.0	795.0	411.1
March	36.3	37.0	795.0	418.4
April	36.3	37.0	795.0	380.8
May	35.9	35.6	751.8	355.9
June	35.5	34.0	700.0	315.2
July	35.5	34.0	700.0	314.4
August	35.5	34.0	700.0	298.7
September	35.5	34.0	700.0	296.7
October	32.5	32.0	700.0	289.1
November	32.5	30.7	604.5	288.9
December	32.5	30.5	600.0	289.7
1977 Average	35.1	34.4	719.7	338.5
1976 Average	37.2	37.5	795.0	394.7

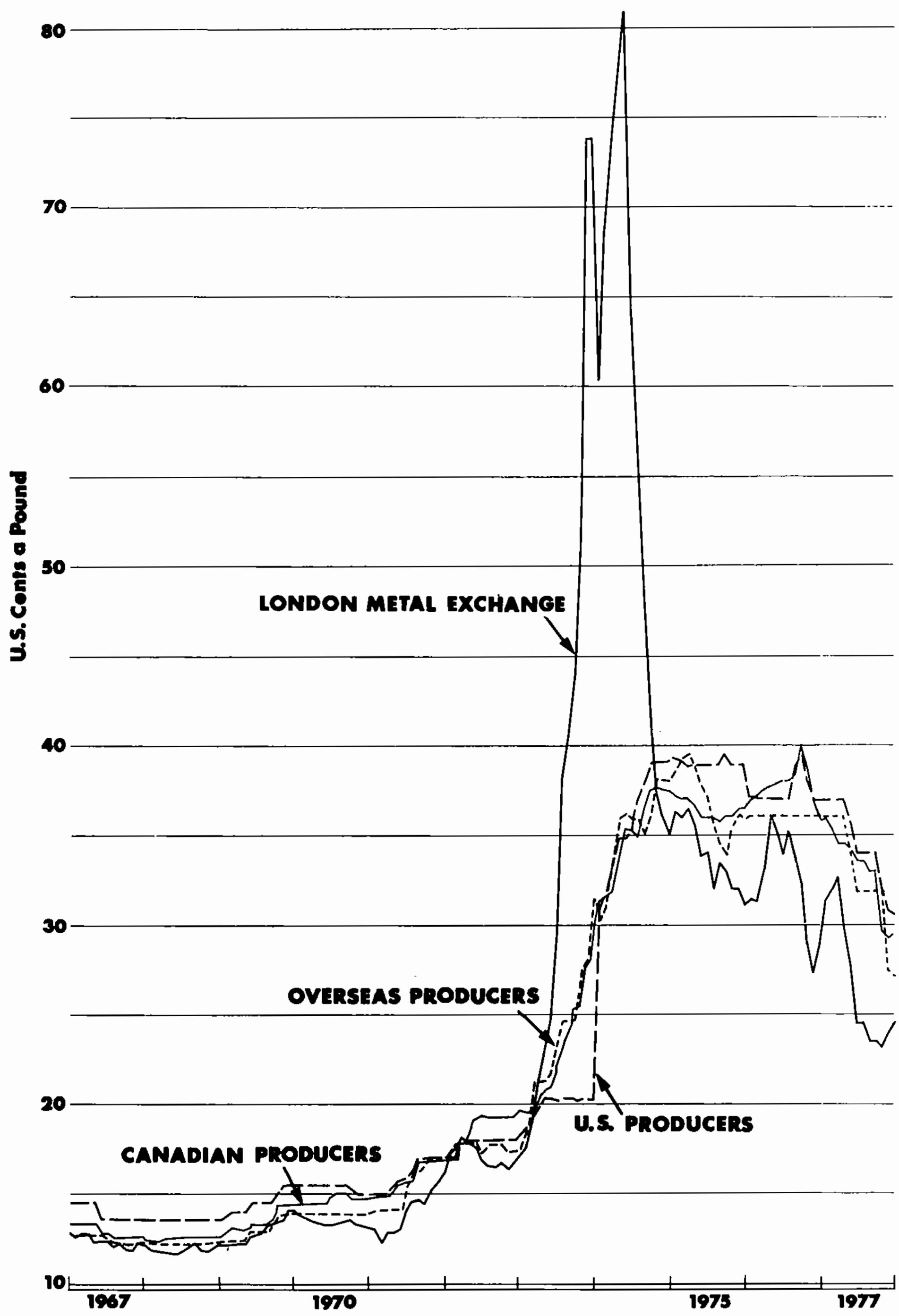
Source: International Lead and Zinc Study Group Bulletin.

Suppliers' stocks of recoverable zinc-in-concentrate are not reported on a comprehensive basis internationally; however, it is estimated that normal working stocks held by mines and refineries in the world are likely to have increased by about 300 000 tonnes in the 1973-77 period. In 1973 and 1974 a sharp decline in such stocks was a limiting factor on world metal production, with working levels drawn down to the point of exhaustion in many cases. Since then a sharp increase in stocks beyond normal working levels has resulted in deteriorating terms of sale for zinc concentrate, and at present many zinc producing mines in the world are in serious difficulty because of lower metal prices, reduced demand for mine output, and five years of record-level cost escalation. These factors combined to reduce mine cash flows for zinc to record lows.

To date, there have been no refinery closures although many have curtailed production, but the mining community is now beginning to record closures of higher cost mines in addition to curtailed production. The basic problem remains that, at U.S. 27.2 cents a pound, zinc is a real bargain, and for some producers the price is too low to support the combined cost of mining, refining and physical distribution. Likewise, it is far from sufficient to justify new productive capacity.

Approximately 60 per cent of zinc mine production

ZINC PRICES-MONTHLY AVERAGE



and 75 per cent of zinc metal production are consumed in the country of origin. The remaining 40 per cent and 25 per cent, respectively, are transported internationally for consumption elsewhere in the world. The effects of depressed prices on exporting nations in times of serious zinc price erosion is severe and competition for markets becomes intense. In this context, the efficiency of the Canadian industry is paramount as Canada is the world's largest exporter of zinc, accounting for some 40 per cent of all trade between the major producing-consuming regions.

Western World mine production

Mine production of zinc in 1977 increased to 4 852 000 tonnes from 4 548 000 tonnes the year before, with the major increases coming from Canada, Ireland and Peru. During the year 389 000 tonnes of new mine capacity came into production, while zinc mine closures only amounted to 40 000 tonnes of annual capacity. The most notable development was the Tara Mines Limited' Navan zinc-lead mine in Ireland where production capacity is expected to be 210 000 tonnes of zinc a year.

Western World metal production

Primary zinc metal production in the western world increased to 4 268 000 tonnes in 1977 from 4 135 000 tonnes in 1976. During the year 49 000 tonnes of new refinery capacity came on stream in India, Brazil and Austria, bringing total zinc refining capacity in the western world to about 5 548 000 tonnes annually. At this level, some 1 280 000 tonnes of capacity was surplus and the utilization of capacity in 1977 was about 76 per cent.

Western World metal consumption

Primary zinc metal consumption in the western world amounted to 4 129 000 tonnes in 1977 which was only 2 000 tonnes higher than in 1976. Since zinc metal production continued to exceed consumption, producers' stocks rose from 683 000 tonnes to 827 000 tonnes during the year. These stocks peaked at 855 000 tonnes in August, 1977 before coming down to the year-end level as producers in various parts of the world began to curtail production as a means of inventory control.

Western World outlook

During the 21st session of the International Lead and Zinc Study Group held in September 1977 the consensus was the world metal consumption in 1978 would only increase 2.5 per cent over 1977. At this level of 4.4 million tonnes, zinc refineries in the world could not operate above 77 per cent of capacity without record stock levels of 1.0 to 1.2 million tonnes increasing even further. The Study Group did not provide a statistical balance for the supply and demand of zinc concentrate; however, based upon a zinc mine production forecast of 5.2 million tonnes which 0.1 million tonnes was exported to Sino-Soviet countries, the net recoverable content of mine production, which assumes a 94 per cent recovery to metal, would be about 0.4 million tonnes surplus to demand. Some allowance for ambitious estimates and recent cutbacks will likely reduce this surplus by about one half, but it represents the fourth straight year of mine production surpluses and could raise concentrate stocks held by mines and refineries to record levels by year-end, approximating 0.5 million tonnes above normal working levels.

Installed refinery capacity in the world is currently sufficient to produce 5.5 million tonnes of zinc metal annually, and during the next five years another 0.5 million tonnes will come on stream. In addition, some 0.7 million tonnes of new capacity is presently under consideration. Metal demand in 1977 was 4.1 million tonnes, leaving 1.3 million tonnes surplus. Assuming a 3 per cent annual growth rate in demand over the next five years, refinery capacity will still be surplus by 1.0

Table 12. Western World, zinc mine production 1975-90

	1975	1980	1985	1990
	(000 tonnes zinc in concentrate)			
Net metal demand	3 440	5 000	5 700	6 700
Necessary mine production[1]	3 760	5 400	6 100	7 200
Zinc mine production				
From mines existing in 1975	4 400	4 200	3 600	3 000
From new capacity 1975-80		1 200	1 050	850
From new capacity 1980-85			1 450	1 300
From new capacity 1985-90				2 050
Total	4 400	5 400	6 100	7 200

Source: Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
[1] After allowance for losses and direct use of zinc ores.

million tonnes, this presumes that none of the capacity under consideration materializes. On this basis alone capacity utilization in the next five years may only improve to 83 per cent from 76 per cent currently. By comparison, capacity utilization in the 1973 to 1974 period was almost 90 per cent.

Zinc mine capacity is much more tenuous as it represents the product of mill capacity and ore grades for roughly 350 mines in the world, many of which do not report operational data publicly. Some observers consider the Study Group forecast of 5.2 million tonnes of mine production in 1978 to be a practical measure of productive capacity, in which case some allowance has to be made for an estimated 0.1 to 0.2 million tonnes of production cutbacks embodied in that forecast. A critical factor in assessing the need for new zinc mines that is frequently overlooked is that mines, once in existence, are being depleted. Based upon some preliminary estimates using historical and expected rates of decline for Canada's zinc producing mines, a decay factor of roughly 2 per cent a year may be applicable for medium-term forecasts. The table entitled, "Western World, zinc mine production 1975-90", illustrates the demand for new zinc mine capacity using this assumption in combination with a market growth for metal demand of 3 per cent a year.

At the present time, new zinc mine capacity that is firmly committed to come into production during the next three years totals 0.7 million tonnes; a further 1.4 million tonnes of capacity is currently under consideration and can possibly be in production in the 1980-85 period, assuming the requisite market conditions prevail. Demand for new zinc mine production in this period is likely to be about 1.45 million tonnes and, assuming an 85 per cent operating rate, new capacity should total about 1.7 million tonnes. Undoubtedly, new discoveries will be made in addition to those under consideration; however, many of the major zinc orebodies being studied are located in remote areas and may be delayed by infrastructure development. Accordingly, temporary mine supply shortages are a possibility during this period. Higher current rates of mine closures, and deferred investment expenditures resulting from depressed prices and profitability, increase the likelihood of this eventuality.

Considering that by 1990 only about 3.0 million tonnes of zinc may be available from mines that existed in 1975, the additional 4.2 million tonnes should be coming from new mine capacity. Since oncoming mines have their own rates of decline the total new mine capacity that should be put on stream between 1975 and 1990 is 4.7 million tonnes. It is estimated that deposits that are known today could provide up to 60 per cent of this total and the remainder will have to come from yet-undiscovered deposits. The obvious implication is that not only very major capital outlays are necessary for new mine development, but a very major and effective effort is necessary in the exploration sector if this total desired mine output of some 7.2 million tonnes of zinc is to be achieved by 1990.

Tariffs

The following tariffs apply for zinc in its various forms

Canada

Item No.		British Preferential	GSP[1]	GATT[2]	General
32900-1	Zinc in ores and concentrates	Free	Free	Free	Free
34505-1	Zinc spelter, zinc and zinc alloys containing not more than 10% by weight of other metal or metals, in the form of pigs, slabs, blocks, dust or granules	Free	Free	Free	2¢/lb
34500-1	Zinc dross and zinc scrap for remelting, or for processing into zinc dust	Free	Free	Free	10%
35800-1	Zinc anodes	Free	Free	Free	10%

United States

USTS Number		GSP	GATT
602.20	Zinc in ores and concentrates	Free	0.67¢/lb[3]
	Unwrought zinc		
626.02	Unalloyed	0.7¢/lb	0.7¢/lb
626.04	Alloys of zinc	19%	19%
626.10	Zinc in waste and scrap	0.75¢/lb[3]	0.75¢/lb[3]

European Economic Community Brussels Tariff Nomenclature (BTN) Number		GSP	GATT
26.01	Zinc in ore and concentrates	Free	Free
79.01	Unwrought zinc	3.5%	3.5%
	Zinc in waste and scrap	Free	Free

Japan

Brussels Tariff Nomenclature (BTN) Number		GSP	GATT
26.01	Zinc in ores and concentrates	Free	Free
79.01	Unwrought zinc, 97% zinc	Free	12 yen/kg[4]
	Zinc in waste and scrap	Free	2.5%[5]

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa; Tariff Schedules of the United States (TSUS) Annotated, 1978, TC Publication 843. Official Journal of the European Communities, Volume 20, No. L 289, 1977. Customs Tariff Schedules of Japan, 1977.
[1]GSP — Generalized System of Preferences extended to all beneficiary developing countries. [2]GATT — General Agreement of Tariffs and Trade (most favoured nation treatment). [3]Duty temporarily suspended. [4]Temporarily reduced to 8 yen/kg. [5]Temporarily reduced to 2%.

Statistical Summary

This chapter of the Yearbook is a statistical summary of Canadian mining and related activities. The statistical information is as comprehensive as possible, given the availability of data.

The summary is divided into nine sections, each containing a number of statistical tables. The sections are preceded by a list of tables by section, number and title and by a table, "Canada, General Economic Indicators, 1963-77".

The sources of Canadian Mining Industry statistics are Statistics Canada, other federal departments and agencies, provincial governments and company annual reports. International mineral statistics are derived from U.S. Bureau of Mines publications, American Bureau of Metal Statistics, World Bureau of Metal Statistics, *Metals Week*, *Engineering and Mining Journal*, the United Nations and the Organization for Economic Cooperation and Development. Where applicable, an explanation of a concept or a term is contained in the footnote to a statistical table. If further information is required, the source of the information should be consulted.

The statistical summary was prepared by J.T. Brennan and staff, Statistical Section, Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.

STATISTICAL TABLES

SECTION 6, EMPLOYMENT, SALARIES AND WAGES

SECTION 7, MINING, EXPLORATION AND DRILLING

SECTION 8, TRANSPORTATION

SECTION 9, INVESTMENT AND FINANCE

		1963	1964	1965	1966	1967
Gross national product, current dollars	$ millions	45 978	50 280	55 364	61 828	66 409
Gross national product, constant dollars (1971 = 100)	,,	61 487	65 610	69 981	74 844	77 344
Value of manufacturing industry shipments	,,	28 015	30 856	33 889	37 303	38 955
Value of mineral production	,,	3 027	3 365	3 715	3 981	4 381
Merchandise exports	,,	6 799	8 094	8 525	10 071	11 112
Merchandise imports	,,	6 558	7 488	8 633	10 072	10 873
Balance of payments, current account	,,	− 521	− 424	− 1 130	− 1 162	− 499
Corporation profits before taxes	,,	4 932	5 841	6 318	6 714	6 823
Capital investment, current dollars	,,	9 398	10 980	12 935	15 088	15 348
Capital investment, constant dollars (1971 = 100)	,,	12 653	14 259	15 944	17 645	17 571
Population	000's	18 931	19 290	19 644	20 015	20 378
Labour force	,,	6 748	6 933	7 141	7 420	7 694
Employed	,,	6 375	6 609	6 862	7 152	7 379
Unemployed	,,	374	324	280	267	315
Unemployment rate	%	5.5	4.7	3.9	3.6	4.1
Employment index	1961 = 100	104.3	108.2	114.3	120.7	122.6
Labour income	$ millions	23 262	25 367	28 201	31 878	35 303
Index industrial production	1971 = 100	62.3	68.0	73.8	79.2	82.3
Index manufacturing production	,,	63.4	69.5	75.8	81.5	83.9
Index mining production	,,	62.2	67.0	70.5	74.1	79.9
Index real domestic product	,,	65.0	69.4	74.5	79.5	82.3
General wholesale price index	1935-39 = 100	244.6	245.4	250.3	259.5	264.1
Consumer price index	1971 = 100	77.2	78.6	80.5	83.5	86.5

[p] Preliminary; [r] Revised.

indicators, 1963-77

1968	1969	1970	1971	1972	1973	1974	1975	1976	1977[p]
72 586	79 815	85 685	94 450	105 234	123 560	147 528[r]	165 428[r]	191 492	210 132
81 864	86 225	88 390	94 450	100 248	107 812	111 678[r]	113 133[r]	119 394	122 561
42 062	45 930	46 381	50 276	56 191	66 674[r]	82 455[r]	88 460[r]	98 597	109 776
4 722	4 734	5 722	5 963	6 408	8 370	11 754[r]	13 345[r]	15 448	18 144
13 270	14 498	16 401	17 397	19 671	24 838	31 739	32 587[r]	37 576	43 506
12 358	14 130	13 952	15 617	18 669	23 325	31 880	34 830[r]	37 444	42 156
− 97	− 917	+ 1 106	+ 431	− 386	+ 108	− 1 460[r]	− 4 757[r]	− 3 801	− 4 150
7 742	8 294	7 699	8 681	10 799	15 417[r]	19 811[r]	20 159	20 102	22 400
15 455	16 927	17 798	20 184	22 218	26 618	32 882	38 216	43 636	46 491
17 628	18 498	18 635	20 184	21 242	23 551[r]	24 970[r]	25 684[r]	26 773	26 403
20 701	21 001	21 297	21 568	21 802[r]	22 043[r]	22 364[r]	22 697[r]	22 993	23 291
7 919	8 162	8 396	8 643	8 918	9 321	9 704	10 060	10 308	10 616
7 537	7 780	7 919	8 107	8 363	8 802	9 185	9 363	9 572	9 754
382	382	476	536	555	519	519	697	736	862
4.8	4.7	5.7	6.2	6.2	5.6	5.3	6.9	7.1	8.1
122.7	127.0	127.1	127.8	129.9	135.9	142.8	141.1	144.1	144.3
38 444	43 065	46 706	51 528	57 570	66 757[r]	80 085[r]	93 562	108 248	120 100
87.6	93.6	94.9	100.0	107.6	117.7	121.4	114.9	120.7	125.6
89.1	95.8	94.5	100.0	106.9	116.1	120.1	114.2	120.0	123.7
86.2	86.9	98.7	100.0	107.4	120.5	119.2	108.9	110.2	114.3
86.9	92.2	94.4	100.0	105.6[r]	113.4[r]	118.1[r]	119.0[r]	125.1	129.0
269.9	282.4	286.4	289.9	310.3	376.9	461.3	491.6	512.4	559.5
90.0	94.1	97.2	100.0	104.8	112.7	125.0	138.5	148.9	160.8

Table 1. Mineral production of Canada, 1976 and 1977, and average 1973-77

	Unit of Measure	1976 (Quantity)	1976 ($000)	1977[p] (Quantity)	1977[p] ($000)	Average 1973-77 (Quantity)	Average 1973-77 ($000)
Metals							
Antimony	t	. .	8 415	. .	8 954	. .	6 833
Bismuth	t	130	2 009	140	1 971	114	1 796
Cadmium	t	1 314	7 603	1 199	8 421	1 370	10 229
Calcium	t	514	1 433	566	2 022	456	1 173
Cobalt	t	1 356	13 239	1 508	17 967	1 460	12 553
Columbium ($Cb^{2}O^{5}$)	t	1 499	6 767	2 540	10 640	1 812	7 035
Copper	000 t	731	1 101 109	781	1 195 579	778	1 177 454
Gold	kg	52 621	208 273	53 404	268 377	54 214	240 330
Indium	kg	6 127	. .	. .	. .	. .	. .
Iron ore	000 t	55 416	1 223 003	51 754	1 360 163	49 269	966 297
Iron remelt	000 t	. .	65 949	. .	70 500	. .	67 492
Lead	000 t	256	128 011	284	195 128	305	147 024
Magnesium	t	6 092	12 825	7 580	17 644	5 932	10 800
Mercury	t	—	—	—	—	265	. .
Molybdenum	t	14 619	98 572	16 431	146 691	14 361	86 019
Nickel	000 t	241	1 146 480	235	1 196 843	247	1 046 308
Platinum group	kg	12 965	50 143	14 588	61 772	12 590	54 239
Selenium	t	110	4 291	207	8 267	202	6 826
Silver	kg	1 281 437	177 074	1 330 000	210 189	1 330 928	176 849
Tantalum ($Ta^{2}O^{5}$)	t	. .	. .	. .	. .	. .	. .
Tellurium	t	49	1 094	36	922	41	800
Thorium	t	—	—	—	—	—	—
Tin	t	274	1 882	317	4 073	273	2 291
Tungsten (WO^{3})	t	2 168	. .	. .	. .	. .	. .
Uranium ($U^{3}O^{8}$)	t	6 635	. .	7 020	. .	5 568	. .
Zinc	000 t	982	814 584	1 055	814 413	1 089	804 281
Total metals			5 072 756		5 600 536		4 826 629
Nonmetals							
Arsenious oxide	t	—	—	—	—	—	—
Asbestos	000 t	1 536	452 208	1 543	564 130	1 494	363 984
Barite	000 t	100	1 852	117	2 325	94	1 703
Feldspar	000 t	—	—	—	—	—	—
Fluorspar	000 t	. .	2 935	. .	10 180	. .	4 971
Gemstones	t	. .	1 641	. .	700	. .	616
Gypsum	000 t	6 002	22 767	7 040	28 530	6 719	23 021
Magnesitic dolomite and brucite	000 t	. .	4 008	. .	5 610	. .	4 398
Mica	kg	. .	51	—	—	. .	. .
Nepheline syenite	000 t	540	10 567	580	12 160	533	9 727
Peat	000 t	394	25 474	394	26 725	368	22 032
Potash ($K^{2}O$)	000 t	5 215	353 505	5 910	421 281	5 206	323 831
Pyrite, pyrrhotite	000 t	31	241	19	197	29	217
Quartz	000 t	2 520	16 007	2 362	18 444	2 478	14 160
Salt	000 t	5 994	84 079	5 933	88 428	5 509	68 494
Soapstone, talc & pyrophyllite	000 t	69	1 833	73	1 980	74	1 808
Sodium sulphate	000 t	460	23 310	416	21 620	496	17 883
Sulphur in smelter gas	000 t	705	18 582	766	20 185	703	13 658
Sulphur, elemental	000 t	4 029	70 171	4 910	72 717	4 444	65 421
Titanium dioxide	000 t	. .	73 121	. .	72 000	. .	59 897
Total nonmetals			1 162 352		1 367 212		995 821

Table 1. (concl'd)

	Unit of Measure	1976 (Quantity)	1976 ($000)	1977^p (Quantity)	1977^p ($000)	Average 1973-77 (Quantity)	Average 1973-77 ($000)
Fuels							
Coal	000 t	25 476	607 100	28 394	670 500	24 191	469 316
Natural gas	000 m^3	87 649 797	2 649 218	89 530 846	3 443 129	87 847 768	1 757 725
Natural gas by-products	000 m^3	16 615	798 906	17 006	981 533	17 590	713 041
Petroleum, crude	000 m^3	76 438	4 053 888	77 179	4 917 314	87 727	3 700 679
Total fuels			8 109 112		10 012 476		6 640 761
Structural materials							
Clay products	000 $	. .	97 547	. .	104 150	. .	82 073
Cement	000 t	9 624	381 112	10 099	408 673	10 145	329 042
Lime	000 t	1 850	59 724	1 879	60 866	1 787	47 441
Sand and Gravel	000 t	249 159	334 414	243 850	343 900	238 251	292 183
Stone	000 t	87 876	230 638	89 267	246 400	88 620	197 132
Total, structural materials			1 103 435		1 163 989		947 871
Total, all minerals			15 447 655		18 144 213		13 411 082

Note: 1. Production statistics for the following are not available for publication: diatomite, helium, nitrogen, tantalum and yttrium. 2. Nil production for the following between 1973 and 1977: arsenious oxide, feldspar, grindstone, iron oxide, lithia and thorium. 3. Dollar values only available for publication for the following: antimony, iron remelt, gemstones, fluorspar, magnesitic dolomite and brucite, titanium dioxide and clay products. 4. Quantities only available for publication for the following: indium, tungsten and uranium.

^{p} Preliminary; . . Not available; — Nil.

Table 2. Canada, value of mineral production, per capita value of mineral production, and population, 1937-77

	Metallics	Industrial Minerals	Fuels	Total	Per Capita Value of Mineral Production	Population of Canada
			($ million)		($)	(thousand)
1937	335	57	66	458	41.48	11 045
1938	324	54	65	443	39.71	11 152
1939	343	61	71	475	42.12	11 267
1940	382	69	79	530	46.55	11 381
1941	395	80	85	560	48.69	11 507
1942	392	83	92	567	48.63	11 654
1943	357	80	93	530	44.94	11 795
1944	308	81	97	486	40.67	11 946
1945	317	88	94	499	41.31	12 072
1946	290	110	103	503	40.91	12 292
1947	395	140	110	645	51.38	12 551
1948	488	172	160	820	63.97	12 823
1949	539	178	184	901	67.01	13 447
1950	617	227	201	1 045	76.24	13 712
1951	746	266	233	1 245	88.90	14 009
1952	728	293	264	1 285	88.90	14 459
1953	710	312	314	1 336	90.02	14 845
1954	802	333	353	1 488	97.36	15 287
1955	1 008	373	414	1 795	114.37	15 698
1956	1 146	420	519	2 085	129.65	16 081
1957	1 159	466	565	2 190	131.87	16 610
1958	1 130	460	511	2 101	122.99	17 080
1959	1 371	503	535	2 409	137.79	17 483
1960	1 407	520	566	2 493	139.48	17 870
1961	1 387	542	674	2 603	142.72	18 238
1962	1 496	574	811	2 881	155.05	18 583
1963	1 510	632	885	3 027	159.91	18 931
1964	1 702	690	973	3 365	174.45	19 290
1965	1 908	761	1 046	3 715	189.11	19 644
1966	1 985	844	1 152	3 981	198.88	20 015
1967	2 285	861	1 235	4 381	214.99	20 378
1968	2 493	886	1 343	4 722	228.10	20 701
1969	2 378	891	1 465	4 734	225.42	21 001
1970	3 073	931	1 718	5 722	268.68	21 297
1971	2 940	1 008	2 015	5 963	276.46	21 568[r]
1972	2 956	1 085	2 367	6 408	293.92[r]	21 802[r]
1973	3 850	1 293	3 227	8 370	379.71[r]	22 043[r]
1974	4 821[r]	1 731[r]	5 202	11 754[r]	525.58[r]	22 364[r]
1975	4 794	1 898[r]	6 653	13 345[r]	587.96[r]	22 697[r]
1976	5 073	2 266	8 109	15 448	671.84	22 993
1977[p]	5 601	2 531	10 012	18 144	779.02	23 291

[p] Preliminary; [r] Revised.

Table 3. Canada, value of mineral production by provinces, territories and mineral classes, 1977[p]

	Metals		Industrial Minerals		Fuels		Total	
	$000	% of total	$000	% of total	$000	% of total	$000	% of total
Alberta	—	—	202 645	8.00	8 323 067	83.13	8 525 712	46.98
Ontario	2 192 775	39.16	506 625	20.02	13 439	0.13	2 712 839	14.95
British Columbia	809 909	14.46	182 603	7.21	900 496	8.99	1 893 008	10.43
Quebec	759 718	13.57	871 900	34.45	—	—	1 631 618	8.99
Saskatchewan	22 581	0.40	483 222	19.09	614 709	6.14	1 120 512	6.18
Newfoundland	781 491	13.95	64 040	2.53	—	—	845 531	4.66
Manitoba	419 398	7.49	72 671	2.87	40 764	0.41	532 833	2.94
New Brunswick	224 225	4.00	37 092	1.47	6 510	0.07	267 827	1.48
Northwest Territories	217 874	3.89	—	—	32 484	0.32	250 358	1.38
Yukon	172 565	3.08	37 180	1.47	507	0.01	210 252	1.16
Nova Scotia	—	—	71 423	2.82	80 500	0.80	151 923	0.84
Prince Edward Island	—	—	1 800	0.07	—	—	1 800	0.01
Total Canada	5 600 536	100.00	2 531 201	100.00	10 012 476	100.00	18 144 213	100.00

[p] Preliminary; — Nil.

Table 4. Canada, production of leading minerals

	Unit of Measure	Nfld.	P.E.I.	Nova Scotia	New Bruns-wick	Quebec	Ontario
Petroleum, crude	000 m³	—	—	—	1	—	100
	$000	—	—	—	40	—	6 867
Natural gas	000 m³	—	—	—	2 719	—	175 633
	$000	—	—	—	20	—	6 572
Iron ore	000 t	24 556	—	—	—	16 285	10 404
	$000	722 184	—	—	—	329 583	299 838
Nickel	000 t	—	—	—	—	—	185
	$000	—	—	—	—	—	931 975
Copper	000 t	8	—	—	13	108	280
	$000	12 778	—	—	20 257	164 927	428 170
Natural gas	000 m³	—	—	—	—	—	—
by-products	$000	—	—	—	—	—	—
Zinc	000 t	47	—	—	162	108	292
	$000	36 425	—	—	124 965	83 106	225 452
Coal	000 t	—	—	2 132	290	—	—
	$000	—	—	80 500	6 450	—	—
Asbestos	000 t	71	—	—	—	1 261	13
	$000	35 000	—	—	—	430 830	1 180
Potash (K_2O)	000 t	—	—	—	—	—	—
	$000	—	—	—	—	—	—
Cement	000 t	. .	—	. .	. .	3 019	3 666
	$000	4 581	—	8 257	10 367	110 654	129 306
Sand and gravel	000 t	4 627	816	7 620	4 990	75 568	70 307
	$000	8 600	1 800	15 100	5 200	69 900	112 400
Gold	kg	435	—	—	218	14 588	22 985
	$000	2 124	—	—	1 157	73 326	115 481
Stone	000 t	454	—	1 451	3 084	49 532	29 484
	$000	1 600	—	4 600	9 200	133 500	79 300
Silver	kg	14 650	—	—	173 184	81 802	513 207
	$000	2 316	—	—	27 370	12 928	81 113
Lead	t	8 200	—	—	61 142	121	8 257
	$000	5 632	—	—	41 991	83	5 671
Molybdenum	t	—	—	—	—	1 049	—
	$000	—	—	—	—	9 053	—
Clay products	$000	575	—	4 575	1 989	17 333	56 511
Salt	000 t	—	—	815	—	—	4 531
	$000	—	—	17 540	—	—	55 823
Sulphur, elemental	000 t	—	—	—	—	—	1
	$000	—	—	—	—	—	21
Titanium dioxide	000 t	—	—	—	—	. .	—
	$000	—	—	—	—	72 000	—
Iron, remelt	000 t	—	—	—	—	. .	—
	$000	—	—	—	—	70 500	—
Platinum group	kg	—	—	—	—	—	14 588
	$000	—	—	—	—	—	61 772
Lime	000 t	—	—	—	. .	326	1 244
	$000	—	—	—	2 137	11 129	38 401
Gypsum	000 t	661	—	4 861	43	—	685
	$000	2 880	—	18 678	204	—	3 677
Total leading minerals	$000	834 695	1 800	149 250	251 347	1 588 852	2 639 530
Total all minerals	$000	845 531	1 800	151 923	267 827	1 631 618	2 712 839
Leading minerals as % of all minerals		98.7	100.0	98.2	93.9	97.4	97.3

ᵖ Preliminary; — Nil; . . Not available.

by provinces and territories, 1977p

Manitoba	Saskat-chewan	Alberta	British Columbia	Yukon	N.W.T.	Total Canada
636	9 666	64 419	2 214	—	143	77 179
40 764	571 520	4 160 843	133 680	—	3 600	4 917 314
—	1 427 723	76 167 896	11 019 530	11 048	726 297	89 530 846
—	14 700	2 989 238	403 208	507	28 884	3 443 129
—	—	—	509	—	—	51 754
—	—	—	8 558	—	—	1 360 163
50	—	—	—	—	—	235
264 868	—	—	—	—	—	1 196 843
60	8		291	12	1	781
92 572	11 463	—	446 840	18 062	510	1 195 579
—	148	16 471	387	—	—	17 006
—	7 689	954 086	19 758	—	—	981 533
57	8	—	111	105	165	1 055
44 295	6 095	—	85 527	81 147	127 401	814 413
—	5 488	11 793	8 691	—	—	28 394
—	20 800	218 900	343 850	—	—	670 500
—	—	—	96	102	—	1 543
—	—	—	59 940	37 180	—	564 130
—	5 910					5 910
—	421 281	—	—	—	—	421 281
587	337	1 052	944	—	—	10 099
29 776	17 790	53 929	44 013	—	—	408 673
15 331	8 346	25 129	31 116	—	—	243 850
25 200	11 900	48 500	45 300	—	—	343 900
1 524	560	—	6 065	1 182	5 847	53 404
7 627	2 737	—	30 520	5 943	29 462	268 377
1 905	—	363	2 994			89 267
7 200	—	1 600	9 400	—	—	246 400
28 615	9 953	—	247 055	132 283	129 173	1 329 922
4 521	1 573	—	39 046	20 908	20 414	210 189
454	—	—	79 877	67 698	58 370	284 119
312	—	—	54 858	46 494	40 087	195 128
—	—	—	15 382	—	—	16 431
—	—	—	137 638	—	—	146 691
2 624	3 243	10 330	6 970	—	—	104 150
27	254	306	—	—	—	5 933
172	8 388	6 505	—	—	—	88 428
1	10	4 853	45	—	—	4 910
15	230	71 798	653	—	—	72 717
—	—	—	—	—	—	. .
—	—	—	—	—	—	72 000
—	—	—	—	—	—	. .
—	—	—	—	—	—	70 500
—	—	—	—	—	—	14 588
—	—	—	—	—	—	61 772
. .	—	130	59	—	—	1 879
2 647	—	4 663	1 889	—	—	60 866
130	—	—	660	—	—	7 040
465	—	—	2 626	—	—	28 530
523 058	1 099 409	8 520 392	1 874 274	210 241	250 358	17 943 206
532 833	1 120 512	8 525 712	1 893 008	210 252	250 358	18 144 213
98.2	98.1	99.9	99.0	100.0	100.0	98.9

Table 5. Canada, percentage contribution of leading minerals to total value of mineral production, 1968-77

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977[p]
Petroleum, crude	19.8	21.4	20.2	22.8	24.5	26.8	30.0	28.2	26.2	27.1
Natural gas	4.8	5.5	5.5	5.7	6.2	5.4	6.2	11.4	17.2	19.0
Iron ore	11.3	9.6	10.3	9.3	7.6	7.2	6.2	6.9	7.9	7.5
Nickel	11.2	10.2	14.5	13.4	11.2	9.7	8.3	8.3	7.4	6.6
Copper	12.9	12.4	13.6	12.7	12.6	13.8	11.9	7.7	7.1	6.6
Natural gas by-products	2.8	2.9	2.8	3.2	3.9	4.2	5.6	5.9	5.2	5.4
Zinc	6.9	7.8	7.0	7.0	7.5	7.8	7.4	6.5	5.3	4.5
Coal	1.1	1.1	1.5	2.0	2.4	2.1	2.6	4.4	3.9	3.7
Asbestos	3.9	4.1	3.6	3.4	3.2	2.8	2.6	2.0	2.9	3.1
Potash ($K^2 0$)	1.4	1.5	1.9	2.3	2.1	2.1	2.6	2.7	2.3	2.3
Cement	3.1	3.4	2.7	3.1	3.3	2.9	2.4	2.5[r]	2.5	2.2
Sand and gravel	2.7	2.6	2.3	2.6	2.8	2.6	2.3	2.3	2.2	1.9
Gold	2.2	2.0	1.5	1.3	1.9	2.3	2.2	2.0	1.3	1.5
Stone	2.0	1.9	1.5	1.6	1.6	1.5	1.5	1.5	1.5	1.4
Silver	2.2	1.8	1.4	1.2	1.2	1.4	1.7	1.3	1.2	1.2
Lead	1.9	2.0	2.2	1.8	1.8	1.5	1.1	1.2	0.8	1.1
Molybdenum	0.8	1.1	1.0	0.6	0.7	0.6	0.5	0.5	0.6	0.8
Clay products	1.0	1.1	0.9	0.8	0.8	0.7	0.6	0.6	0.6	0.6
Salt	0.7	0.6	0.6	0.7	0.6	0.6	0.5	0.5	0.5	0.5
Sulphur, elemental	1.7	1.3	0.5	0.4	0.3	0.3	0.6	0.7	0.4	0.4
Titanium dioxide	0.6	0.6	0.6	0.7	0.6	0.6	0.4	0.4	0.5	0.4
Iron, remelt	0.5	0.6	0.6	0.5	0.7	0.6	0.6	0.6	0.4	0.4
Platinum group	1.0	0.7	0.8	0.7	0.5	0.5	0.5	0.4	0.3	0.3
Lime	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3[r]	0.4	0.3
Gypsum	0.3	0.3	0.2	0.3	0.3	0.3	0.2	0.2	0.1	0.2
Other minerals	2.8	3.1	1.9	1.5	1.3	1.3	1.1	1.0	1.3	1.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[p] Preliminary; [r] Revised.

Table 6. Canada, value of mineral production by provinces and territories, 1968-77

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977^p
					($ million)					
Alberta	1 092	1 205	1 396	1 641	1 979	2 760	4 517	5 750^r	6 935	8 526
Ontario	1 356	1 222	1 593	1 555	1 536	1 855	2 435	2 354^r	2 526	2 713
British Columbia	389	434	490	541	678	978	1 156	1 296^r	1 605	1 893
Quebec	725	717	803	766	786	936	1 222	1 230^r	1 493	1 632
Saskatchewan	357	345	379	410	410	510	791	862	919	1 120
Newfoundland	310	257	353	343	291	374	448	551	745	845
Manitoba	210	246	332	330	323	414	489	530	512	533
New Brunswick	88	95	105	107	120	164	217	232	236	268
Northwest Territories	116	119	134	116	120	165	223	206	225	250
Yukon	21	35	78	93	107	151	171	230	125	210
Nova Scotia	57	58	58	60	57	61	83^r	102	125	152
Prince Edward Island	1	1	1	1	1	2	1	2	2	2
Total	4 722	4 734	5 722	5 963	6 408	8 370	11 753^r	13 345^r	15 448	18 144

^{p} Preliminary; ^{r} Revised.

Table 7. Canada, percentage contribution of provinces and territories tototal value of mineral production, 1968-77

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977^p
Alberta	23.1	25.5	24.4	27.5	30.9	33.0	38.4	43.1	44.9	47.0
Ontario	28.7	25.8	27.8	26.0	23.9	22.2	20.7	17.6	16.4	14.9
British Columbia	8.2	9.2	8.6	9.1	10.6	11.7	9.8	9.7	10.4	10.4
Quebec	15.4	15.2	14.0	12.9	12.3	11.2	10.4	9.2^r	9.7	9.0
Saskatchewan	7.6	7.3	6.6	6.9	6.4	6.1	6.7	6.5	5.9	6.2
Newfoundland	6.6	5.4	6.2	5.8	4.5	4.5	3.8	4.1	4.8	4.7
Manitoba	4.4	5.2	5.8	5.5	5.0	4.9	4.2	4.0	3.3	2.9
New Brunswick	1.9	2.0	1.8	1.8	1.9	1.9	1.9	1.7	1.5	1.5
Northwest Territories	2.5	2.5	2.4	1.9	1.9	2.0	1.9	1.6^r	1.5	1.4
Yukon	0.4	0.7	1.4	1.6	1.7	1.8	1.5	1.7	0.8	1.2
Nova Scotia	1.2	1.2	1.0	1.0	0.9	0.7	0.7	0.8	0.8	0.8
Prince Edward Island	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

^{p} Preliminary; ^{r} Revised.

Table 8. Canada's world role as a producer of certain

		World production
Nickel (mine production)	t % of world total	760 525
Zinc (mine production)	t % of world total	6 226 013
Asbestos	t % of world total	5 042 752
Uranium (U_3O_8 concentrates)	t % of world total	27 886
Potash (K_2O equivalent)	000 t % of world total	24 794
Titanium concentrates (Ilmenite)	t % of world total	4 439 446
Molybdenum	t % of world total	88 617
Silver	kg % of world total	9 493 123
Elemental sulphur	000 t % of world total	29 801
Platinum group metals (mine production)	kg % of world total	185 953
Gold (mine production)	kg % of world total	1 240 667
Copper (mine production)	t % of world total	7 900 330
Gypsum	000 t % of world total	65 750
Lead (mine production)	t % of world total	3 510 356
Cadmium (smelter production)	t % of world total	16 965
Iron ore	000 t % of world total	874 716
Aluminum (primary metal)	t % of world total	13 101 930

[p] Preliminary; [e] Estimated.

important minerals, 1976[p]

Rank of Six Leading Countries					
1	2	3	4	5	6
Canada	U.S.S.R.	New Caledonia	Australia	Cuba	Dominican Republic
240 825	130 000[e]	18 900	75 400	36 800	24 400
31.7	17.1	15.6	9.9	4.8	3.2
Canada	U.S.S.R.	U.S.A.	Australia	Peru	Mexico
1 145 013	1 020 000[e]	483 000	467 600	458 500	269 000
18.4	16.4	7.8	7.5	7.4	4.3
U.S.S.R.	**Canada**	Rep. of South Africa	Southern Rhodesia	Italy	People's Rep. of China
2 290 000[e]	1 536 091	369 840	165 000[e]	164 788	150 000[e]
45.4	30.5	7.3	3.3	3.3	3.0
U.S.A.	**Canada**	Rep. of South Africa	France	Niger	Gabon
11 521	6 635	3 254	2 138	1 722	1 085
41.3	23.8	11.7	7.7	6.2	3.9
U.S.S.R.	**Canada**	East Germany	U.S.A.	West Germany	France
8 500[e]	5 215	3 161[e]	2 177	2 036	1 604
34.3	21.0	12.8	8.8	8.2	6.5
Australia	**Canada**	Norway	U.S.A.	U.S.S.R.	Malaysia
1 397 147[e]	822 998	766 816	591 851	407 326[e]	179 995
31.5	18.5	17.3	13.3	9.2	4.1
U.S.A.	**Canada**	Chile	U.S.S.R.	People's Rep. of China	Peru
51 362	14 619	10 899	9 350[e]	1 500[e]	450
58.0	16.5	12.3	10.6	1.7	0.5
U.S.S.R.	Mexico	**Canada**	Peru	U.S.A.	Australia
1 368 553[e]	1 326 252	1 281 437	1 106 631	1 067 720	780 604
14.4	14.0	13.5	11.7	11.3	8.2
U.S.A.	Poland	**Canada**	U.S.S.R.	Mexico	France
9 553	4 800	4 029	3 100	2 147	1 850
32.1	16.1	13.5	10.4	7.2	6.2
U.S.S.R.	Republic of South Africa	**Canada**	Japan	Colombia	U.S.A.
87 090[e]	83 980[e]	12 965	833	809	190
46.8	45.2	7.0	0.5	0.4	0.1
Republic of South Africa	U.S.S.R.	**Canada**	Papua-New Guinea	U.S.A.	Southern Rhodesia
713 389	239.497[e]	52 621	38 213	32 598	24 883
57.5	19.3	4.2	3.1	2.6	2.0
U.S.A.	U.S.S.R.	Chile	**Canada**	Zambia	Zaire
1 456 600	1 130 000	1 005 200	730 930	708 900	444 600
18.4	14.3	12.7	9.3	9.0	5.6
U.S.A.	Iran	U.S.S.R.	**Canada**	France	Spain
11 980	6 500[e]	6 400[e]	6 002	5 850	4 200[e]
18.2	9.9	9.7	9.1	8.9	6.4
U.S.S.R.	U.S.A.	Australia	**Canada**	Mexico	Peru
600 000[e]	565 400	399 300	243 956	200 000	182 100
17.1	16.1	11.4	7.0	5.7	5.2
U.S.S.R.	Japan	U.S.A.	West Germany	**Canada**	Belgium
2 900[e]	2 532	2 150	1 454	1 314	1 176
17.1	14.9	12.7	8.6	7.8	6.9
U.S.S.R.	Australia	U.S.A.	Brazil	**Canada**	China
239 000	92 400	81 200	70 000	55 416	50 000
27.3	10.6	9.3	8.0	6.3	5.7
U.S.A.	U.S.S.R.	Japan	West Germany	**Canada**	Norway
3 856 800	2 200 000[e]	919 400	697 100	633 430	620 900
29.4	16.8	7.0	5.3	4.8	4.7

Table 9. Canada, census value added, commodity producing industries, 1969-75

	1969	1970	1971	1972	1973	1974	1975[p]
				($ million)			
Primary industries							
Agriculture	3 049	2 869	3 130	3 332[r]	5 024[r]	6 236[r]	6 630
Forestry	747	694	698	829[r]	1 109[r]	1 245[r]	1 125
Fishing	186	204	205	237	320	292	291
Hunting and trapping	16	13	11	17	29	31	21
Mining[1]	3 355	3 831	3 826	4 292[r]	6 289[r]	8 930[r]	9 750
Electrical power	1 511	1 707	1 855	2 051	2 345	2 697	2 706
Total	8 864	9 318	9 725	10 758[r]	15 116[r]	19 431[r]	20 523
Secondary Industries							
Manufacturing	21 456	21 418	23 188	25 982[r]	30 767[r]	37 654[r]	38 715
Construction	5 794	6 167	7 581	8 244	9 695	11 850	13 718
Total	27 250	27 585	30 769	34 226[r]	40 462[r]	49 504[r]	52 433
Grand Total	36 114	36 903	40 494	44 984[r]	55 578[r]	68 935[r]	72 956

[1] Cement, lime, clay and clay products (from dooestic clays) industries are included under Manufacturing.
[p] Preliminary; [r] Revised.

Table 10. Canada, census value added, total activity, mining and mineral manufacturing industries, 1971-75

	1971	1972	1973	1974	1975p
Mining					
Metallic minerals					
Placer gold	92	113	. .	. .	. .
Gold quartz	59 606	75 055	119 192	163 590	149 869
Copper-gold-silver	386 765	449 533	1 026 497	1 028 643	595 410
Silver-cobalt	2 945	3 626	(1)	(1)	(1)
Silver-lead-zinc	157 301	176 263	292 731	382 281	320 776
Nickel-copper	451 059	529 445	820 344	1 049 650	729 656
Iron	345 093	279 610	345 830	403 910	556 710
Miscellaneous metal mines	91 590	96 114	106 713	143 301	211 517
Total	1 494 451	1 609 759	2 711 307	3 171 375	2 563 938
Industrial minerals					
Asbestos	164 749	161 736	176 368	239 816	230 612
Feldspar, quartz and nepheline syenite	9 420	11 069	13 933	15 339	14 707
Gypsum	11 541	14 512	16 748	16 542	14 861
Peat	11 147	11 500	14 216	19 772	20 556
Potash	107 874	112 245	128 957	232 652	298 471
Salt	29 873	32 376	36 731	49 751	45 888
Sand and gravel	52 650	54 864	59 841	83 522	102 305
Stone	50 626	57 898	66 999	92 852	111 031
Talc and soapstone	920	1 162	1 456	1 412	(2)
Miscellaneous nonmetals	10 081	11 263	12 400	20 711	25 711
Total	448 881	468 625	527 649	772 369	864 142
Fuels					
Coal	103 563	130 615	166 705	261 246	483 493
Petroleum and natural gas	1 779 369	2 083 466	2 883 273	4 724 990	5 838 459
Total	1 882 932	2 214 081	3 049 978	4 986 236	6 321 952
Total mining industry	3 826 264	4 292 465	6 288 934	8 929 980	9 750 032
Mineral manufacturing					
Primary metal industries					
Iron and steel mills	874 322	921 737	1 169 567	1 398 735	1 364 022
Steel pipe and tube mills	85 648	112 947	115 589	152 339	170 265
Iron foundries	123 127	138 758	163 711	222 415	238 117
Smelting and refining	563 956	556 918	590 724	794 193	886 405
Aluminum rolling, casting and extruding	87 122	98 186	94 600	146 721	132 636
Copper and alloy rolling, casting and extruding	55 465	67 075	91 040	91 301	68 282
Metal rolling, casting and extruding, nes	52 139	64 972	83 647	106 108	88 446
Total	1 841 779	1 960 593	2 308 878	2 911 812	2 948 173
Nonmetallic mineral products industries					
Cement manufacturers	131 276	154 787	172 236	190 396	210 342
Lime manufacturers	11 913	12 584	17 871	25 033	24 913
Concrete products manufacturers	166 190	182 476	197 733	248 548	282 131
Ready-mix concrete manufacturers	140 297	163 640	202 110	236 308	282 597
Clay products (domestic clay)	37 933	39 974	41 595	51 531	59 732
Clay products (imported clay)	23 244	27 039	33 802	41 661	41 698
Refractories manufacturers	24 241	22 815	28 075	37 163	45 823

Table 10. (concl'd)

	1971	1972	1973	1974	1975[p]
Mineral manufacturing (concl'd)					
Stone products manufacturers	10 670	9 363	11 002	12 327	13 975
Glass manufacturers	127 631	150 110	162 436	190 028	185 639
Glass products manufacturers	56 423	59 107	73 340	72 378	74 327
Abrasive manufacturers	28 454	33 063	38 038	45 962	43 863
Other nonmetallic mineral products industries	131 011	155 188	171 604	195 228	237 369
Total	889 283	1 010 146	1 149 842	1 346 563	1 502 409
Petroleum and coal products industries					
Petroleum refining	403 895	430 520	539 560	925 246	789 680
Manufacturers of lubricating oil and greases	18 877	21 156	22 410	26 289	32 633
Other petroleum and coal products industries	12 513	13 843	18 725	26 717	43 639
Total	435 285	465 519	580 695	978 252	865 952
Total mineral manufacturing	3 166 347	3 436 258	4 039 415	5 236 627	5 316 534
Total mining and mineral manufacturing	6 992 611	7 728 723	10 328 349	14 166 607	15 066 566

(1) Included with silver-lead-zinc mines. (2) Included with miscellaneous nonmetals
[p] Preliminary; .. Not available; nes Not elsewhere specified.

Table 11. Canada, indexes of physical volume of total industrial production, mining and mineral manufacturing, 1963-77 (1971 = 100)

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977[p]
Total industrial production	62.3	68.0	73.8	79.2	82.3	87.6	93.6	94.9	100.0	107.6	117.7	121.4	114.9	120.7	125.6
Total mining	62.2	67.0	70.5	74.1	79.9	86.2	86.9	98.7	100.0	107.4	120.5	119.2	108.9	110.2	114.3
Metals															
All metals	70.7	75.5	78.0	81.5	89.9	95.5	88.4	105.4	100.0	97.8	110.3	110.5	101.1	106.4	109.4
Placer gold and gold quartz mines	167.2	164.6	159.7	150.0	134.1	121.7	118.2	105.3	100.0	90.9	81.1	69.9	71.2	74.6	73.6
Iron mines	54.6	65.6	65.9	82.7	88.8	104.8	91.9	116.1	100.0	89.3	114.9	112.9	109.7	135.6	131.3
Other metal mines	60.4	66.7	76.5	76.5	87.8	92.0	85.3	103.0	100.0	100.3	110.5	111.9	100.5	100.7	105.7
Fuels															
All Fuels	49.1	53.2	56.8	61.3	67.1	73.4	80.8	92.6	100.0	118.5	134.3	128.2	118.7	111.5	113.9
Coal	71.2	74.8	75.1	70.7	70.3	68.7	68.4	87.5	100.0	148.3	160.6	158.4	201.7	193.8	209.4
Crude petroleum and natural gas	47.6	51.7	55.5	60.7	66.8	73.7	81.7	93.0	100.0	116.1	132.1	125.7	111.9	104.8	106.1
Nonmetals															
All nonmetals	54.6	61.0	65.6	71.8	76.8	83.7	92.8	95.0	100.0	100.8	108.5	124.6	105.5	117.9	129.9
Asbestos	69.0	74.0	71.7	79.5	78.9	82.6	89.8	95.2	100.0	102.0	104.6	110.4	75.9	104.4	107.8
Mineral manufacturing															
Primary metals	68.4	76.8	84.4	87.9	84.5	92.9	94.9	100.9	100.0	103.5	112.1	120.8	110.1	108.0	116.7
Nonmetallic minerals products	68.4	76.0	83.3	86.0	80.7	87.1	90.5	86.6	100.0	107.9	121.6	125.1	121.1	124.2	133.4
Petroleum and coal products	72.4	73.0	75.7	79.2	79.9	88.7	92.1	94.4	100.0	108.1	123.4	127.1	125.5	127.9	133.7

[p] Preliminary.

Table 12. Canada, indexes of real domestic product by industries, 1967-77 (1971 = 100)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977[p]
Real domestic product, all industries	82.3	86.9	92.2	94.4	100.0	105.6	113.4	118.1	119.0	125.2	129.0
Agriculture	78.9	85.2	90.6	89.0	100.0	88.2	89.5	82.0	91.7	104.2	101.3
Forestry	90.1	94.4	102.4	103.3	100.0	102.4	123.9	117.8	97.6	109.0	120.2
Fishing and trapping	102.0	115.6	102.6	105.4	100.0	95.5	100.4	90.0	86.0	101.3	88.8
Mining (including milling), quarries and oil wells	79.9	86.2	86.9	98.7	100.0	107.4	120.5	119.2	108.9	110.2	114.3
Electric power, gas and water utilities	72.6	78.2	85.4	93.3	100.0	111.3	121.6	131.3	131.0	143.7	152.9
Manufacturing	83.9	89.1	95.8	94.5	100.0	107.2	116.9	120.8	114.1	120.2	124.8
Construction	87.1	90.1	92.5	90.9	100.0	102.4	107.5	112.3	116.3	122.3	119.8
Transportation, storage and communication	77.9	82.8	89.0	94.2	100.0	107.0	115.7	123.6	126.1	131.4	136.7
Trade	83.7	87.1	91.7	93.2	100.0	109.0	118.0	125.7	126.3	133.2	134.9
Community, business and personal service	81.4	85.7	91.6	95.5	100.0	104.8	109.8	115.3	120.0	125.4	129.4
Finance, insurance and real estate	81.7	86.7	92.4	94.6	100.0	105.9	114.3	119.3	126.4	134.0	142.6
Public administration and defence	86.8	89.1	91.6	95.2	100.0	104.3	109.9	114.2	118.6	122.6	124.4

[p] Preliminary.

Table 13. Canada, value of exports of crude minerals and fabricated mineral products, by main groups, 1973-77

	1973	1974	1975	1976	1977^p
			($ million)		
Ferrous					
Crude material	497.7	574.0^r	721.5^r	984.4	1 115.0
Fabricated material	598.7^r	917.7^r	913.1^r	1 004.0	1 242.4
Total	1 096.4^r	1 491.7^r	1 634.6^r	1 988.4	2 357.4
Nonferrous					
Crude material	1 501.8^r	1 801.8^r	1 519.6^r	1 516.9	1 614.8
Fabricated material	1 897.8^r	2 102.7^r	1 843.5^r	2 210.0	2 577.9
Total	3 399.6^r	3 904.5^r	3 363.1^r	3 726.9	4 192.7
Nonmetals					
Crude material	595.5^r	799.0^r	794.9^r	1 101.1	1 275.9
Fabricated material	166.2^r	178.4^r	162.7^r	194.1	253.6
Total	761.7	977.4	957.6^r	1 295.2	1 529.5
Mineral fuels					
Crude material	1 998.4^r	4 232.6^r	4 637.3	4 464.1	4 428.9
Fabricated material	311.6^r	611.3^r	638.5	559.0	649.1
Total	2 310.0^r	4 843.9^r	5 275.8	5 023.1	5 078.0
Total minerals and products					
Crude material	4 593.4^r	7 407.4^r	7 673.3^r	8 066.5	8 434.6
Fabricated material	2 974.3^r	3 810.1^r	3 557.8^r	3 967.1	4 723.0
Total	7 567.7^r	11 217.5^r	11.231.1^r	12 033.6	13 157.6

^{p} Preliminary; ^{r} Revised.

Table 14. Canada, value of imports of crude minerals and fabricated mineral products, by main groups, 1973-77

	1973	1974	1975	1976	1977[p]
			($ millions)		
Ferrous					
Crude material	75.3	94.6	179.5	129.8	106.0
Fabricated material	1 022.1	1 759.8	1 494.7[r]	1 274.0	1 500.4
Total	1 097.4	1 854.4	1 674.2[r]	1 403.8	1 606.4
Nonferrous					
Crude material	255.1	302.7	288.9	294.5	420.3
Fabricated material	474.0	816.2	621.8[r]	600.4	662.8
Total	729.1	1 118.9	910.7[r]	894.9	1 083.1
Nonmetals					
Crude material	89.0	121.0[r]	183.0	157.9	166.9
Fabricated material	243.1	326.1	358.7[r]	413.5	470.7
Total	332.1	447.1	541.7[r]	571.4	637.6
Mineral fuels					
Crude material	1 116.1	2 955.5	3 886.8[r]	3 834.1	3 870.6
Fabricated material	214.5	373.6	275.8	219.7	301.2
Total	1 330.6	3 329.1	4 162.6[r]	4 053.8	4 171.8
Total minerals and products					
Crude material	1 535.5	3 473.8[r]	4 538.2[r]	4 416.3	4 563.8
Fabricated material	1 953.7	3 275.7	2 751.0[r]	2 507.6	2 935.1
Total	3 489.2	6 749.5[r]	7 289.2[r]	6 923.9	7 498.9

[p] Preliminary; [r] Revised.

Table 15. Canada, value of exports of crude minerals and fabricated mineral products in relation to total export trade, 1973-77

	1973		1974		1975		1976		1977[p]	
	$ Million	% of Total	$ Million	% of Total	$ Million	% of Total	$ Million	% of Total	$ Million	% of Total
Crude material	4 593.4[r]	18.5	7 407.4[r]	23.3	7 673.3[r]	23.6[r]	8 066.5	21.5	8 434.6	19.4
Fabricated material	2 974.3[r]	12.0[r]	3 810.1[r]	12.0	3 557.8[r]	10.9[r]	3 967.1	10.5	4 723.0	10.9
Total	7 567.7[r]	30.5[r]	11 217.5[r]	35.3	11 231.1[r]	34.5[r]	12 033.6	32.0	13 157.6	30.3
Total exports, all products	24 837 9	100.0	31 739.6[r]	100.0	32 586.9[r]	100.0	37 575.7	100.0	43 505.8	100.0

[p] Preliminary; [r] Revised.

Table 16. Canada, value of imports of crude minerals and fabricated mineral products in relation to total import trade, 1973-77

	1973		1974		1975		1976		1977[p]	
	$ Million	% of Total	$ Million	% of Total	$ Million	% of Total	$ Million	% of Total	$ Million	% of Total
Crude material	1 535.5	6.6	3 473.8[r]	10.9[r]	4 538.2[r]	13.0[r]	4 416.3	11.8	4 563.8	10.8
Fabricated material	1 953.7	8.4	3 275.7	10.3	2 751.0[r]	7.9	2 507.6	6.7	2 935.1	7.0
Total	3 489.2	15.0	6 749.5[r]	21.2[r]	7 289.2[r]	20.9[r]	6 923.9	18.5	7 498.9	17.8
Total imports, all products	23 325.3	100.0	31 880.3[r]	100.0	34 829.7[r]	100.0	37 444.4	100.0	42 156.0	100.0

[p] Preliminary; [r] Revised.

Table 17. Canada, value of exports of crude minerals and fabricated mineral products, by main groups and destination, 1977[p]

	United Kingdom	United States	Other Countries	Total
	($ million)			
Ferrous materials and products	71.6	1 816.0	469.8	2 357.4
Nonferrous materials and products	594.0	2 072.8	1 525.9	4 192.7
Nonmetallic mineral materials and products	53.6	809.9	666.0	1 529.5
Mineral fuels, materials and products	6.1	4 417.5	654.4	5 078.0
Total	725.3	9 116.2	3 316.1	13 157.6
Percentage of total mineral exports	5.5	69.3	25.2	100.0

[p] Preliminary.

Table 18. Canada, value of imports of crude minerals and fabricated mineral products, by main groups and origin, 1977[p]

	United Kingdom	United States	Other Countries	Total
	($ million)			
Ferrous materials and products	101.2	1 018.9	486.3	1 606.4
Nonferrous materials and products	36.2	634.7	412.2	1 083.1
Nonmetallic mineral materials and products	17.8	450.6	169.2	637.6
Mineral fuels, materials and products	13.3	1 085.4	3 073.1	4 171.8
Total	168.5	3 189.6	4 140.8	7 498.9
Percentage of total mineral imports	2.3	42.5	55.2	100.0

[p] Preliminary.

Table 19. Canada, value of exports of crude minerals and fabricated mineral products, by commodity and destination, 1977[p]

	U.S.A.	United Kingdom	E.F.T.A.[1]	E.E.C.[2]	Japan	Other Countries	Total
				($ 000)			
Aluminum	569 496	13 198	4 052	11 156	49 443	165 036	812 381
Asbestos	159 619	34 857	16 127	121 834	38 483	207 674	578 594
Copper	240 878	120 473	44 087	142 801	215 613	68 880	832 732
Fuels	4 417 556	6 103	5 438	28 184	564 161	56 586	5 078 028
Iron ore	756 310	55 239	1 893	174 629	54 075	21 777	1 063 923
Lead	57 900	25 479	1 346	16 452	31 524	6 078	138 779
Molybdenum	9 781	16 049	—	56 002	41 739	2 023	125 594
Nickel	387 010	279 658	150 475	82 700	23 103	51 434	974 380
Primary ferrous metals	143 257	6 791	365	41 876	3 669	23 550	219 508
Uranium	72 848	2 590	—	—	—	—	75 438
Zinc	189 231	37 524	1 317	126 229	50 100	40 476	444 877
All other minerals	2 112 408	127 299	38 038	122 102	77 864	335 703	2 813 414
Total	9 116 294	725 260	263 138	923 965	1 149 774	979 217	13 157 648

[1] European Free Trade Association; includes Austria, Norway, Portugal, Sweden. Switzerland, Finland and Iceland.
[2] European Economic Community; includes Belgium-Luxembourg, France, Italy, Netherlands, West Germany, Denmark and Ireland, and excludes United Kingdom.
[p] Preliminary; — Nil.

Table 20. Canada, apparent consumption[1] of some minerals and relation to production[2], 1974-77

	Unit of Measure	1974 Apparent Consumption	1974 Production	1974 Consumption as % of Production	1975 Apparent Consumption	1975 Production	1975 Consumption as % of Production
Asbestos	tonnes	. .	1 643 763	. .	. .	1 055 667	. .
Cement	tonnes	9 688 012	10 585 105	91.5	9 626 183[r]	10 193 984[r]	94.4
Gypsum	tonnes	2 069 024	7 225 203	28.6	2 083 113	5 719 451	36 4
Iron ore	tonnes	11 669 824	46 784 500	24.9	13 703 104	44 892 530	30.5
Lime	tonnes	1 593 216	1 958 842	81.3	1 255 267[r]	1 459 202[r]	86.0
Quartz (silica)	tonnes	3 319 463	2 505 670	132.5	3 497 448	2 491 715	140.4
Salt	tonnes	3 975 513[e]	5 446 720	73.0	5 533 450[e]	5 122 573	108.0
Asbestos	tonnes	64 036	1 536 091	4.2	131 894	1 543 000	8.6
Cement	tonnes	9 033 241	9 624 320	93.9	8 593 859	9 605 000	89.5
Gypsum	tonnes	2 258 681	6 002 154	37.6	2 069 744	7 040 000	29.4
Iron ore	tonnes	13 751 609	55 416 346	24.8	9 199 034	51 754 000	17.8
Lime	tonnes	1 577 652	1 850 103	85.3	1 543 935	1 879 000	82.2
Quartz (silica)	tonnes	3 810 533	2 520 476	151.2	3 408 102	2 362 000	144.3
Salt	tonnes	6 093 517	5 994 019	101.7	5 895 997	5 933 000	99.4

[1] Apparent consumption is production, plus imports, less exports. [2] Production refers to producers' shipments.
[r] Revised; [e] Estimated; [p] Preliminary; . . Not available or not applicable.

Table 21. Canada, reported consumption of miner

	Unit of Measure	1974 Consumption	1974 Production	1974 Consumption as % of Production	1975 Consumption	1975 Production	1975 Consumtion as of Production
Metals							
Aluminum	t	359 790	1 006 632	35.7	293 280	878 056[r]	33.
Antimony	kg	983 785	. .	. .	454 164	. .	. .
Bismuth	kg	29 278	111 006	26.4	29 267	156 605	18.
Cadmium	kg	47 876	1 240 970	3.9	38 209	1 191 674	3.
Chromium (chromite)	t	60 471	—	. .	36 790	—	. .
Cobalt	kg	185 442	1 563 568	11.9	123 002	1 354 213	9.
Copper	t	247 984[1]	821 380	30.2	185 198[1]	733 826	25.
Lead	t	99 734[2]	294 268	33.9	89 192[2]	349 133	25.
Magnesium	t	6 216	5 957	104.4	5 404	3 826	141.
Manganese ore	t	210 595	—	. .	160 976	—	. .
Mercury	kg	46 812	482 622	9.7	32 869	413 676	8.
Molybdenum (Mo content)	kg	1 673 146	13 941 775	12.0	1 436 883	13 026 696	11.
Nickel	t	11 567	269 071	4.3	11 308	242 180	4.
Selenium	kg	13 825	273 133	5.1	9 933	182 385	5.
Silver	kg	598 114	1 331 531	44.9	642 089	1 234 642	52.
Tellurium	kg	445	56 388	0.8	614	19 854	3.
Tin	t	5 425	324	1 674.4	4 315	319	1 352.
Tungsten (W content)	kg	534 959	1 613 700	33.2	451 335	1 477 731	30.
Zinc	t	117 619[2]	1 127 008	10.4	98 280[2]	1 055 151	9.
Nonmetals							
Barite	t	58 439	78 019	74.9	40 229	81 356	49.
Feldspar	t	6 847	—	. .	5 630	—	. .
Fluorspar	t	237 009	136 000[e]	174.3	202 126	64 000[e]	315.
Mica	kg	3 124 342	—	. .	3 717 643	. .	. .
Nepheline syenite	t	110 881	559 986	19.8	103 774	468 427	22.
Phosphate rock	t	2 298 384	—	. .	2 095 368	—	. .
Potash (K_2O)	t	202 039[3]	5 776 019	3.5	206 813[3]	4 673 425	4.
Sodium sulphate	t	305 366	638 179	47.9	256 385	472 196	54.
Sulphur	t	906 227	5 033 057	18.0	832 702	4 078 780	20.
Talc	t	41 126	85 952	47.9	40 532	66 029	61.
Fuels							
Coal	t	24 844 710	21 269 588	116.8	26 126 654	25 258 956	103.
Natural gas	000 m^3	37 231 875[4]	86 272 607	43.2	37 526 031[4]	87 519 740[r]	42.
Petroleum, crude	m^3	102 831 813[5]	97 741 735	105.2	98 739 939[5]	82 802 176	119.

Note: Unless otherwise stated, consumption refers to reported consumption of refined metals or nonmetallic minerals by consume Production of metals, in most cases, refers to production in all forms, and includes the recoverable content of ores, concentrates, matte, e and metal content of primary products recoverable at domestic smelters and refineries. Production of nonmetals refers to produce shipments. For fuels, production is equivalent to actual output, less waste.

[1] Producers' domestic shipments of refined metal. [2] Includes primary and secondary refined metal. [3] Consumption of potash fertilizers year ended June 30. [4] Domestic sales. [5] Refinery receipts.

[p] Preliminary; — Nil; . . Not available or not applicable; [e] Estimate; [r] Revised.

and relation to production, 1974-77

1976			1977[p]		
Consumption	Production	Consumption as % of Production	Consumption	Production	Consumption as % of Production
322 206	633 430	50.9	332 393	983 266	33.8
437 998	. .	. .	370 867	. .	. .
21 105	129 576	16.3	25 015	140 000	17.9
53 815	1 313 723	4.2	50 369	1 199 000	4.2
30 783	—	. .	30 299	—	. .
160 492	1 356 337	11.8	146 763	1 508 000	9.7
206 205[1]	730 930	28.2	200 372[1]	780 633	25.7
107 654[2]	256 323	42.0	110 763	284 119	39.0
4 230	6 092	69.4	6 222	7 580	82.1
238 629	—	. .	182 157	—	. .
26 039	—	. .	30 447	—	. .
1 260 329	14 618 607	8.6	927 847	16 431 000	5.7
9 972	240 825	4.1	9 033	235 000	3.8
11 212	109 649	10.2	12 476	207 000	6.0
551 212	1 281 436	43.0	298 724	1 330 000	22.5
589	48 698	1.2	291	36 000	0.8
4 849	275	1 763.3	5 286	317	1 667.5
337 345	2 168 153	15.6	449 365	. .	. .
98 897[2]	982 057	10.1	105 412[2]	1 055 000	10.0
58 066	100 266	57.9	. .	116 950	. .
4 053	—	. .	. .	—	. .
128 352	73 000[e]	175.8	. .	73 000[e]	. .
5 023 989	. .	. .	. .	—	. .
103 241	540 121	19.1	. .	580 000	. .
1 582 861	—	. .	. .	—	. .
242 077[3]	5 215 435	4.6	234 232	5 910 000	4.0
265 608	460 193	57.7	. .	416 000	. .
653 723	4 029 427	16.2	. .	4 910 000	. .
43 595	68 834	63.3	. .	73 000	. .
28 219 804	25 476 044	110.8	30 895 999	28 394 000	108.8
38 834 918[4]	87 683 816	44.3	40 547 054	91 147 120	44.5
98 326 624[5]	76 075 000	129.3	104 238 897[5]	76 447 000	136.4

Table 22. Canada, domestic consumption of principal refined metals in relation to refinery production[1], 1968-77

	Unit of Measure	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977[p]
Copper											
Domestic production[2]	t	226 891	205 279	215 834	200 536	207 661	230 981	247 984	185 198	206 205	200 372
Production	t	475 795	407 536	493 261	477 545	495 944	497 581	559 124	529 199	510 468	508 767
Consumption of production	%	47.7	50.4	43.8	42.0	41.9	46.4	44.4	35.0	40.4	39.4
Zinc											
Domestic consumption[3]	t	107 575	110 150	98 306	109 380	125 019	116 386[r]	117 619	98 280	98 897	105 412
Production	t	387 121	423 072	413 196	372 529	476 423	532 556	437 725	426 902	472 316	494 888
Consumption of production	%	27.8	26.0	23.8	29.4	26.2	21.9	26.9	23.0	20.9	21.3
Lead											
Domestic production[3]	t	85 874	96 084	84 765	85 835	78 559	108 349	99 734	89 192	107 654	110 763
Production	t	183 342	169 773	185 637	168 332	186 860	186 891	126 460	171 516	175 720	187 457
Consumption of production	%	46.8	56.6	45.7	51.0	42.0	58.0	78.99	52.0	61.3	59.1
Aluminum											
Domestic consumption[4]	t	219 893	244 057	250 150	292 188	302 591	331 782	359 790	293 280	322 206	332 393
Production	t	888 290	978 596	962 541	1 002 116	907 130	930 210	1 006 632	878 056[r]	633 430	983 266
Consumption of production	%	24.8	24.9	26.0	29.2	33.4	35.7	35.7	33.4[r]	50.9	33.8

[1] Production of refined metal from all sources, including metal derived from secondary materials at primary refineries. [2] Producers' domestic shipments of refined metal. [3] Consumption of primary and secondary refined metal, reported by consumers. [4] Consumption of primary refined metal, reported by consumers.
[p] Preliminary; .. Not available; [r] Revised.

Table 23. Average annual prices[1] of main metals, 1973-77

	Unit of Measure	1973	1974	1975	1976	1977
Aluminum, major U.S. producer	cents/lb	25.000	34.133	39.786	44.341	51.339
Antimony, RMM/Laredo	cents/lb	66.498	179.764	174.575	163.194	175.000
Bismuth, major producer	$/lb	4.92	8.41	7.715	7.500	6.010
Cadmium, U.S. producer	cents/lb	364.000	407.800	335.500	266.200	296.200
Calcium, metal crowns	$/lb	0.950	1.071	1.315	1.335	1.482
Chrome, U.S. metal, 9% carbon	$/lb	1.52	1.90	2.57	2.64	2.90
Cobalt metal, shot/cathode/ 250 kg	$/lb	3.007	3.474	3.979	4.508	5.633
Columbite, spot ore	$/lb	. .	. .	1.800-1.900	2.500-2.800	2.637-3.500
Copper, U.S. producer refinery	cents/lb	58.852	76.649	63.535	68.824	65.808
Gold, Royal Canadian Mint buying price	$Cdn./troy oz	38.86	41.18	43.22	39.85	43.49
London free market[2]	$Cdn./troy oz	97.25	155.67	163.74	123.15	157.31
Iridium, major producer	$/troy oz	227.08-235.42	401.67-409.17	475.00-485.00	316.666-326.666	300.00-310.00
Iron ore						
Non-Bessemer						
Mesabi	$/lt	11.86	14.00	17.890	18.500-19.670	21.103-21.180
Old Range	$/lt	12.13	14.26	18.140	18.750-19.920	21.353-21.430
Lead, U.S. producer	cents/lb	16.285	22.533	21.529	23.102	30.703
Manganese, U.S. metal, regular	cents/lb	33.250	41.771	54.000	55.333-57.000	58.000
Magnesium, U.S. primary ingot	cents/lb	38.250	60.548	82.000	89.537	97.487
Mercury, New York	$/flask (76 lb)	285.23	281.69	158.115	121.302	135.710
Molybdenum, climax concentrate	$/lb	1.720	2.057	2.493	2.999	3.730

Table 23. (concl'd)

	Unit of Measure	1973	1974	1975	1976	1977
Nickel, major producer cathode	cents/lb	153.000	173.500	207.300	225.600	236.000
Osmium, major producer	$/troy oz	200.00-225.00	200.00-225.00	200.00-225.00	200.00-225.00	170.00-184.00
Palladium, major producer	$/troy oz	77.68	133.22	92.702	50.928	59.702
Platinum, major producer	$/troy oz	150.04	180.85	164.005	161.729	162.544
Rhenium U.S. producer powder	$/lb	887.50-1,050.00	737.50	570.52	540.00	468.54
Rhodium, major producer	$/troy oz	225.83-230.83	335.58-342.92	337.50-347.50	350.00-364.166	441.666-453.750
Ruthenium, major producer	$/troy oz	59.17-64.17	60.00-65.00	60.00-65.00	60.00-65.00	60.00-65.00
Selenium, major producer commercial	$/lb	9.17-10.33	16.33	18.00	18.00	17.00
Silver, Handy & Harman, N.Y.	cents/troy oz	255.756	470.798	441.852	435.346	462.302
Tantalum, U.S. rod	$/lb	30.00-40.00	41.25-56.17	46.75-60.50	52.00-80.00	52.00-80.00
Tellurium, major producer slab	$/lb	6.08	8.33	9.333	10.500-11.083	17.416-17.666
Tin, N.Y. market	cents/lb	227.558	396.266	320.345	349.241	499.381
Titanium, U.S. sponge	$/lb	1.42-1.43	1.85	2.554	2.700	2.671-2.784
Titanium, rutile ore	$/st	206.667	469.167	710.000	526.666	485.000
Tungsten, U.S. hydrogen red metal	$/lb	4.97-6.74	8.06-9.75	10.210-12.010	10.087-12.337	14.065-15.050
Vanadium, pentoxide metal	$/lb	..	..	2.980-3.060	2.600-3.229	2.750-3.350
Zinc, U.S. prime western	cents/lb	20.658	35.945	38.959	37.010	34.392

[1]These prices, except for gold, are in United States currency and are quoted from *Metals Week*. [2]Average of a.m. and p.m. fixings of the London Gold Market, converted to Canadian dollars.
.. Not available.

Table 24. Canada, wholesale price indexes of minerals and mineral products, 1974-77 (1935-39 = 100)

	1974	1975	1976	1977[p]
Iron and products	447.7	519.9	563.4	596.2
Pig iron	475.5	748.8	814.0	796.2
Rolling mill products	431.1	507.2	540.7	567.4
Iron foundries and pipe and tubing	452.4	557.1	604.4	657.0
Wire	507.1	620.6	667.7	692.6
Scrap iron and steel	740.6	529.7	532.4	466.0
Tinplate and galvanized steel	357.4	420.2	. .	. .
Nonferrous metal and products				
Total (including gold)	417.7	417.4	441.3	497.9
Total (excluding gold)	607.3	606.2	647.1	732.7
Copper and products	706.7	541.4	521.8	495.6
Lead and products	500.1	420.5	379.3	472.5
Silver	1 180.8	1 176.7	1 061.2	1 056.4
Tin	764.4	704.4	. .	. .
Zinc and products	785.4	842.0	763.8	654.3
Nonmetallic minerals and products	331.2	392.1	432.4	474.9
Clay and clay products	384.2	422.0	476.6	530.7
Pottery	476.0	493.4	533.7	564.5
Petroleum products	342.0	394.3	452.4	515.4
Asphalt	432.5	516.2	589.4	671.1
Asphalt shingles	189.6	216.9	. .	. .
Plaster	247.6	276.3	301.2	337.5
Lime	497.0	625.2	686.4	761.1
Cement	271.6	322.8	377.5	405.5
Sand and gravel	273.1	327.3	349.6	377.0
Crushed stone	236.5	271.2	314.7	353.8
Building stone	336.1	364.8	415.2	490.5
Asbestos	550.8	679.4	790.0	853.2
General wholesale price index				
(all products)	461.3	491.6	512.4	559.5

[p] Preliminary; . . Not available.

Table 25. Canada, general wholesale price index and wholesale price indexes of mineral and nonmineral products, 1953-77 (1935-39 = 100)

	Mineral products			Nonmineral products					
	Iron Products	Nonferrous Metal Products	Nonmetallic Mineral Products	Vegetable Products	Animal Products	Textile Products	Wood Products	Chemical Products	General Wholesale Price Index
1953	221.4	168.6	176.9	199.0	241.7	239.0	288.6	175.7	220.7
1954	213.4	167.5	177.0	196.8	236.0	231.1	286.8	176.4	217.0
1955	221.4	187.6	175.2	195.1	226.0	226.2	295.7	177.0	218.9
1956	239.8	199.2	180.8	197.3	227.7	230.2	303.7	180.1	225.6
1957	252.7	176.0	189.3	197.0	238.4	236.0	299.4	182.3	227.4
1958	252.6	167.3	188.5	198.1	250.7	229.0	298.5	183.0	227.8
1959	255.7	174.6	186.5	199.5	254.3	228.0	304.0	187.0	230.6
1960	256.2	177.8	185.6	203.0	247.6	229.8	303.8	188.2	230.9
1961	258.1	181.6	185.2	203.1	254.7	234.5	305.1	188.7	233.3
1962	256.2	192.1	189.1	211.6	262.5	241.2	315.9	190.5	240.0
1963	253.6	197.5	189.5	227.8	255.6	248.0	323.4	189.3	244.6
1964	256.4	205.9	190.9	223.3	250.8	248.4	330.9	191.2	245.4
1965	264.5	217.6	191.6	218.4	270.7	246.4	334.0	200.2	250.3
1966	268.0	229.9	193.7	225.9	296.2	251.5	337.8	207.1	259.5
1967	274.4	240.2	199.2	230.9	293.1	252.7	346.3	212.6	264.1
1968	276.8	250.8	206.0	230.8	294.6	256.5	367.9	213.7	269.9
1969	285.8	264.0	210.0	237.9	322.4	256.7	389.4	219.7	282.4
1970	305.1	281.0	215.7	238.4	326.0	257.0	377.5	225.7	286.4
1971	316.4	260.1	225.8	237.1	326.0	261.9	394.4	237.8	289.9
1972	325.0	262.9	233.6	249.2	371.8	278.3	436.0	245.5	310.3
1973	354.3[r]	326.5	254.1	354.9[r]	455.3	337.7[r]	504.1[r]	263.3	376.9
1974	447.7	417.7	331.2	485.6	493.0	423.1	563.1	325.3	461.3
1975	519.9	417.4	392.1	469.6	537.5	404.9	639.3[r]	383.9	491.6
1976	563.4	441.3	432.4	449.9	551.9	442.5	687.9	389.0	512.4
1977[p]	596.2	497.9	474.9	493.8	578.4	471.9	790.6	408.3	559.5

[p] Preliminary; [r] Revised.

Table 26. Canada, mineral products industries, selling price indexes, 1974-77 (1971 = 100)

	1974	1975	1976	1977^p
Iron and steel products industries				
Agricultural implements industry	128.1	155.2^r	165.7	177.6
Hardware, tool and cutlery manufacturers	122.2	137.9	147.3	162.6
Heating equipment manufacturers	121.9	137.3	146.9	156.5
Primary metal industries	147.7	160.8^r	169.9	190.5
Iron and steel mills	136.3	162.0^r	177.2	187.9
Steel pipe and tube mills	132.0	162.9	179.1	197.8
Iron foundries	141.6	168.4	181.0	189.6
Wire and wire products manufacturers	136.6	158.3	171.0	175.4
Nonferrous metal products industries				
Aluminum rolling, casting and extruding	129.1	145.4	155.8	173.6
Copper and alloy, rolling, casting and extruding	154.8	131.6	138.4	144.5
Jewellery and silverware manufacturers	216.3	234.1	235.2	277.7
Metal rolling, casting and extruding, nes	184.2	171.8	181.0	216.3
Nonmetallic mineral products industries				
Abrasives manufacturers	114.6	140.5	167.5	194.7
Cement manufacturers	122.2	146.3	171.1	186.7
Clay products manufacturers from imported clay	127.3	151.0	161.7	164.7
Glass and glass products manufacturers	114.5	127.1	138.6	150.4
Lime manufacturers	143.5	181.7	204.3	228.7
Concrete products manufacturers	129.7	152.0	161.5	173.7
Clay products from domestic clay	129.1	157.1	169.6	182.8
Petroleum and coal products industries	159.4	183.7	210.1	253.3
Petroleum refineries	160.1	184.5	211.5	237.2
Lubricating oils	132.7	150.1	155.8	166.6
Mixed fertilizers	167.5^r	204.0	176.9	180.2

Note: Industry selling price indexes reflect wholesale price trends of products or groups of products sold by the industries listed.
^{p} Preliminary; nes Not elsewhere specified; ^{r} Revised.

Table 27. Canada, principal statistics of the mining industry[1], 1975

	Mining Activity								Total activity[2]		
		Production and Related Workers			Costs						
	Establishments	Employees	Man-hours Paid	Wages	Fuel and Electricity	Materials and Supplies	Value of Production	Value Added	Employees	Salaries and Wages	Value Added
	(number)	(number)	(000)	($000)	($000)	($000)	($000)	($000	(number)	($000)	($000)
Metals											
Gold quartz	23	4 841	9 993	57 883	7 147	43 485	200 118	149 486	5 798	72 094	149 869
Copper-gold-silver	41	11 980	25 341	164 794	44 924	547 027	1 187 050	595 099	16 309	235 060	595 410
Silver-lead-zinc	24	5 339	10 987	71 656	17 978	333 208	679 477	328 291	7 362	104 249	320 776
Nickel-copper	10	15 052	29 262	190 064	23 218	476 781	1 224 253	724 254	19 229	267 035	729 656
Iron	18	9 990	20 504	159 107	88 291	331 610	991 984	572 083	16 155	268 254	556 710
Misc. metal mines	11	3 117	6 312	42 059	11 313	62 380	269 756	196 063	4 308	59 743	211 517
Total	127	50 319	102 399	685 563	192 871	1 794 491	4 552 638	2 565 276	69 161	1 006 435	2 563 938
Nonmetals											
Asbestos	12	4 442	10 310	62 483	20 985	66 447	315 399	227 967	6 042	87 186	230 612
Feldspar, quartz and nepheline syenite	10	345	728	3 787	1 387	3 874	20 050	14 789	431	5 077	14 707
Gypsum	10	477	984	4 380	1 524	4 066	20 500	14 911	576	5 590	14 861
Peat	46	1 098	2 143	7 680	1 179	6 478	27 279	19 622	1 303	10 042	20 556
Potash	9	2 575	5 448	34 039	16 275	42 496	356 324	297 552	3 351	46 948	298 471
Salt	9	722	1 518	8 978	3 238	9 021	57 598	45 339	1 210	15 653	45 888
Sand and gravel	159	2 131	4 737	25 159	8 309	27 005	132 773	97 460	2 838	35 620	102 305
Stone	118	2 952	6 698	35 772	9 503	54 979	174 011	109 530	3 544	43 631	111 031
Talc and soapstone[3]	..	..	..	..	..	..	..	..	..	..	..
Misc. nonmetals	17	655	1 292	6 676	4 211	5 253	35 257	25 793	790	8 417	25 710
Total	390	15 397	33 858	188 954	66 611	219 619	1 139 191	852 863	20 085	258 164	864 141
Fuels											
Coal	21	6 696	13 400	88 115	17 304	89 821	573 452	466 327	8 416	109 795	483 493
Petroleum and natural gas	807	4 679	9 772	67 376	42 711	110 260	5 974 735	5 821 764	18 053	280 884	5 838 459
Total	828	11 375	23 172	155 491	60 015	200 081	6 548 187	6 288 091	26 469	390 679	6 321 952
Total mining industry	1 345	77 091	159 431	1 030 009	319 496	2 214 191	12 240 016	9 706 329	115 715	1 655 278	9 750 032

[1] Cement manufacturing, lime manufacturers, clay and clay products (domestic clays) are included in the mineral manufacturing industries. Industry coverage is the same as in Tables 29, 31 and 33. [2] Total activity includes sales and head offices. [3] Included in miscellaneous nonmetal mines.
.. Not available.

Table 28. Canada, principal statistics of the mineral manufacturing industries[1], 1975

	Mineral manufacturing activity								Total activity[2]		
		Production and related workers			Costs						
	Establishments	Employees	Man-hours Paid	Wages	Fuel and Electricity	Materials and Supplies	Value of Production	Value Added	Employees	Salaries and Wages	Value Added
	(number)	(number)	(000)	($000)	($000)	($000)	($000)	($000)	(number)	($000)	($000)
Primary metal industries											
Iron and steel mills	46	42 169	86 419	554 499	139 982	1 797 394	3 147 693	1 348 021	54 003	761 004	1 364 022
Steel pipe and tube mills	25	4 898	10 575	65 488	7 595	411 158	561 454	167 210	5 785	79 326	170 265
Iron foundries	107	9 776	20 128	101 641	12 039	181 699	430 166	232 752	11 480	126 301	238 117
Smelting and refining	28	22 932	45 613	287 743	141 134	564 944	1 550 616	844 537	35 577	491 840	886 405
Aluminum rolling, casting and extruding	61	4 196	8 748	46 962	7 744	300 311	440 501	132 801	5 672	69 309	132 636
Copper and alloy rolling, casting and extruding	40	2 639	5 488	30 016	4 201	242 722	319 641	68 761	3 240	38 733	68 282
Metal rolling, casting and extruding, nes	73	3 559	7 354	32 809	4 900	142 929	232 286	85 822	4 573	46 410	88 446
Total	380	90 169	184 325	1 119 158	317 595	3 641 157	6 682 357	2 879 904	120 330	1 612 923	2 948 173
Nonmetallic mineral products industries											
Cement manufacturers	27	2 990	6 267	42 308	73 134	61 870	339 194	209 913	4 577	70 193	210 342
Lime manufacturers	16	602	1 252	6 364	12 183	7 231	44 297	24 866	790	9 081	24 913
Concrete products manufacturers	423	8 916	18 838	96 743	11 048	177 924	459 206	274 548	11 201	128 341	282 131
Ready-mix concrete manufacturers	356	7 703	16 531	96 656	16 353	309 132	596 027	271 824	9 541	122 860	282 597
Clay products manufacturers (domestic)	60	2 438	5 145	23 688	9 653	17 779	84 761	59 517	2 945	30 688	59 732
Clay products manufacturers (imported)	30	1 691	3 575	16 016	1 755	18 198	59 080	41 367	2 097	20 657	41 698
Refractories manufacturers	17	800	1 740	10 212	3 173	33 479	69 860	35 318	1 260	16 712	45 823
Stone products manufacturers	82	799	1 661	6 537	581	9 566	23 768	13 806	946	8 385	13 975
Glass and glass products manufacturers	89	9 193	19 226	95 597	21 512	140 579	420 530	260 471	11 779	132 598	259 966
Abrasive manufacturers	19	1 788	3 743	18 997	9 966	50 845	101 908	42 217	2 318	26 482	43 863

Table 28. (concl'd)

	Mineral manufacturing activity								Total activity[2]		
		Production and related workers			Costs						
	Establishments	Employees	Man-hours Paid	Wages	Fuel and Electricity	Materials and Supplies	Value of Production	Value Added	Employees	Salaries and Wages	Value Added
	(number)	(number)	(000)	($000)	($000)	($000)	($000)	($000)	(number)	($000)	($000)
Other nonmetallic mineral products industries	80	5 229	11 006	58 348	14 911	148 085	370 753	212 290	8 478	103 353	237 369
Total	1 199	42 149	88 984	471 466	174 269	974 688	2 569 384	1 446 137	55 932	669 350	1 502 409
Petroleum and coal products industries											
Petroleum refining industry	42	6 806	14 680	110 355	46 320	4 998 611	5 773 460	789 784	15 624	277 268	789 680
Manufacture of lubricating oils and greases	14	359	764	3 796	724	64 327	93 411	28 758	656	8 170	32 633
Other petroleum and coal products industries	45	712	1 511	8 117	2 742	45 739	86 458	39 125	984	12 602	43 639
Total	101	7 877	16 955	122 268	49 786	5 108 677	5 953 329	857 667	17 264	298 040	865 952
Total mineral manufacturing industries	1 680	140 195	290 264	1 712 892	541 650	9 724 522	15 205 070	5 183 708	193 526	2 580 313	5 316 534

[1] Industry coverage is the same as in Tables 30, 32 and 34. [2] Includes sales and head offices.
nes Not elsewhere specified.

Table 29. Canada, principal statistics of the mining industry[1], 1970-75

	Mining activity								Total activity[2]		
		Production and related workers			Costs						
	Esta-blish-ments	Employees	Man-hours Paid	Wages	Fuel and Electricity	Materials and Supplies	Value of Production	Value Added	Employees	Salaries and Wages	Value Added
	(number)	(number)	(000)	($000)	($000)	($000)	($000)	($000)	(number)	($000)	($000)
1970	1 636	77 208	164 835	614 084	146 049	1 167 456	5 118 396	3 804 891	110 094	994 014	3 830 364
1971	1 662	76 701	158 835	646 900	164 332	1 223 982	5 198 173	3 809 859	110 410	1 015 661	3 826 264
1972	1 716	73 044	150 929	666 505	175 562	1 210 445	5 652 775	4 266 767	107 322	1 068 783	4 292 465
1973	1 626	75 165	156 960	751 878	215 096	1 551 560	8 030 314	6 263 659	111 443	1 214 871	6 283 935
1974	1 438	79 928	165 999	894 538	285 767	2 004 476	11 187 764	8 897 522	118 730	1 450 330	8 929 981
1975	1 345	77 091	159 431	1 030 009	319 496	2 214 191	12 240 016	9 706 329	115 715	1 665 278	9 750 032

[1] Cement manufacturing, lime manufacturers, clay and clay products (domestic clays) are included in the mineral manufacturing industries. Industry coverage is the same as in Tables 27, 31 and 33. [2] Includes sales and head offices.

Table 30. Canada, principal statistics of the mineral manufacturing industries[1], 1970-75

	Mineral manufacturing activity								Total activity[2]		
		Production and related workers			Costs						
	Establishments	Employees	Man-hours Paid	Wages	Fuel and Electricity	Materials and Supplies	Value of Production	Value Added	Employees	Salaries and Wages	Value Added
	(number)	(number)	(000)	($000)	($000)	($000)	($000)	($000)	(number)	($000)	($000)
1970	1 781	131 570	278 547	989 725	263 827	3 954 629	7 002 306	2 849 055	181 620	1 480 524	2 920 381
1971	1 813	131 044	276 629	1 063 861	288 016	4 192 544	7 551 956	3 097 001	181 122	1 595 437	3 166 347
1972	1 783	132 067	282 307	1 172 977	304 705	4 667 819	8 299 939	3 353 101	182 454	1 753 069	3 436 258
1973	1 749	138 177	295 213	1 347 918	349 521	5 735 529	9 914 174	3 934 216	188 498	1 970 456	4 039 415
1974	1 708	145 209	309 481	1 582 014	463 395	8 809 583	14 003 237	5 110 117	197 220	2 315 107	5 236 626
1975	1 680	140 195	290 264	1 712 892	541 650	9 724 522	15 205 070	5 183 708	193 526	2 580 313	5 316 534

[1] Industry coverage is the same as in Tables 28, 33 and 34. [2] Includes sales and head offices.

Table 31. Canada, consumption of fuel and electricity in the mining industry[1], 1975

	Unit	Metals	Nonmetals	Fuels	Total
Coal and coke	000 t	174	23	—	197
	$000	4 074	258	—	4 332
Gasoline	000 litres	26 922	41 236	10 939	79 097
	$000	3 948	5 478	1 339	10 766
Fuel oil, kerosene, coal oil	000 litres	1 197 401	341 380	69 091	1 607 872
	$000	85 117	29 068	6 848	121 033
Liquefied petroleum gas	000 litres	71 514	4 789	4 522	80 825
	$000	5 180	467	227	5 874
Natural gas	000 m^3	299 701	630 809	109 778	1 040 288
	$000	9 477	11 289	2 937	23 703
Other fuels[2]	$000	13	—	—	13
Total fuels	$000	107 809	46 560	11 351	165 721
Electricity purchased	million kwh	10 259	1 763	2 539	14 560
	$000	85 063	20 049	48 663	153 775
Total value of fuels and electricity purchased, all reporting companies	$000	192 871	66 610	60 015	319 496

[1]Cement and lime manufacturing and manufacturers of clay products (domestic clays) are included under mineral manufacturing, Tables 32 and 34. Industry coverage is the same as in Tables 27, 29 and 33; [2]Includes wood, manufactured gas, steam purchased and other miscellaneous fuels.
— Nil.
Note: Totals may not add due to rounding.

Table 32. Canada, consumption of fuel and electricity in the mineral manufacturing industries[1], 1975

	Unit	Primary Metals Industries	Nonmetallic Mineral Products Industries	Petroleum and Coal Products Industries	Total
Coal and coke	000 t	371	281	2	654
	$ 000	26 150	9 255	7	35 412
Gasoline	000 litres	19 230	60 163	2 569	81 962
	$ 000	2 374	7 957	371	10 702
Fuel oil, kerosene, coal oil	000 litres	1 191 489	977 073	24 463	2 193 025
	$ 000	69 993	58 846	1 795	130 634
Liquefied petroleum gas	000 litres	76 870	11 533	105	88 508
	$ 000	5 282	1 005	9	6 296
Natural gas	000 m^3	2 468 293	1 752 247	848 939	5 069 479
	$ 000	77 724	55 012	18 121	150 857
Other fuels	$ 000	6 323	941	1 455	8 719
Total fuels	$ 000	187 846	133 016	21 758	342 620
Electricity purchased	million kwh	16 544	3 723	2 904	23 171
	$ 000	129 750	41 258	28 028	199 036
Total value of fuels and electricity purchased, all reporting companies	$ 000	317 596	174 274	49 786	541 656

[1]Industry coverage is the same as in Tables 28, 30 and 34.

Table 33. Canada, cost of fuel and electricity used in the mining industry[1], 1968-75

	Unit	1968	1969	1970	1971	1972[r]	1973	1974	1975
Metals									
Fuel	$000	29 340	27 070	33 370	39 887	40 505	54 430	90 596	107 808
Electricity purchased	million kwh	7 020	7 073	7 995	8 692	8 807	10 032	10 282	10 259
	$000	42 340	46 002	52 257	56 847	58 103	68 089	77 669	85 063
Total cost of fuel and electricity	$000	71 680	73 072	85 627	96 734	98 608	122 519	168 265	192 871
Electricity generated for own use and for sale	million kwh	466	476	459	359	446	..	..	..
Nonmetals[2]									
Fuel	$000	18 448	19 793	20 029	22 951	25 277	29 101	42 209	46 561
Electricity purchased	million kwh	1 291	1 473	1 468	1 584	1 642	1 782	2 015	1 763
	$000	10 809	12 728	13 980	14 474	15 080	16 593	20 065	20 049
Total cost of fuel and electricity	$000	29 257	32 521	34 009	37 425	40 357	45 694	62 274	66 610
Electricity generated for own use and for sale	million kwh	156	173	161	178	194	..	..	..
Fuels									
Fuels	$000	678	739	2 072	2 635	4 103	4 600	5 755	11 352
Electricity purchased	million kwh	1 101	1 265	1 540	1 763	2 154	2 792	2 972	2 539
	$000	17 662	20 244	23 320	27 528	32 494	42 283	49 473	48 663
Total cost of fuel and electricity	$000	18 340	20 983	25 392	30 163	36 597	46 883	55 228	60 015
Electricity generated for own use and for sale	million kwh	—	—	—	—	—	—	—	—
Total mining industry									
Fuel	$000	48 466	47 602	55 470	65 473	69 885	88 131	138 560	165 721
Electricity purchased	million kwh	9 412	9 811	11 003	12 039	12 603	14 606	15 267	14 560
	$000	70 811	78 974	90 558	98 849	105 677	126 965	147 207	153 775
Total cost of fuel and electricity	$000	119 277	126 576	146 028	164 322	175 562	215 096	285 767	319 496
Electricity generated for own use and for sale	million kwh	622	649	620	537	640	..	..	..

[1]Excludes cement and lime manufacturing and manufacture of clay products (domestic clays). These industries are included in mineral manufacturing, Tables 32 and 34. Industry coverage is same as in Tables 27, 29 and 31. [2]Includes structural materials.

.. Not available; — Nil.

Table 34. Canada, cost of fuel and electricity used in the mineral manufacturing industries[1], 1968-75

	Unit	1968	1969	1970	1971	1972	1973	1974	1975
Primary metals									
Fuel	$000	73 938	69 185	83 034	92 903	90 850	103 321	153 468	187 846
Electricity purchased	million kwh	14 363	15 370	14 539	15 028	15 678	16 584	17 727	16 544
	$000	68 834	73 114	87 656	90 512	95 447	108 575	122 567	129 750
Cost of fuel and electricity for small establishments[2]	$000	171	202	—	—	—	—	—	—
Total cost of fuel and electricity	$000	142 943	142 501	170 690	183 415	186 297	211 896	276 035	317 596
Nonmetallic mineral products									
Fuel	$000	45 237	47 310	49 451	57 249	65 166	75 144	112 531	133 016
Electricity purchased	million kwh	3 118	3 182	3 270	3 279	2 280	4 080	4 106	3 723
	$000	21 566	23 297	24 507	25 932	29 367	34 624	38 671	41 258
Cost of fuel and electricity for small establishments[2]	$000	1 165	1 231	—	—	—	—	—	—
Total cost of fuel and electricity	$000	67 968	71 838	73 958	83 181	94 533	109 768	151 202	174 274
Petroleum and coal products									
Fuel	$000	5 294	5 450	4 749	5 346	6 431	7 796	13 275	21 758
Electricity purchased	million kwh	1 818	1 980	2 171	2 326	2 475	2 683	2 715	2 904
	$000	11 467	13 059	14 430	16 074	17 444	20 061	22 885	28 028
Cost of fuel and electricity for small establishments[2]	$000	7	13	—	—	—	—	—	—
Total cost of fuel and electricity	$000	16 768	18 522	19 179	21 420	23 875	27 857	36 160	49 786
Total mineral manufacturing industries									
Fuel	$000	124 469	121 945	137 234	155 498	162 447	186 261	279 274	342 620
Electricity purchased	million kwh	19 299	20 532	19 980	20 633	20 433	23 347	24 548	23 171
	$000	101 867	109 470	126 593	132 518	142 258	163 260	184 123	199 036
Cost of fuel and electricity for small establishments[2]	$000	1 343	1 446	—	—	—	—	—	—
Total cost of fuel and electricity	$000	227 679	232 861	263 827	288 016	304 705	349 521	463 397	541 656

[1] Industry coverage is the same as in Tables 28, 30 and 33. [2] Total cost of fuel and electricity purchased by small establishments without detail.
— Nil.

Table 35. Canada, employment, salaries and wages in the mining industry[1], 1968-75

	Unit	1968	1969	1970	1971	1972	1973	1974	1975
Metals									
Production and related workers	Number	49 238	46 023	51 102	50 121	46 257	47 984	50 886	50 319
Salaries and wages	$000	350 321	341 495	421 893	434 222	430 919	494 631	580 185	685 562
Annual average salary and wage	$	7 115	7 420	8 256	8 664	9 316	10 308	11 402	13 624
Administrative and office workers	Number	14 131	14 527	15 488	15 891	15 737	18 150	19 152	18 842
Salaries and wages	$000	124 451	137 756	158 653	178 640	189 669	238 454	282 348	320 873
Annual average salary and wage	$	8 807	9 483	10 244	11 242	12 052	13 138	14 732	17 030
Total metals									
Employees	Number	63 369	60 550	66 590	66 012	61 994	66 134	70 038	69 161
Salaries and wages	$000	474 772	479 251	580 546	612 862	620 588	733 085	862 533	1 006 435
Annual average salary and wage	$	7 492	7 915	8 718	9 284	10 011	11 085	12 315	14 552
Nonmetals									
Production and related workers	Number	15 458	15 933	16 245	16 155	15 911	16 344	17 767	15 397
Salaries and wages	$000	94 850	107 622	114 345	122 355	131 372	147 027	180 962	188 956
Annual average salary and wage	$	6 136	6 755	7 039	7 574	8 257	9 002	10 185	12 272
Administrative and office workers	Number	4 051	4 081	4 415	4 278	4 109	4 335	4 628	4 688
Salaries and wages	$000	32 836	34 980	39 533	40 222	43 030	47 092	57 243	69 208
Annual average salary and wage	$	8 106	8 571	8 954	9 402	10 472	10 863	12 369	14 763
Total nonmetals									
Employees	Number	19 509	20 014	20 660	20 433	20 020	20 679	22 395	20 085
Salaries and wages	$000	127 686	142 602	153 878	162 577	174 402	194 119	238 205	258 164
Annual average salary and wage	$	6 545	7 125	7 448	7 957	8 711	9 393	10 637	12 854
Fuels									
Production and related workers	Number	10 370	9 412	9 861	10 425	10 876	10 849	11 275	11 375
Salaries and wages	$000	64 832	64 591	77 846	90 324	104 214	110 220	133 392	155 491
Annual average salary and wage	$	6 252	6 863	7 894	8 664	9 582	10 160	11 831	13 670
Administrative and office workers	Number	11 668	12 112	12 983	13 540	14 432	13 793	15 022	15 094
Salaries and wages	$000	105 163	118 395	131 744	149 898	169 579	177 447	216 200	235 188
Annual average salary and wage	$	9 013	9 775	10 147	11 071	11 750	12 865	14 392	15 582
Total fuels									
Employees	Number	22 038	21 524	22 844	23 965	25 308	24 642	26 297	26 469
Salaries and wages	$000	169 995	182 986	209 590	240 222	273 793	287 667	349 592	390 679
Annual average salary and wage	$	7 714	8 502	9 175	10 024	10 818	11 674	13 294	14 760

Table 35. (concl'd)

	Unit	1968	1969	1970	1971	1972	1973	1974	1975
Total mining									
Production and related workers	Number	75 066	71 368	77 208	76 701	73 044	75 177	79 928	77 091
Salaries and wages	$000	510 003	513 708	614 084	646 901	666 505	751 878	894 538	1 030 009
Annual average salary and wage	$	6 794	7 198	7 954	8 434	9 125	10 003	11 192	13 361
Administrative and office workers	Number	29 850	30 720	32 886	33 709	34 278	36 278	38 802	38 624
Salaries and wages	$000	262 450	291 131	329 930	368 760	402 278	462 993	555 792	625 269
Annual average salary and wage	$	8 792	9 477	10 033	10 940	11 736	12 762	14 324	16 189
Total mining									
Employees	Number	104 916	102 088	110 094	110 410	107 322	111 455	118 730	115 715
Salaries and wages	$000	772 453	804 839	944 014	1 015 661	1 068 783	1 214 871	1 450 330	1 655 278
Annual average salary and wage	$	7 363	7 884	8 575	9 199	9 959	10 901	12 215	14 305

[1] According to the revised Standard Industrial Classification, 1970. Does not include cement and lime manufacturing and clay products (domestic clays) manufacturing. These industries are included in Table 36 under "Nonmetallic mineral products industries". See Table 27 for detail of industries.

Table 36. Canada, employment, salaries and wages in the mineral manufacturing industries[1], 1968-75

	Unit	1968	1969	1970	1971	1972	1973	1974	1975
Primary metal industries									
Production and related workers	Number	86 237	83 564	88 839	86 452	86 335	89 853	94 538	90 169
Salaries and wages	$000	570 183	583 498	680 779	714 600	781 209	897 353	1 052 519	1 119 159
Annual average salary and wage	$	6 612	6 983	7 663	8 266	9 049	9 987	11 133	12 412
Administrative and office workers	Number	26 786	27 389	27 706	27 862	27 623	26 609	27 681	30 161
Salaries and wages	$000	233 273	255 548	277 728	303 113	327 598	340 547	403 151	493 764
Average annual salary and wage	$	8 709	9 330	10 024	10 879	11 860	12 798	14 564	16 371
Total primary metal industries									
Employees	Number	113 023	110 953	116 545	114 314	113 958	116 462	122 219	120 330
Salary and wages	$000	803 456	839 046	958 507	1 017 713	1 108 807	1 237 900	1 455 671	1 612 923
Annual average salary and wage	$	7 109	7 562	8 224	8 903	9 730	10 629	11 910	13 404
Nonmetallic mineral products industries									
Production and related workers	Number	37 796	38 107	36 045	38 035	39 159	41 502	42 884	42 149
Salaries and wages	$000	223 173	246 196	244 201	281 046	316 033	366 028	424 096	471 466
Annual average salary and wage	$	5 905	6 461	6 775	7 389	8 071	8 820	9 889	11 186
Administrative and office workers	Number	13 874	13 781	13 383	13 256	13 928	14 447	14 682	13 783
Salaries and wages	$000	102 869	111 568	117 163	124 085	142 193	156 085	180 802	197 884
Annual average salary and wage	$	7 415	8 096	8 755	9 361	10 209	10 804	12 314	14 357
Total nonmetallic mineral products									
Employees	Number	51 670	51 888	49 428	51 291	53 087	55 949	57 566	55 932
Salaries and wages	$000	326 042	357 764	361 364	405 131	458 226	522 113	604 898	669 350
Annual average salary and wage	$	6 310	6 895	7 311	7 899	8 632	9 332	10 507	11 967
Petroleum and coal products industries									
Production and related workers	Number	6 876	6 590	6 686	6 557	6 583	6 822	7 787	7 877
Salaries and wages	$000	56 703	61 217	64 745	68 215	75 735	84 537	105 398	122 268
Annual average salary and wage	$	8 247	9 289	9 684	10 403	11 505	12 392	13 535	15 522
Administrative and office workers	Number	8 755	9 043	8 961	8 960	8 826	9 265	9 648	9 387
Salaries and wages	$000	81 767	90 436	95 908	104 378	110 301	125 906	149 140	175 772
Annual average salary and wage	$	9 340	10 001	10 703	11 649	12 497	13 589	15 458	18 725
Total petroleum and coal products									
Employees	Number	15 631	15 633	15 647	15 517	15 409	16 087	17 435	17 264
Salaries and wages	$000	138 470	151 653	160 653	172 593	186 036	210 443	254 539	298 040
Annual average salary and wage	$	8 859	9 701	10 267	11 123	12 073	13 082	14 599	17 264

Table 36 (concl'd)

	Unit	1968	1969	1970	1971	1972	1973	1974	1975
Total mineral manufacturing industries									
Production and related workers	Number	130 909	128 261	131 570	131 044	132 077	138 177	145 209	140 195
Salaries and wages	$000	850 059	890 911	989 725	1 063 861	1 172 977	1 347 918	1 582 014	1 712 892
Annual average salary and wage	$	6 494	6 946	7 522	8 118	8 881	9 755	10 895	12 218
Administrative and office workers	Number	49 415	50 213	50 050	50 078	50 377	50 321	52 011	53 331
Salaries and wages	$000	417 909	457 552	490 799	531 576	580 092	622 538	733 093	867 421
Annual average salary and wage	$	8 457	9 112	9 806	10 615	11 515	12 371	14 095	16 269
Total mineral manufacturing industries									
Employees	Number	180 324	178 474	181 620	181 122	182 454	188 498	197 220	193 526
Salaries and wages	$000	1 267 968	1 348 463	1 480 524	1 595 437	1 753 069	1 970 456	2 315 107	2 580 313
Annual average salary and wage	$	7 032	7 556	8 151	8 809	9 608	10 454	11 739	13 333

[1] See footnote, Table 35. See Table 28 for detail of industries covered.

Table 37. Canada, number of wage earners employed in the mining industry[1] (surface, underground and mill), 1972-75

	1972	1973	1974	1975
Metals				
Surface	13 171	15 060	16 229	16 230
Underground	22 177	20 336	21 045	20 555
Mill	10 909	12 588	13 612	13 534
Total	46 257	47 984	50 886	50 319
Nonmetals				
Surface	6 952	7 080	7 743	7 180
Underground	1 792	1 881	2 210	1 870
Mill	7 167	7 383	7 814	6 347
Total	15 911	16 344	17 767	15 397
Fuels				
Surface	7 576	7 820	8 443	8 790
Underground	3 300	3 029	2 832	2 585
Total	10 876	10 849	11 275	11 375
Total mining industry				
Surface	27 699	29 960	32 415	32 200
Underground	27 269	22 246	26 087	25 010
Mill	18 076	19 971	21 426	19 881
Total	73 044	75 177	79 928	77 091

[1] See Table 27 for detail of industry coverage.

Table 38. Canada, labour costs in relation to tonnes mined, metal mines, 1973-75

Type of metal mine	Number of Wage Earners	Total Wages	Average Annual Wage	Tonnes of Ore Mined	Average Annual Tonnes Mined per Wage Earner	Wage Cost per Tonne Mined
		($000)	($)	(000 tonnes)	(tonnes)	($)
1975						
Auriferous quartz[1]	4 841	57 883	11 957	5 901	1 219	9.80
Copper-gold-silver	11 980	164 794	13 756	97 656	8 152	1.69
Nickel-copper	15 052	190 064	12 627	23 265	1 546	8.17
Silver-lead-zinc	5 339	71 656	13 421	16 094	3 014	4.43
Iron ore	9 990	159 107	15 927	101 482	10 158	1.20
Miscellaneous metals	3 117	42 059	13 493	19 744	6 334	2.13
Total	50 319	685 563	13 624	264 142	5 249	2.60
1974						
Auriferous quartz[1]	4 716	47 597	10 092	5 629	1 194	8.46
Copper-gold-silver	13 878	169 800	12 235	111 380	8 026	1.52
Nickel-copper	15 125	148 335	9 807	25 303	1 673	5.86
Silver-lead-zinc	4 940	52 702	10 668	14 189	2 872	3.71
Iron ore	9 560	131 199	13 723	107 105	11 203	1.22
Miscellaneous metals	2 667	30 552	11 455	15 008	5 627	2.04
Total	50 886	580 185	11 401	278 614	5 475	2.08
1973						
Auriferous quartz[1]	4 727	37 438	7 920	5 863	1 240	6.39
Copper-gold-silver	12 994	133 032	10 238	106 072	8 163	1.25
Nickel-copper	14 696	149 720	10 188	23 168	1 576	6.46
Silver-lead-zinc	4 489	44 082	9 820	15 254	3 398	2.89
Iron ore	8 521	104 030	12 209	108 622	12 748	0.96
Miscellaneous metals	2 557	26 329	10 297	15 687	6 135	1.68
Total	47 984	494 631	10 308	274 666	5 726	1.30

[1] Placer gold mines no longer surveyed.

Table 39. Canada, man-hours paid, production and related workers, tonnes of ore mined and rock quarried, metal mines and nonmetallic mineral operations, 1969-75

	Unit	1969	1970	1971	1972	1973	1974	1975
Metal mines[1]								
Ore mined	million tonnes	172.0	213.0	211.4	205.9	274.7	278.7	295.7
Man-hours paid[2]	million	95.8	108.2	102.1	93.8	98.4	104.0	102.4
Man-hours paid per tonne mined	number	0.56	0.51	0.48	0.46	0.36	0.37	0.35
Tonnes mined per man-hour paid	tonnes	1.80	1.97	2.07	2.20	2.79	2.68	2.89
Nonmetallic mineral operations[3]								
Ore mined and rock quarried	million tonnes	163.2	161.5	165.9	169.3	190.5	209.7	180.2
Man-hours paid[2]	million	28.4	28.6	27.5	27.4	28.6	30.5	25.6
Man-hours paid per tonne mined	number	0.17	0.18	0.17	0.16	0.15	0.15	0.15
Tonnes mined per man-hour paid	tonnes	5.75	5.65	6.03	6.18	6.66	6.88	7.04

[1]Excludes placer mining. [2]Man-hours paid for production and related workers only. [3]Excludes salt, cement, clay products, stone for cement and lime manufacture, and peat.

Table 40. Canada, average weekly wages and hours worked, hourly-rated employees in mining, manufacturing and construction industries, 1970-77

	1970	1971	1972	1973	1974	1975	1976	1977[p]
Mining								
Average hours per week	41.0	40.4	40.3	40.9	40.4	40.0	40.3	40.6
Average weekly wage ($)	152.10	163.22	174.94	196.89	225.25	260.74	298.44	328.79
Metals								
Average hours per week	40.3	39.3	39.0	39.6	39.4	39.4	39.6	39.8
Average weekly wage ($)	154.68	164.27	174.69	195.89	222.80	260.33	296.21	325.75
Mineral fuels								
Average hours per week	42.0	41.4	41.0	41.0	40.6	39.7	40.6	41.3
Average weekly wage ($)	146.68	161.46	176.36	198.08	231.51	264.98	309.24	329.89
Nonmetals								
Average hours per week	41.3	41.4	41.3	41.3	41.1	40.1	40.5	40.3
Average weekly wage ($)	139.21	151.52	158.30	173.10	191.51	230.84	273.56	301.93
Manufacturing								
Average hours per week	40.0	40.3	40.4	39.6	38.9	38.6	38.7	38.7
Average weekly wage ($)	119.69	130.22	141.53	152.77	170.03	195.12	222.79	145.13
Construction								
Average hours per week	39.2	39.2	40.1	39.5	39.1	39.0	38.9	38.7
Average weekly wage ($)	165.04	186.20	206.43	223.86	251.08	293.96	330.95	372.83

[p] Preliminary.

Table 41. Canada, average weekly wages of hourly-rated employees in the mining industry, in current and 1971 dollars, 1970-77

	1970	1971	1972	1973	1974	1975	1976	1977[p]
Current dollars								
All mining	152.10	163.22	174.94	196.89	222.25	260.74	298.44	328.79
Metals	154.68	164.27	174.69	195.89	222.80	260.33	296.21	325.75
Gold	113.72	124.61	131.92	151.73	192.78	219.97	251.23	286.42
Mineral fuels	146.68	161.46	176.36	198.08	231.51	264.98	309.24	329.89
Coal	130.37	144.26	158.18	181.29	212.56	243.01	274.00	303.53
Nonmetals, except fuel	139.21	151.52	158.30	173.10	191.51	230.84	273.56	301.93
1971 dollars								
All mining	156.48	163.22	166.93	174.70	177.80	188.26	200.43	204.47
Metals	159.14	164.27	166.69	173.82	178.24	187.96	198.93	202.58
Gold	117.00	124.61	125.88	134.63	154.22	158.82	168.72	178.12
Mineral fuels	150.91	161.46	168.27	175.76	185.21	191.32	207.68	205.16
Coal	134.13	144.26	150.94	160.86	170.05	175.46	184.02	188.76
Industrial minerals	143.22	151.52	151.05	153.59	153.21	166.67	183.72	187.77

[p] Preliminary.

Table 42. Canada, industrial fatalities per thousand workers, by industry groups, 1975-77

	Fatalities (number)			Number of workers (000)			Rate per 1 000 workers		
	1975[r]	1976	1977[p]	1975[r]	1976	1977[p]	1975[r]	1976	1977[p]
Agriculture	13	18	15	489	477	471	0.03	0.04	0.03
Forestry	71	64	61	62	72	71	1.15	0.89	0.86
Fishing	27	27	18	21	20	20	1.29	1.35	0.90
Mining[1]	159	161	127	141	147	154	1.13	1.10	0.83
Manufacturing	223	195	175	1 901	1 957	1 926	0.12	0.10	0.09
Construction	218	190	168	614	646	645	0.36	0.29	0.26
Transportation	216	217	172	825	839	834	0.26	0.26	0.21
Trade	74	62	71	1 659	1 668	1 708	0.05	0.04	0.04
Finance	3	10	8	481	504	540	0.01	0.02	0.02
Service	83	60	61	2 552	2 610	2 736	0.03	0.02	0.02
Public administration	85	54	48	674	689	711	0.13	0.08	0.07
Total	1 172	1 058	924	9 419	9 629	9 813	0.12	0.11	0.09

Note: See footnotes, Table 43.
[1] Includes fatalities resulting from occupational chest diseases such as silicosis, lung cancer, etc. In 1977, 47 (1976, 76) fatalities of this type were reported.
[p] Preliminary; [r] Revised.

Table 43. Canada, industrial fatalities per thousand workers, by industry groups, 1967-1977p

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977p
Agriculture	0.05	0.05	0.06	0.03	0.04	0.06	0.06	0.07	0.03	0.04	0.03
Forestry	1.34	1.28	1.10	1.31	1.31	1.09	1.25	1.04	1.15	0.89	0.86
Fishing[1]	1.32	0.79	0.86	1.25	0.50	0.36	0.60	0.46	1.29	1.35	0.90
Mining[2]	1.61	1.16r	1.46	1.26	1.34r	1.43r	1.51r	1.62r	1.13	1.10	0.83
Manufacturing	0.11	0.10	0.11	0.10	0.10	0.14	0.13	0.15	0.12	0.10	0.09
Construction	0.47	0.46	0.49	0.41	0.46	0.42	0.41	0.39	0.36	0.29	0.26
Transportation[3]	0.36	0.27r	0.30	0.27	0.29	0.31	0.35	0.32	0.26	0.26	0.21
Trade	0.05	0.05	0.05	0.05	0.06	0.05	0.06	0.08	0.05	0.04	0.04
Finance[4]	0.02	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.02	0.02
Service[5]	0.03	0.03r	0.03	0.03	0.03	0.05	0.04	0.04	0.03	0.02	0.02
Public administration	0.08	0.14	0.14	0.17	0.13	0.12	0.18	0.10	0.13	0.08	0.07
Total	0.16	0.14	0.14	0.13	0.14	0.15	0.16	0.16	0.12	0.11	0.09

[1]Includes trapping, hunting. [2]Includes quarrying and oil wells. [3]Includes storage, communication, electric power and water utilities. [4]Includes insurance and real estate. [5]Includes community, business and personal service.
p Preliminary; r Revised.

Table 44. Canada, industrial fatalities by occupational injuries and illnesses, 1975-77

	Occupational Injuries			Occupational Illnesses			Total		
	1975	1976	1977p	1975	1976	1977p	1975	1976	1977p
					(number)				
Agriculture	13	18	15	—	—	—	13	18	15
Forestry	71	64	61	—	—	—	71	64	61
Fishing	27	27	18	—	—	—	27	27	18
Mining	70	85	78	89	76	49	159	161	127
Manufacturing	176	151	133	47	44	42	223	195	175
Construction	210	181	160	8	9	8	218	190	168
Transportation	212	215	170	4	2	2	216	217	172
Trade	71	62	71	3	—	—	74	62	71
Finance	3	10	8	—	—	—	3	10	8
Service	82	60	61	1	—	—	83	60	61
Public administration	82	54	48	3	—	—	85	54	48
Total	1 017	927	823	155	131	101	1 172	1 058	924

p Preliminary.

Table 45. Canada, number of strikes and lockouts by industries, 1976-77

	1976			1977p		
	Strikes and Lockouts	Workers Involved	Duration in Man-days	Strikes and Lockouts	Workers Involved	Duration in Man-days
Agriculture	—	—	—	—	—	—
Forestry	4	784	36 320	6	949	22 170
Fishing and trapping	1	350	350	4	1 379	14 960
Mines	49	24 930	579 430	28	11 217	91 050
Manufacturing	457	166 534	4 493 260	342	95 521	1 665 460
Construction	76	135 668	2 856 370	84	33 215	404 990
Transportation and utilities	142	52 065	622 630	98	32 650	527 100
Trade	93	8 518	199 550	70	4 851	128 470
Finance, insurance & real estate	8	168	13 110	7	544	10 720
Service	147	148 840	1 298 490	96	22 532	328 150
Public administration	59	22 883	62 680	68	14 699	114 810
Other industries [1]	3	1 010 200 [2]	1 447 700	—	—	—
All industries	1 039	1 570 940	11 609 890	803	217 557	3 307 880

[1] Includes the Common Front in Québec. [2] 1976 includes the National Day of Protest.
p Preliminary; — Nil.

Table 46. Canada, number of strikes and lockouts by mining and mineral manufacturing, 1976-77

	1976			1977p		
	Strikes and Lockouts	Workers Involved	Duration in Man-days	Strikes and Lockouts	Workers Involved	Duration in Man-days
Mines	49	24 930	579 430	28	11 217	91 050
Metal	28	17 350	350 500	15	8 961	70 460
Mineral fuels	8	5 570	158 110	4	953	11 050
Nonmetals	5	1 238	36 180	6	1 232	4 470
Quarries	8	772	34 640	3	71	5 070
Mineral manufacturing	56	20 422	1 546 740	34	7 911	219 840
Primary metals	18	14 809	1 451 450	14	5 144	107 970
Nonmetallic mineral products	28	4 393	84 470	19	2 714	109 860
Petroleum and coal products	10	1 220	10 820	1	53	2 010

p Preliminary.

Table 47. Canada, ore mined and rock quarried in the mining industry, 1973-75

	1973	1974	1975
		(tonnes)	
Metals			
Gold quartz	5 862 987	5 628 780	5 900 860
Copper-gold-silver	106 072 012	111 380 587	97 656 374
Silver-cobalt	108 378	105 761	75 020
Silver-lead-zinc	15 254 434	14 189 710	16 094 171
Nickel-copper	23 168 058	25 302 458	23 264 576
Iron	108 621 534	107 104 902	101 482 119
Miscellaneous metals[1]	15 686 680	15 008 660	19 744 630
Total	274 774 083	278 720 858	264 217 750
Nonmetals			
Asbestos	80 568 423	85 541·458	61 709 522
Feldspar, nepheline syenite	622 382	647 616	596 787
Quartz (excluding sand)	1 411 464	1 273 667	1 268 565
Gypsum	7 619 183	6 916 833	5 578 241
Talc, soapstone	85 441	90 756	75 051
Rock salt	4 105 136	4 290 820	3 626 984
Other nonmetallics	16 522 876	22 432 148	22 030 535
Total	110 934 905	121 193 298	94 885 685
Structural materials			
Stone, all kinds quarried[2]	83 709.735	92 833 055	88 920 782
Stone used to make cement	14 941 305	14 947 658	13 653 506
Stone used to make lime	3 190 799	3 391 122	2 979 661
Total	101 841 839	111 171 835	105 553 949
Total ore mined and rock quarried	487 550 827	511 085 991	464 657 384

[1] Includes uranium ore. [2] Excludes stone used to manufacture cement and lime.

Table 48. Canada, ore mined and rock quarried in the mining industry, 1940-75

	Metals	Nonmetals[1]	Total
		(million tonnes)	
1940	35.9	18.4	54.3
1941	39.0	19.5	58.5
1942	38.5	19.6	58.1
1943	35.1	18.7	53.8
1944	32.0	17.5	49.5
1945	28.3	18.6	46.9
1946	26.2	22.4	48.6
1947	30.2	27.5	57.7
1948	33.4	30.3	63.7
1949	39.2	29.8	69.0
1950	41.6	37.9	79.5
1951	44.2	39.7	83.9
1952	47.4	40.0	87.4
1953	49.3	42.8	92.1
1954	53.5	55.7	109.2
1955	62.7	57.6	120.3
1956	70.2	66.2	136.4
1957	76.4	74.5	150.9
1958	71.4	71.2	142.6
1959	89.9	82.2	172.1
1960	92.1	88.7	180.8
1961	90.1	96.7	186.8
1962	103.6	103.8	207.4
1963	112.7	120.4	233.1
1964	128.0	134.1	262.1
1965	151.0	146.5	297.5
1966	147.6	171.8	319.4
1967	169.1	177.5	346.6
1968	186.9	172.7	359.6
1969	172.0	178.8	350.8
1970	213.0	179.1	392.1
1971	211.5	185.8	397.3
1972	206.0	189.7	395.7
1973	274.8	212.8	487.6
1974	278.7	232.4	511.1
1975	264.2	200.5	464.7

[1] Includes nonmetallic mineral mining and all stone quarried, including stone used to make cement and lime. Excludes coal. Coverage is the same as in Table 47.

Table 49. Canada, exploration and capital expenditures in the mining industry[1], by provinces and territories, 1975-77

		Capital						Repair						
		Construction												
		On-property Exploration	On-property Development	Structures	Total	Machinery and Equipment	Total Capital	Construction	Machinery and Equipment	Total Repair	Total Capital and Repair	Outside or General Exploration	Land and Mining Rights	Total all Expenditures
		($ million)												
Atlantic Provinces	1975	1.9	25.7	38.0	65.5	35.0	100.6	16.2	106.2	122.4	223.0	13.4	0.5	236.9
	1976	1.9	17.9	31.7	51.5	43.6	95.1	7.2	128.0	135.2	230.3	15.0	0.2	245.5
	1977p	1.9	19.8	16.6	38.3	46.4	84.7	11.4	126.8	138.2	222.9	19.5	0.7	243.1
Quebec	1975	4.1	73.0	164.0	241.1	101.4	342.5	11.9	142.6	154.5	497.0	25.0	(2)	(2)
	1976	7.3	109.4	193.0	309.7	162.8	472.5	14.6	178.4	193.0	665.5	21.1	5.5	692.1
	1977p	(2)	(2)	(2)	318.5	211.9	530.4	15.8	184.5	200.3	730.7	26.1	5.3	762.1
Ontario	1975	8.3	98.4	52.6	159.3	84.6	243.9	25.3	141.0	166.3	410.2	23.3	(2)	(2)
	1976	10.0	120.9	67.2	198.1	112.1	310.2	26.9	182.6	209.5	519.7	24.6	(2)	(2)
	1977p	10.3	125.8	52.0	188.1	96.7	284.8	24.7	194.8	219.5	504.3	28.6	1.3	534.2
Manitoba	1975	(2)	(2)	(2)	20.7	13.9	34.6	1.8	37.8	39.6	74.2	6.0	—	80.2
	1976	(2)	(2)	(2)	21.2	8.4	29.6	2.2	31.3	33.5	63.1	5.6	(2)	(2)
	1977p	(2)	(2)	(2)	23.4	11.5	34.9	3.4	30.1	33.5	68.4	7.9	0.1	76.4
Saskatchewan	1975	(2)	(2)	(2)	22.7	71.6	94.3	11.3	38.4	49.7	144.0	9.7	0.3	154.0
	1976	(2)	(2)	(2)	10.8	56.1	66.9	3.2	41.9	45.1	112.0	11.9	0.5	124.4
	1977p	(2)	(2)	(2)	36.2	73.7	109.9	3.7	55.8	59.5	169.4	14.5	0.3	184.2
Alberta	1975	(2)	(2)	(2)	18.3	33.4	51.7	2.3	15.8	18.1	69.8	3.5	0.4	73.7
	1976	0.7	6.6	20.0	27.3	65.4	92.7	5.3	23.8	29.1	121.8	4.3	1.3	127.4
	1977p	(2)	(2)	(2)	53.1	47.9	101.0	5.5	38.9	44.4	145.4	3.0	2.6	151.0
British Columbia	1975	4.7	30.6	19.8	55.1	62.0	117.1	10.8	124.3	135.1	252.2	24.5	2.1	278.8
	1976	8.1	58.9	44.0	111.0	55.3	166.3	10.9	132.7	143.6	309.9	22.9	4.5	337.3
	1977p	21.0	65.8	61.6	148.4	71.2	219.6	12.8	155.8	168.6	388.2	26.0	3.5	417.7
Yukon and Northwest Territories	1975	2.8	11.3	15.5	29.6	23.0	52.6	7.9	24.9	32.8	85.4	23.7	0.4	109.5
	1976	3.7	15.4	10.2	29.3	16.2	45.5	11.2	29.1	40.3	85.8	25.7	0.3	111.8
	1977p	3.9	13.2	17.4	34.5	18.8	53.3	6.4	27.3	33.7	87.0	38.1	—	125.1
Canada	1975	25.7	274.3	312.4	612.4	424.9	1 037.3	87.5	631.0	718.5	1 755.8	129.1	12.5	1 897.4
	1976	35.4	351.5	372.0	758.9	519.9	1 278.8	81.5	747.8	829.3	2 108.1	131.1	13.8	2 253.0
	1977p	73.7	362.5	404.3	840.5	578.1	1 418.6	83.7	814.0	897.7	2 316.3	163.7	13.8	2 493.8

[1] Excludes the petroleum and natural gas industries and the smelting and refining industries. (2) Confidential, figures are included in "Canada".
p Preliminary; — Nil.

Table 50. Canada, exploration and capital expenditures[1] in the mining industry, by type of mining, 1975-77

		Capital						Repair						
		Construction												
		On-Property Exploration	On-Property Development	Structures	Total	Machinery and Equipment	Total Capital	Construction	Machinery and Equipment	Total Repair	Total Capital and Repair	Outside or General Exploration	Land and Mining Rights	Total all Expenses
		($ million)												
Metal mining														
Gold	1975	1.7	17.3	1.7	20.7	5.3	26.0	0.8	10.9	11.7	37.7	1.6	—	39.3
	1976	1.6	12.8	2.9	17.3	4.5	21.8	0.7	11.4	12.1	33.9	(2)	—	(3)
	1977p	2.8	16.0	1.6	20.4	4.5	24.9	1.3	12.5	13.8	38.7	0.3	(3)	(4)
Copper-gold-silver	1975	6.4	54.1	48.7	109.2	51.8	161.0	10.3	125.1	135.4	296.4	5.3	0.7	302.4
	1976	6.5	72.2	49.7	128.4	69.5	197.9	12.5	133.2	145.7	343.6	4.8	0.2	348.6
	1977p	10.2	53.0	44.6	107.8	74.2	182.0	14.1	137.5	151.6	333.6	5.2	(3)	(4)
Silver-lead-zinc	1975	4.0	24.9	26.4	55.3	29.3	84.6	7.2	23.7	30.9	115.5	3.5	—	119.0
	1976	3.2	33.6	18.3	55.1	22.7	77.8	10.8	36.4	47.2	125.0	2.6	(3)	(3)
	1977p	6.6	29.1	18.1	53.8	23.1	76.9	5.8	32.3	38.1	115.0	6.2	(3)	(4)
Iron	1975	(3)	(3)	(3)	225.8	83.8	309.6	20.5	191.3	211.8	521.4	1.5	—	522.9
	1976	(2)	(2)	(2)	277.3	149.1	426.4	14.2	226.0	240.2	666.6	1.0	—	667.6
	1977p	(2)	(2)	(2)	265.7	(2)	(2)	18.8	225.1	243.9	(2)	(4)	(3)	(4)
Other metal mining	1975	(3)	(3)	(3)	86.1	43.0	129.1	24.7	95.4	120.1	249.2	9.9	(4)	(4)
	1976	12.7	155.5	220.0	110.9	58.5	169.4	23.3	114.5	137.8	307.2	14.2	(3)	(3)
	1977p	26.0	163.1	246.8	170.2	247.5	683.4	22.8	130.1	152.9	1 080.2	9.7	0.1	(4)
Total metal mining	1975	21.3	217.2	258.6	497.1	213.2	710.3	63.5	446.4	509.9	1 220.2	21.8	(4)	(4)
	1976	24.0	274.1	290.9	589.0	304.3	893.3	61.5	521.5	583.0	1 476.3	22.6	1.5	1 500.4
	1977p	45.6	261.2	311.1	617.9	349.3	967.2	62.8	537.5	600.3	1 567.5	(4)	2.1	(4)
Nonmetal mining														
Asbestos	1975	0.5	28.8	13.2	42.5	19.3	61.8	4.1	46.0	50.1	111.9	0.1	(4)	(4)
	1976	(6)	43.2	22.7	65.9	29.0	94.9	5.9	69.8	75.7	170.6	0.2	(5)	(5)
	1977p	2.0	43.8	20.6	66.4	37.3	103.7	7.5	73.1	80.6	184.3	(4)	(5)	(4)
Other non-metal mining	1975	2.6	27.6	40.1	70.3	190.3	260.6	19.7	138.3	158.0	418.6	7.8	1.3	427.7
	1976	(6)	37.8	57.6	95.4	185.6	281.0	14.1	156.4	170.5	451.5	8.9	(5)	(5)
	1977p	18.7	56.5	72.3	147.5	188.7	336.2	13.1	203.2	216.3	552.5	5.2	(5)	(4)

Table 50 (concl'd)

		Capital						Repair						
		Construction												
		On-property Exploration	On-property Development	Structures	Total	Machinery and Equipment	Total Capital	Construction	Machinery and Equipment	Total Repair	Total Capital and Repair	Outside or General Exploration	Land and Mining Rights	Total all Expenses
		($ million)												
Total non-metal mining	1975	3.1	56.4	53.3	112.8	209.6	322.4	23.8	184.3	208.1	530.5	7.9	(4)	(4)
	1976	8.0	73.0	80.3	161.3	214.6	375.9	20.0	226.2	246.2	622.1	9.1	6.9	638.1
	1977[p]	20.7	100.3	92.9	213.9	226.0	439.9	20.6	276.3	296.9	736.8	(4)	8.0	(4)
Metal and non-metal mining exploration	1975	1.3	0.7	0.5	2.5	2.1	4.6	0.2	0.3	0.5	5.1	99.4	3.3	107.8
	1976	3.4	4.4	0.8	8.6	1.0	9.6	—	0.1	0.1	9.7	99.4	5.4	114.5
	1977[p]	7.4	1.0	0.3	8.7	2.8	11.5	0.3	0.2	0.5	12.0	135.3	3.7	151.0
Total mining	1975	25.7	274.3	312.4	612.4	424.9	1 037.3	87.5	631.0	718.5	1 755.8	129.1	12.5	1 897.4
	1976	35.4	351.5	372.0	758.9	519.9	1 278.8	81.5	747.8	829.3	2 108.1	131.1	13.8	2 253.0
	1977[p]	73.7	362.5	404.3	840.5	578.1	1 418.6	83.7	814.0	897.7	2 316.3	163.7	13.8	2 493.8

[1]Excludes expenditures in the petroleum and natural gas industries. (2)Confidential, included in "other metal mining". (3)Confidential, included in "total metal mining". (4)Confidential, included in "total mining". (5)Confidential, included in "total nonmetal mining". (6)Confidential, included in "on-property development".
[p]Preliminary; — Nil.

Table 51. Canada, diamond drilling in the mining industry, by mining companies with own equipment and by drilling contractors, 1974-75

		1974			1975		
		Exploration	Other	Total	Exploration	Other	Total
		(metres)					
Metal mining							
Gold quartz	Own equipment	21 024	10 069	31 093	25 105	11 289	36 394
	Contractors	212 800	6 355	219 155	170 413	9 351	179 764
	Total	233 824	16 424	250 248	195 518	20 640	216 158
Copper-gold-silver	Own equipment	90 214	—	90 214	77 482	7 544	85 026
	Contractors	362 582	13 445	376 027	185 524	24 334	209 858
	Total	452 796	13 445	466 241	263 006	31 878	294 884
Nickel-copper	Own equipment	228 591	—	228 591	201 098	—	201 098
	Contractors	103 732	—	103 732	37 064	—	37 064
	Total	332 323	—	332 323	238 162	—	238 162
Silver-lead-zinc and silver-cobalt	Own equipment	17 994	15 975	33 969	37 080	13 139	50 219
	Contractors	158 268	5 085	163 353	139 382	790	140 172
	Total	176 262	21 060	197 322	176 462	13 929	190 391
Molybdenum	Own equipment	(1)	(1)	(1)	(1)	(1)	(1)
	Contractors	(1)	(1)	(1)	(1)	(1)	(1)
	Total	(1)	(1)	(1)	(1)	(1)	(1)
Iron mines	Own equipment	—	—	—	—	—	—
	Contractors	28 709	—	28 709	17 103	—	17 103
	Total	28 709	—	28 709	17 103	—	17 103
Miscellaneous metal mining	Own equipment	—	28 309	28 309	12 193	—	12 193
	Contractors	26 466	—	26 466	68 675	—	68 675
	Total	26 466	28 309	54 775	80 868	—	80 868
Total metal mining	Own equipment	357 823	54 353	412 176	352 958	31 972	384 930
	Contractors	892 557	24 885	917 442	618 161	34 475	652 636
	Total	1 250 380	79 238	1 329 618	971 119	66 447	1 037 566

Table 51. (concl'd)

		1974			1975		
		Exploration	Other	Total	Exploration	Other	Total
		(metres)					
Nonmetal mining							
Asbestos	Own equipment	35 627	—	35 627	—	—	—
	Contractors	21 581	—	21 581	9 615	—	9 615
	Total	57 208	—	57 208	9 615	—	9 615
Feldspar and quartz	Own equipment	—	—	—	—	—	—
	Contractors	2 564	—	2 564	1 034	—	1 034
	Total	2 564	—	2 564	1 034	—	1 034
Gypsum	Own equipment	—	—	—	—	—	—
	Contractors	1 514	—	1 514	549	—	549
	Total	1 514	—	1 514	549	—	549
Salt	Own equipment	—	—	—	1 088	—	1 088
	Contractors	—	—	—	—	—	—
	Total	—	—	—	1 088	—	1 088
Miscellaneous nonmetal mining	Own equipment	1 675	—	1 675	3 100	—	3 100
	Contractors	2 256	—	2 256	—	—	—
	Total	3 931	—	3 931	3 100	—	3 100
Total nonmetal mining	Own equipment	37 302	—	37 302	4 188	—	4 188
	Contractors	27 915	—	27 915	11 198	—	11 198
	Total	65 217	—	65 217	15 386	—	15 386
Total mining industry	Own equipment	395 125	54 353	449 478	357 146	31 972	389 118
	Contractors	920 472	24 885	945 357	629 359	34 475	663 834
	Total	1 315 597	79 238	1 394 835	986 505	66 447	1 052 952

(1) Confidential, included in "Miscellaneous metal mining".
— Nil.

Table 52. Canada, total diamond drilling, metal deposits, 1962-75

	Gold-quartz deposits	Copper-gold-silver and nickel-copper deposits	Silver-lead-zinc and silver-cobalt deposits	Other metal bearing deposits[1]	Total metal deposits
			(metres)		
1962	902 288	1 025 048	350 180	358 678	2 636 194
1963	529 958	977 257	288 204	148 703	1 944 122
1964	458 933	709 588	401 099	104 738	1 674 358
1965	440 020	779 536	331 294	275 917	1 826 767
1966	442 447	729 148	292 223	164 253	1 628 071
1967	391 347	947 955	230 182	120 350	1 689 834
1968	375 263	935 716	198 038	56 780	1 565 797
1969	274 410	923 452	197 670	109 592	1 505 124
1970	214 717	1 132 915	375 019	99 373	1 822 024
1971	193 291	1 089 103	308 798	83 851	1 675 043
1972	229 771	967 640	240 195[r]	50 225	1 487 831[r]
1973	243 708	713 134	185 946	57 730	1 200 518
1974	250 248	798 564	197 322	83 484	1 329 618
1975	216 158	533 046	190 391	97 971	1 037 566

Note: Nonproducing companies not included since 1964.
[1] Includes iron, titanium, uranium, molybdenum and other metal deposits.

Table 53. Canada, exploration diamond drilling, metal deposits, 1962-75

	Mining companies with own personnel and equipment	Diamond drill contractors	Total
		(metres)	
1962	167 214	1 748 022	1 915 236
1963	361 180	1 169 292	1 530 472
1964	143 013	1 072 985	1 215 998
1965	209 002	1 176 996	1 385 998
1966	163 379	1 044 860	1 208 239
1967	93 164	1 123 137	1 216 301
1968	159 341	990 690	1 150 031
1969	135 311	1 072 328	1 207 639
1970	62 147	1 228 061	1 290 208
1971	86 838	1 053 330	1 140 168
1972	251 651[r]	839 753[r]	1 091 404[r]
1973	321 333	742 899	1 064 232
1974	357 823	892 557	1 250 380
1975	352 958	618 161	971 119

Note: Nonproducing companies are not included since 1964. See footnote to Table 54.

Table 54. Canada, diamond drilling other than for exploration, metal deposits, 1962-75

	Mining companies with own personnel and equipment	Diamond drill contractors	Total
		(metres)	
1962	528 700	192 259	720 959
1963	388 228	25 422	413 650
1964	385 765	72 594	458 359
1965	393 947	46 822	440 769
1966	227 968	191 863	419 831
1967	186 463	187 071	473 534
1968	122 851	292 914	415 765
1969	87 552	209 933	297 485
1970	290 363	241 453	531 816
1971	295 966	238 910	534 876
1972	304 523	91 903	396 426
1973	77 162	59 124	136 286
1974	54 353	24 885	79 238
1975	31 972	34 475	66 447

Note: Nonproducing companies not included since 1964. The total footage drilled shown in Tables 53 and 54 equals the total footage drilled reported in Table 52.

Table 55. Canada, total contract diamond drilling operations[1], 1962-75

	Metres Drilled	Income from Drilling	Average number of Employees	Total salaries and Wages
		($ million)		($ million)
1962	1 691 558	17.9	1 926	8.0
1963	1 738 020	20.1	2 201	9.0
1964	1 974 828	23.7	2 401	11.2
1965	2 256 993	30.7	2 776	14.1
1966	2 275 717	33.7	2 887	15.1
1967	2 120 575	31.3	2 669	14.9
1968	2 321 105	38.7	2 985	18.8
1969	2 367 368	44.8	3 109	21.3
1970	2 324 859	53.2	3 207	24.3
1971	1 888 453	38.1	2 514	18.9
1972	1 578 218	35.9	2 083	16.6
1973	1 596 967	39.1	2 123	18.7
1974	1 689 598	51.6	2 317	22.6
1975	1 536 115	62.6	1 899	25.1

[1] Includes contract diamond drilling in mining and in other industries.

Table 56. Canada, contract drilling for oil and natural gas, 1964-75

	Metres drilled				Gross Income from Drilling	Number of Employees	Total Salaries and Wages
	Rotary	Cable	Diamond	Total	($ million)		($ million)
1964	4 512 190	70 020	1 898	4 584 108	81.9	4 158	25.2
1965	4 875 969	103 737	—	4 979 706	100.2	4 648	31.7
1966	4 082 617	64 039	—	4 146 656	95.8	4 428	33.9
1967	3 876 269	51 217	—	3 927 486	94.7	4 249	32.9
1968	4 054 073	70 239	—	4 124 312	109.5	4 434	36.9
1969	3 974 024	85 442	—	4 059 466	115.5	4 821	39.5
1970	3 505 457	50 304	—	3 555 761	112.6	4 267	37.9
1971	3 551 027	41 002	—	3 592 029	109.5	4 093	38.0
1972	4 332 240	42 362	—	4 374 602	154.6	4 817	53.5
1973	4 881 533	24 045	—	4 905 578	213.3	5 680	75.5
1974	4 380 546	17 372	—	4 397 918	206.1	5 054	74.4
1975	3 927 744	39 075	—	3 966 819	193.2	5 096	75.1

— Nil.

Table 57. Canada, crude minerals transported by Canadian railways, 1975-76

	1975	1976
	(000 tonnes)	
Metallic minerals		
Alumina and bauxite	2 379	1 140
Copper ores and concentrates	2 255	1 987
Iron ores and concentrates	49 004	57 837
Iron pyrite	22	24
Lead ores and concentrates	668	537
Lead-zinc ores and concentrates	89	41
Manganese ores	12	9
Nickel-copper ores and concentrates	4 087	4 913
Nickel ores and concentrates	1 814	1 757
Tungsten ores and concentrates	...	1
Zinc ores and concentrates	2 124	2 044
Metallic ores and concentrates, nes	85	60
Total metallic minerals	62 539	70 350
Nonmetallic minerals		
Abrasives, natural	85	109
Asbestos	776	855
Barite	53	61
Clay	523	579
Gravel	935	982
Gypsum	3 639	3 665
Limestone, agricultural	185	149
Limestone, industrial	233	325
Limestone, nes	3 514	3 366
Nepheline syenite	3	154
Phosphate rock	2 548	1 849
Potash (KCl)	7 300	7 864
Refractory materials, nes	17	27
Salt, rock	851	974
Salt, nes	253	204
Sand, industrial	1 192	1 363
Sand, nes	354	102
Silica	42	17
Sodium carbonate	329	273
Sodium sulphate	526	519
Stone, building, rough	19	17
Stone, nes	1 175	1 058
Sulphur, liquid	1 206	1 215
Sulphur, nes	2 884	2 366
Nonmetallic minerals, nes	196	179
Total nonmetallic minerals	28 838	28 272
Mineral fuels		
Coal, anthracite	253	187
Coal, bituminous	18 181	16 660
Coal, lignite	423	791
Coal, nes	18	7
Natural gas and other crude bituminous substances	10	12
Petroleum, crude	383	336
Total mineral fuels	19 268	17 993
Total crude minerals	110 645	116 615
Total revenue freight moved by Canadian railways	225 981	238 793
Per cent crude minerals of total revenue freight	49.0	48.8

nes Not elsewhere specified: ... Too small to be expressed.

Table 58. Canada, crude minerals transported by Canadian railways, 1967-76

	Total revenue freight	Total crude minerals	Crude Minerals as % of total revenue freight
	(million tonnes)		
1967	190.0	81.2	42.7
1968	195.4	86.7	44.4
1969	189.0	81.9	43.4
1970	211.6	97.5	46.1
1971	214.5	95.6	44.6
1972	215.8	89.4	41.4
1973	241.2	113.1	46.9
1974	246.3	115.3	46.8
1975	226.0	110.6	49.0
1976	239.0	116.6	48.8

Table 59. Canada, fabricated mineral products transported by Canadian railways, 1975-76

	1975	1976
	(000 tonnes)	
Metallic mineral products		
Ferrous mineral products		
Ferroalloys	140	177
Pig iron	87	59
Ingots, blooms, billets, slabs of iron and steel	295	282
Other primary iron and steel	58	38
Castings and forgings, iron and steel	254	252
Bars and rods, steel	695	643
Plates, steel	515	315
Sheet and strip, steel	1 208	1 112
Structural shapes and sheet piling, iron and steel	420	354
Rails and railway track material	162	165
Pipes and tubes, iron and steel	757	484
Wire, iron or steel	42	33
Iron and steel scrap	1 771	1 651
Slag, dross, etc.	190	190
Total ferrous mineral products	6 594	5 755
Nonferrous mineral products		
Aluminum paste, powder, pigs, ingots, shot	131	82
Aluminum and aluminum alloy fabricated material, nes	224	272
Copper matte and precipitates	6	3
Copper and alloys, in primary forms	387	392
Copper and alloys, nes	198	137
Lead and alloys	145	151
Nickel and nickel-copper matte	150	150
Nickel and alloys	53	48
Zinc and alloys	340	457
Other nonferrous base metals and alloys	11	10
Nonferrous metal scrap	179	154
Total nonferrous mineral products	1 824	1 856
Total metallic mineral products	8 418	7 611

Table 59. (concl'd)

	1975	1976
	(000 tonnes)	
Nonmetallic mineral products		
Natural stone basic products, chiefly structural	207	216
Bricks and tiles, clay	57	59
Fire brick and similar shapes	154	111
Dolomite and magnesite, calcined	97	73
Refractories, nes	44	35
Glass basic products	116	130
Asbestos and asbestos-cement basic products	23	23
Portland cement, standard	1 731	1 836
Concrete pipe	70	73
Cement and concrete basic products, nes	251	343
Plaster	33	28
Gypsum wallboard and sheathing	82	68
Gypsum basic products, nes	1	1
Lime, hydrated and quick	393	438
Nonmetallic mineral basic products, nes	740	752
Fertilizers and fertilizer materials, nes	1 696	1 529
Total nonmetallic mineral products	5 695	5 715
Mineral fuel products		
Gasoline	1 942	1 773
Aviation turbine fuel	78	68
Diesel fuel	3 524	3 374
Kerosene	52	6
Fuel oil, nes	840	967
Lubricating oils and greases	356	363
Petroleum coke	432	450
Coke, nes	943	814
Refined and manufactured gases, fuel type	3 249	3 082
Asphalts and road oils	273	216
Bituminous pressed or molded fabricated materials	1	1
Other petroleum and coal products	870	1 056
Total mineral fuel products	12 560	12 170
Total fabricated mineral products	26 673	25 496
Total revenue freight moved by Canadian railways	225 981	238 793
Fabricated mineral products as a percentage of total revenue freight	11.8	10.7

nes Not elsewhere specified.

Table 60. Canada, crude and fabricated minerals transported through the St. Lawrence Seaway, 1976-77

	Montreal-Lake Ontario Section		Welland Canal Section	
	1976	1977	1976	1977
	(tonnes)			
Crude minerals				
Bituminous coal	346 001	215 969	6 743 696	6 734 179
Iron ore	18 629 322	20 205 284	19 549 493	19 926 555
Aluminum ores and concentrates	47 485	103 906	47 485	103 906
Clay and bentonite	234 602	313 204	250 932	333 665
Gravel and sand	27 779	28 839	294 387	289 440
Stone, ground or crushed	51 710	98 070	993 734	1 013 306
Stone, rough	3 243	326	3 243	307
Petroleum, crude	—	—	—	—
Salt	752 355	783 679	1 507 482	1 489 821
Phosphate rock	36 246	5 279	—	—
Sulphur	43 742	14 309	43 742	14 309
Other crude minerals	712 110	1 238 939	479 449	553 052
Total crude minerals	20 884 595	23 007 804	29 913 643	30 458 540
Fabricated mineral products				
Coke	1 620 383	2 026 004	1 746 942	2 101 542
Gasoline	175 848	52 772	211 048	110 003
Fuel oil	1 360 776	2 015 026	725 982	958 013
Lubricating oils and greases	182 955	145 492	174 999	157 266
Other petroleum products	228 779	158 420	50 913	112 287
Tar, pitch and creosote	31 291	35 745	43 869	53 762
Pig iron	124 920	160 155	114 773	148 565
Iron and steel: bars, rods, slabs	266 257	203 078	218 824	151 638
Iron and steel: rails, wire	50 498	39 191	42 051	34 040
Iron and steel: other manufactured products	2 709 490	4 730 629	2 413 011	4 529 822
Scrap iron and steel	429 760	348 673	415 016	354 157
Cement	36	3 050	165 553	222 796
Total fabricated minerals	7 180 993	9 918 235	6 322 981	8 933 891
Total crude and fabricated minerals	28 065 588	32 926 039	36 236 624	39 392 431
Total all products	49 348 441	57 456 343	58 368 446	65 077 450
Crude and fabricated minerals as a per cent of total	56.9	57.3	62.1	60.5

— Nil.

Table 61. Canada, crude minerals loaded and unloaded in coastwise shipping, 1976

	Loaded				Unloaded			
	Atlantic	Great Lakes	Pacific	Total	Atlantic	Great Lakes	Pacific	Total
				(tonnes)				
Metallic minerals								
Alumina, bauxite ores	33 432	—	—	33 432	33 432	—	—	33 432
Copper ore and concentrates	22 721	—	—	22 721	18 865	3 856	—	22 721
Iron ore and concentrates	3 359 766	2 544 151	—	5 903 917	551 414	5 352 503	—	5 903 917
Lead ore and concentrates	5 452	—	—	5 452	5 452	—	—	5 452
Manganese ore	8 350	—	—	8 350	—	8 350	—	8 350
Titanium ore	2 134 600	—	—	2 134 600	2 134 600	—	—	2 134 600
Zinc ore and concentrates	46 022	—	—	46 022	46 022	—	—	46 022
Ores and concentrates, nes	4 560	54	—	4 614	—	4 614		4 614
Iron and steel scrap	4 108	2 358	640	7 106	4 108	2 358	640	7 106
Nonferrous metal scrap	12	—	362	374	12	—	362	374
Total metals	5 619 023	2 546 563	1 002	8 166 588	2 793 90	55 371 681	1 002	8 166 588
Nonmetallic minerals								
Asbestos	4 897	—	—	4 897	3 719	1 178	—	4 897
Clay materials, nes	472	—	—	472	472	—	—	472
Fluorspar	46 126	—	—	46 126	46 126	—	—	46 126
Gypsum	554 050	—	6 622	560 672	460 849	93 201	6 622	560 672
Limestone	8 492	1 838 026	202 735	2 049 253	8 492	1 838 026	202 735	2 049 253
Salt	276 654	1 219 152	42 392	1 538 198	752 700	743 106	42 392	1 538 198
Sand and gravel	46 743	2 224	2 242 340	2 291 307	46 680	2 287	2 242 340	2 291 307
Stone, crude, nes	87	374 419	2 540	377 046	13 144	361 362	2 540	377 046
Sulphur	8 489		8 647	17 136	8 489	—	8 647	17 136
Crude nonmetallic minerals, nes	—	—	1 969	1 969	—	—	1 969	1 969
Total nonmetals	946 010	3 433 821	2 507 245	6 887 076	1 340 671	3 039 160	2 507 245	6 887 076
Mineral fuels								
Coal, bituminous	187 374	273 326	87 576	548 276	87 233	461 043	—	548 276
Crude petroleum	322 177	—	—	322 177	322 177	—	—	322 177
Total mineral fuels	509 551	273 326	87 576	870 453	409 410	461 043	—	870 453
Total crude minerals	7 074 584	6 253 710	2 595 823	15 924 117	4 543 986	8 871 884	2 508 247	15 924 117
Total, all commodities	19 479 010	23 305 279	11 097 875	53 882 164	26 836 242	16 042 059	11 003 863	53 882 164
Crude minerals as a percent of all commodities	36.3	26.8	23.4	29.6	16.9	55.3	22.8	29.6

— Nil: nes Not elsewhere specified.

Table 62. Canada, crude minerals loaded and unloaded at Canadian ports in international shipping trade, 1975-76

	1975		1976	
	Loaded	Unloaded	Loaded	Unloaded
	(tonnes)			
Metallic minerals				
Alumina, bauxite ore	23 584	3 011 798	—	1 848 004
Copper ores and concentrates	694 818	—	747 099	—
Iron ore and concentrates	36 212 648	5 244 036	45 675 427	3 885 409
Lead ore and concentrates	94 155	—	167 437	—
Manganese ore	14 333	169 277	13 623	221 197
Nickel ore and concentrates	59 696	23 468	74 520	21 979
Titanium ore	328 931	—	270 585	—
Zinc ore and concentrates	971 890	—	1 139 442	—
Ores and concentrates, nes	52 365	—	25 712	113 021
Iron and steel scrap	178 592	420	328 291	1 694
Nonferrous metal scrap	8 350	282	5 768	1 343
Slag, dross, residue	671 837	9 049	724 044	44 094
Total metals	39 311 189	8 458 330	49 171 948	6 136 741
Nonmetallic minerals				
Asbestos	396 990	5 569	447 117	5 162
Barite	—	—	56 514	—
Bentonite	90	136 332	1 999	196 972
China clay	14	41 285	—	21 795
Clay materials, nes	58	55 449	18	42 938
Dolomite	971 156	—	878 849	—
Fluorspar	31 539	194 932	25 524	156 580
Gypsum	3 813 138	52 721	4 057 951	51 728
Limestone	999 417	3 135 812	819 511	2 949 456
Phosphate rock	—	1 411 899	—	1 071 821
Potash (KCl)	1 744 469	—	1 514 650	21 532
Salt	870 696	1 046 516	1 418 527	1 106 345
Sand and gravel	13 361	1 392 582	9 149	1 287 573
Stone, crude, nes	76 993	15 127	71 500	9 614
Sulphur	1 838 373	8 232	2 244 080	13 165
Crude, nonmetallic minerals, nes	43 735	35 228	57 090	22 165
Total nonmetals	10 800 029	7 531 684	11 602 479	6 956 846
Mineral fuels				
Coal bituminous	10 649 700	15 384 838	9 812 549	14 178 421
Coal, nes	78 565	348 003	9 807	220 914
Petroleum, crude	1 130 327	19 834 275	930 504	16 939 895
Total fuels	11 858 592	35 567 116	10 752 860	31 339 230
Total crude minerals	61 969 810	51 557 130	71 527 287	44 432 817
Total, all commodities	102 444 469	63 776 026	114 815 138	56 475 039
Crude minerals as a per cent of all commodities	60.5	80.8	62.3	78.7

— Nil; nes Not elsewhere specified.

Table 63. Canada, fabricated mineral products loaded and unloaded at Canadian ports in international shipping trade, 1975-76

	1975		1975	
	Loaded	Unloaded	Loaded	Unloaded
	(tonnes)			
Metallic products				
Aluminum	215 332	1 617	212 709	1 185
Copper and alloys	66 208	3 791	55 688	4 863
Ferroalloys	2 015	15 294	5 013	9 265
Iron and steel, primary	8 597	65 554	68 867	22 041
Iron, pig	327 852	23	440 297	2 497
Iron and steel, other				
bars and rods	10 712	178 380	80 551	170 300
castings and forgings	27 416	15 315	23 089	10 990
pipe and tubes	57 628	55 606	23 953	76 679
plate and sheet	149 802	242 064	273 601	245 905
rails and track material	86 387	28 968	78 148	17 756
structural shapes	53 406	165 636	77 465	197 208
wire	2 322	11 617	2 752	11 812
Lead and alloys	49 352	—	33 557	1 088
Nickel and alloys	1 686	16 040	4 997	37 713
Zinc and alloys	59 323	117	66 012	11 958
Nonferrous metals, nes	14 779	5 006	2 999	7 410
Metal fabricated basic products	23 743	15 958	11 631	27 925
Total metals	1 156 560	820 986	1 461 329	856 595
Nonmetallic products				
Asbestos basic products	2 145	443	834	689
Building brick, clay	—	—	45	—
Bricks and tiles, nes	11 149	11 479	7 753	3 050
Cement	999 850	91 908	1 009 400	84 129
Cement basic products	669	1 462	1 514	186
Drain tiles and pipes	9	58	—	—
Glass basic products	6 921	8 440	6 695	14 539
Lime	2 420	45	1 227	602
Nonmetallic mineral basic products	4 433	4 692	6 290	13 291
Fertilizers, nes	115 555	137 707	88 261	155 928
Total nonmetals	1 143 151	256 234	1 122 019	272 414
Mineral fuel products				
Asphalts, road oils	626	13 252	965	4 536
Coal tar, pitch	7 047	71 819	1 821	65 271
Coke	300 334	656 420	503 656	694 851
Fuel oil	3 921 851	1 121 032	2 379 101	1 175 438
Gasoline	582 154	22 255	393 117	4 162
Lubricating oils and greases	468	74 340	2 015	23 145
Petroleum and coal products, nes	382 445	33 886	244 206	115 425
Total fuels	5 194 925	1 993 004	3 524 881	2 082 828
Total fabricated mineral products	7 494 636	3 070 224	6 108 229	3 211 837
Total, all commodities	102 444 469	63 776 026	114 815 138	56 475 039
Fabricated mineral products as a per cent of all commodities	7.3	4.8	5.3	5.7

— Nil; nes Not elsewhere specified.

Table 64. Canada, financial statistics of corporations in the mining industry[1]

	Corporations		Assets	
	(number)	(%)	($ million)	(%)
Metal mines				
Reporting corporations				
50% and over, nonresident	48	22.0	6 478	58.2
Under 50%, nonresident	104	47.7	4 519	40.6
Government business enterprise	3	1.4	126	1.1
Other corporations	63	28.9	5	0.1
Total, all corporations	218	100.0	11 127	100.0
Minerals fuels				
Reporting corporations				
50% and over, nonresident	232	26.5	7 655	68.4
Under 50%, nonresident	250	28.5	3 308	29.6
Government business enterprise	4	0.5	201	1.8
Other corporations	389	44.5	25	0.2
Total, all corporations	875	100.0	11 189	100.0
Other mining (including mining services)				
Reporting corporations				
50% and over, nonresident	179	6.4	2 056	55.6
Under 50%, nonresident	970	34.4	1 459	39.4
Government business enterprise	3	0.1	56	1.5
Other corporations	1 666	59.1	131	3.5
Total, all corporations	2 818	100.0	3 701	100.0
Total mining				
Reporting corporations				
50% and over, nonresident	459	11.7	16 188	62.2
Under 50%, nonresident	1 324	33.8	9 286	35.7
Government business enterprise	10	0.3	382	1.5
Other corporations	2 118	54.2	161	0.6
Total, all corporations	3 911	100.0	26 018	100.0

Note: Footnotes for Table 65 apply to this table. Figures may not add to totals due to rounding.
[1] Classification of the industry is the same as in Table 27.
— Nil; (1) Amount too small to be expressed.

by degree of nonresident ownership, 1975

Equity		Sales		Profits		Taxable Income	
($ million)	(%)	($ million)	(%)	($ million)	(%)	($ million)	(%)
2 865	52.8	2 712	56.1	530	62.6	140.0	30.5
2 497	46.0	2 063	42.7	306	36.1	319.6	69.5
59	1.1	59	1.2	11	1.3	—	—
2	0.1	(1)	(1)	(1)	(1)	—	—
5 423	100.0	4 835	100.0	847	100.0	459.6	100.0
4 114	67.8	5 776	85.0	1 425	80.8	1 645.2	88.6
1 810	29.9	966	14.2	342	19.4	208.7	11.2
154	2.5	40	0.6	−1	−0.1	—	—
−13	−0.2	14	0.2	−2	−0.1	2.6	0.2
6 064	100.0	6 796	100.0	1 763	100.0	1 856.5	100.0
1 063	55.1	1 042	56.9	206	80.8	173.1	81.2
792	41.0	683	37.3	45	17.7	33.1	15.5
51	2.6	12	0.6	7	2.7	—	—
24	1.3	95	5.2	−3	−1.2	7.1	3.3
1 930	100.0	1 833	100.0	255	100.0	213.3	100.0
8 043	59.9	9 530	70.8	2 161	75.4	1 958.2	77.4
5 098	38.0	3 712	27.6	694	24.2	561.4	22.2
264	2.0	111	0.8	17	0.6	—	—
13	0.1	110	0.8	−6	−0.2	9.8	0.4
13 417	100.0	13 463	100.0	2 866	100.0	2 529.4	100.0

Table 65. Canada, financial statistics of corporations in the mineral

	Corporations[2]		Assets[5]	
	(number)	(%)	($ million)	(%)
Primary metal products				
Reporting corporations[2]				
50% and over, nonresident	55	10.9	1 008	14.1
under 50%, nonresident	219	43.3	5 809	81.1
Government business enterprises[3]	2	0.4	. .	. .
Other[4]	230	45.4	. .	. .
Total, all corporations	506	100.0	7 164	100.0
Nonmetallic mineral products				
Reporting corporations[2]				
50% and over, nonresident	109	9.0	2 042	62.9
under 50%, nonresident	541	44.5	1 143	35.2
Government business enterprises[3]	1	0.1	. .	. .
Others[4]	564	46.4	. .	. .
Total, all corporations	1 215	100.0	3 245	100.0
Petroleum and coal products				
Reporting corporations[2]				
50% and over, nonresident	19	35.9	10 547	90.2
under 50%, nonresident	20	37.7	1 146	9.8
Government business enterprises[3]	—	—	—	—
Other[4]	14	26.4	1	0.01
Total, all corporations	53	100.0	11 694	100.0
Total mineral manufacturing industries				
Reporting corporations[2]				
50% and over, nonresident	183	10.3	13 597	61.5
under 50%, nonresident	780	44.0	8 098	36.6
Government business enterprises[3]	3	0.2	. .	. .
Other[4]	808	45.5	. .	. .
Total, all corporations	1 774	100.0	22 103	100.0

[1]Classification of industries is the same as in Table 28. [2]Corporations reporting under the Corporations and Labour Unions Returns Act. A corporation is considered to be foreign controlled if 50% or more of its voting rights are known to be held outside Canada, and/or by one or more Canadian corporations which are, in turn, foreign controlled. Each corporation is classified according to the percentage of its voting rights which are owned by nonresidents, either directly or through other Canadian corporations, and the whole of the corporation is assigned to this particular degree of foreign ownership. [3]Nontaxable federal and provincial Crown Corporations and municipally owned corporations. [4]Corporations exempt from reporting under the Corporations and Labour Unions Returns Act. These include corporations reporting under other acts, small companies and corporations and nonprofit organizations. [5]Included are cash, marketable securities, accounts receivable, inventories, fixed assets, investments in affiliated corporations and other assets. The amounts tabulated are those shown on the balance sheets of corporations after deducting allowances for doubtful accounts, amortization, depletion and depreciation. [6]Equity represents the shareholders' interest in the net assets of the corporation and includes the total amount of all issued and paid-up share capital, earnings retained in the business and other surplus accounts such as contributed and capital surplus. [7]For nonfinancial corporations, sales are gross revenues from nonfinancial operations. For financial corporations, sales include total income from financial as well as nonfinancial sources. [8]The net earnings from operations, investment income and net capital gains. Profits are tabulated after deducting allowances for amortization, depletion and depreciation, but before income tax provisions or declaration of dividends. [9]Taxable income figures are as reported by corporations prior to assessment by the Department of National Revenue. They include earnings in the reference year after the deduction of applicable losses of other years.

— Nil; . . Not available or not applicable; (1) Amount too small to be expressed.

manufacturing industries[1], by degree of nonresident ownership, 1975

Equity[6]		Sales[7]		Profits[8]		Taxable Income[9]	
($ million)	(%)	($ million)	(%)	($ million)	(%)	($ million)	(%)
620	19.7	1 025	17.4	117	28.0	83.7	43.5
2 527	80.3	4 583	77.7	345	82.5	106.5	55.3
..	..	..	..	..	..	—	—
..	..	..	..	..	..	2.3	1.2
3 146	100.0	5 899	100.0	418	100.0	192.5	100.0
1 032	68.6	1 526	52.5	170	59.2	113.3	61.0
450	29.9	1 307	44.9	113	39.4	67.9	36.6
..	..	..	..	..	..	—	—
..	..	..	..	..	..	4.5	2.4
1 505	100.0	2 908	100.0	287	100.1	185.7	100.0
5 534	93.7	11 332	94.8	1 366	92.2	1 382.2	99.6
375	6.3	623	5.2	116	7.8	6.0	0.4
—	—	—	—	—	—	—	—
(1)	(1)	1	0.01	(1)	(1)	(1)	(1)
5 909	100.0	11 957	100.0	1 482	100.0	1 388.2	100.0
7 186	68.1	13 883	66.9	1 653	75.6	1 579.2	89.4
3 352	31.7	6 513	31.4	574	26.3	180.4	10.2
..	..	..	..	..	..	—	—
..	..	..	..	..	..	6.8	0.4
10 560	100.0	20 764	100.0	2 187	100.0	1 766.4	100.0

Table 66. Canada, financial statistics of corporations in nonfinancial

		Agriculture, Forestry, Fishing and Trapping		Mining		Manufacturing	
		1974	1975ᵖ	1974	1975ᵖ	1974	1975ᵖ
Number of corporations							
Foreign control	number	108	107	465	459	2 439	2 368
Canadian control	number	3 076	3 488	1 337	1 324	10 099	10 677
Other corporations	number	6 569	7 244	2 139	2 128	13 943	14 428
Total corporations	number	9 753	10 839	3 941	3 911	26 481	27 473
Assets							
Foreign control	$ million	259	284	14 530	16 188	39 485	43 511
Canadian control	$ million	1 854	2 129	8 088	9 286	31 420	34 810
Other corporations	$ million	646	702	421	543	2 108	2 284
Total corporations	$ million	2 759	3 115	23 038	26 018	73 013	80 605
Equity							
Foreign control	$ million	117	138	7 575	8 043	19 251	21 447
Canadian control	$ million	611	662	4 720	5 098	12 711	14 060
Other corporations	$ million	159	169	191	277	485	493
Total corporations	$ million	886	969	12 486	13 417	32 447	36 000
Sales							
Foreign control	$ million	204	187	8 501	9 530	53 853	59 170
Canadian control	$ million	1 704	1 853	3 394	3 712	41 118	43 479
Other corporations	$ million	604	635	176	221	2 427	2 617
Total corporations	$ million	2 512	2 675	12 072	13 463	97 399	105 267
Profits							
Foreign control	$ million	15	24	1 917	2 161	5 164	4 939
Canadian control	$ million	129	72	889	694	3 465	2 678
Other corporations	$ million	40	35	− 4	11	69	9
Total corporations	$ million	184	131	2 802	2 866	8 697	7 626

Note: Figures may not add due to rounding.
ᵖ Preliminary.

industries, by major industry group and by control, 1974 and 1975

Construction		Transportation, Communication and Other Utilities		Trade		Services		Total	
1974	1975^p	1974	1975^p	1974	1975^p	1974	1975^p	1974	1975^p
199	202	269	261	2 020	1 958	588	563	6 088	5 918
8 083	9 203	2 754	3 058	21 958	24 504	7 748	9 068	55 055	61 322
21 484	23 948	8 921	9 347	50 093	52 147	35 712	39 158	138 861	148 400
29 766	33 353	11 944	12 666	74 071	78 609	44 048	48 789	200 004	215 640
1 618	1 968	1 933	2 090	9 159	9 538	3 330	3 312	70 315	76 891
8 950	10 279	22 897	24 915	22 449	25 686	7 908	9 404	103 566	116 508
1 456	1 630	33 339	38 473	6 369	6 272	2 322	2 521	46 660	52 424
12 024	13 876	58 169	65 478	37 978	41 496	13 559	15 237	220 541	245 825
411	452	739	761	3 199	3 186	1 203	1 245	32 495	35 272
1 759	2 232	8 529	9 409	7 313	8 352	2 589	2 867	38 231	42 679
435	493	8 114	8 584	1 420	1 507	699	730	11 503	12 252
2 605	3 177	17 382	18 755	11 932	13 044	4 490	4 842	82 228	90 204
1 900	2 909	1 148	1 351	19 546	21 178	2 673	2 966	87 823	97 292
11 958	14 435	10 407	12 109	58 265	65 699	6 548	8 406	133 397	149 694
2 905	3 162	7 984	8 984	11 825	12 869	3 249	3 609	29 171	32 097
16 764	20 507	19 539	22 444	89 636	99 746	12 470	14 981	250 392	279 084
101	174	170	147	949	719	398	322	8 715	8 486
551	827	1 386	1 628	2 047	2 006	504	552	8 970	8 456
138	148	400	193	1 077	1 159	214	243	1 935	1 799
789	1 150	1 956	1 968	4 073	3 883	1 118	1 117	19 619	18 741

Table 67. Canada, capital and repair expenditures in mining[1] and mineral manufacturing industries, 1976-78

	1976			1977[p]			1978[f]		
	Capital	Repair	Total	Capital	Repair	Total	Capital	Repair	Total
					($ million)				
Mining industry									
Metal mines									
Gold	21.8	12.1	33.9	23.1	11.0	34.1	24.4	11.9	36.3
Silver-lead-zinc	77.8	47.2	125.0	78.7	46.4	125.1	73.2	47.3	120.5
Copper-gold-silver	197.9	145.7	343.6	188.3	157.3	345.6	129.1	167.5	296.6
Iron	426.4	240.2	666.6	402.5	232.3	634.8	154.5	236.4	390.9
Other metal mines	179.0	137.9	316.9	238.9	136.3	375.2	184.2	127.9	312.1
Total metal mines	902.9	583.1	1 486.0	931.5	583.3	1 514.8	565.4	591.0	1 156.4
Nonmetal mines									
Asbestos	94.9	75.7	170.6	99.4	88.9	188.3	119.2	94.1	213.3
Other nonmetal mines[2]	281.0	170.5	451.5	368.3	194.2	562.5	364.9	204.3	569.2
Total nonmetal mines	375.9	246.2	622.1	467.7	283.1	750.8	484.1	298.4	782.5
Mineral fuels									
Petroleum and gas[3]	2 162.1	370.3	2 532.4	2 636.1	396.0	3 032.1	2 723.9	442.3	3 166.2
Total mining industries	3 440.9	1 199.6	4 640.5	4 035.3	1 262.4	5 297.7	3 773.4	1 331.7	5 105.1
Mineral manufacturing									
Primary metal industries									
Iron and steel mills	392.0	399.6	791.6	390.7	439.1	829.8	387.2	497.9	885.1
Steel pipe and tube mills	11.1	30.9	42.0	14.5	27.0	41.5	31.0	27.8	58.8
Iron foundries	20.5	28.0	48.5	26.7	12.4	39.1	27.5	13.4	40.9
Smelting and refining	131.4	207.5	338.9	248.1	179.8	427.9	291 4	204.4	495.8
Aluminum rolling, casting and extruding	10.2	15.2	25.4	16.7	16.1	32.8	17.6	16.9	34.5
Other primary metal industries	75.7	14.4	90.1	21.0	13.4	34.4	19.6	13.5	33.1
Total primary metal industries	640.9	695.6	1 336.5	717.7	687.8	1 405.5	774.3	773.9	1 548.2

Table 67 (concl'd)

	1976			1977[p]			1978[f]		
	Capital	Repair	Total	Capital	Repair	Total	Capital	Repair	Total
				($ million)					
Nonmetallic mineral products									
Cement	73.6	41.4	115.0	114.5	43.1	157.6	79.0	47.8	126.8
Concrete products	26.7	31.8	58.5	24.4	25.3	49.7	14.7	26.0	40.7
Ready mix concrete	42.5	43.9	86.4	27.3	41.7	69.0	21.8	44.5	66.3
Clay products	10.4	9.3	19.7	7.5	4.0	11.5	7.5	4.1	11.6
Glass and glass products	28.8	11.5	40.3	23.4	12.0	35.4	28.1	15.8	43.9
Abrasives	5.4	10.6	16.0	4.4	10.5	14.9	7.9	10.9	18.8
Other nonmetallic mineral products	54.6	31.8	86.4	83.0	27.3	110.3	96.4	36.7	133.1
Total nonmetallic mineral products	242.0	180.3	422.3	284.5	163.9	448.4	255.4	185.8	441.2
Petroleum and coal products	344.2	137.0	481.2	377.4	167.7	545.1	293.4	185.4	478.8
Total mineral manufacturing industries	1 227.1	1 012.9	2 240.0	1 379.6	1 019.4	2 399.0	1 323.1	1 145.1	2 468.2
Total mining and mineral manufacturing industries	4 668.0	2 212.5	6 880.5	5 414.9	2 281.8	7 696.7	5 096.5	2 476.8	7 573.3

[1] Does not include cement, lime and clay products (domestic clay) manufacturing, smelting and refining. [2] Includes coal mines, gypsum, salt, potash and miscellaneous nonmetal mines and quarrying. [3] The total of capital expenditures shown under "petroleum and gas" is equal to the total capital expenditure under the column entitled "petroleum and natural gas extraction" and under the column "natural gas processing plants" of Table 70.
[p] Preliminary; [f] Forecast.

Table 68. Canada capital and repair expenditures in the mining industry[1], 1968-78

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977[p]	1978[f]
						($ million)					
Metal mines											
Capital											
Construction	264.8	295.1	335.6	590.8	345.7	357.1	409.6	499.6	597.6	514.4	340.0
Machinery	105.2	98.2	150.3	239.8	313.0	241.3	157.9	215.3	305.3	417.1	225.4
Total	370.0	393.3	485.9	830.6	658.7	598.4	567.5	714.9	902.9	931.5	565.4
Repair											
Construction	47.9	35.7	36.6	38.9	26.4	48.0	58.7	63.7	61.5	70.0	72.8
Machinery	152.2	160.9	220.2	240.9	242.4	299.7	383.4	446.7	521.6	513.3	518.2
Total	200.1	196.6	256.8	279.8	268.8	347.7	442.1	510.4	583.1	583.3	591.0
Total capital and repair	570.1	589.9	742.7	1 110.4	927.5	946.1	1 009.6	1 225.3	1 486.0	1 514.8	1 156.4
Nonmetal mines[2]											
Capital											
Construction	110.2	128.1	107.9	84.6	59.8	67.5	116.0	112.8	161.3	234.9	229.5
Machinery	128.4	113.9	115.9	105.6	81.3	79.7	125.7	209.6	214.6	232.8	254.6
Total	238.6	242.0	223.8	190.2	141.1	147.2	241.7	322.4	375.9	467.7	484.1
Repair											
Construction	4.3	10.4	7.1	7.9	6.2	6.5	13.1	23.8	20.0	20.2	20.7
Machinery	57.5	64.7	99.9	107.1	116.4	135.2	167.0	184.3	226.2	262.9	277.7
Total	61.8	75.1	107.0	115.0	122.6	141.7	180.1	208.1	246.2	283.1	298.4
Total capital and repair	300.4	317.1	330.8	305.2	263.7	288.9	421.8	530.5	622.1	750.8	782.5
Mineral fuels											
Capital											
Construction	407.4	465.3	552.6	639.4	729.3	851.7	1 060.9	1 355.7	1 598.0	2 123.0	2 380.1
Machinery	58.0	76.6	86.2	101.3	91.2	83.4	165.3	219.0	564.1	513.1	343.8
Total	465.4	541.9	638.8	740.7	820.5	935.1	1 226.2	1 574.7	2 162.1	2 636.1	2 723.9

Table 68 (concl'd)

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977p	1978f
						($ million)					
Repair											
Construction	56.3	73.7	93.5	102.7	106.8	138.0	159.0	215.2	287.4	285.8	315.1
Machinery	19.2	19.0	22.5	28.7	35.6	54.2	62.3	68.5	82.9	110.2	127.2
Total	75.5	92.7	116.0	131.4	142.4	192.2	221.3	283.7	370.3	396.0	442.3
Total capital and repair	540.9	634.6	754.8	872.1	962.9	1 127.3	1 447.5	1 858.4	2 532.4	3 032.1	3 166.2
Total mining											
Capital											
Construction	782.4	888.5	996.1	1 314.8	1 134.8	1 276.3	1 586.5	1 968.1	2 356.9	2 872.3	2 949.6
Machinery	291.6	288.7	352.4	446.7	485.5	404.4	448.9	643.9	1 084.0	1 163.0	823.8
Total	1 074.0	1 177.2	1 348.5	1 761.5	1 620.3	1 680.7	2 035.4	2 612.0	3 440.9	4 035.3	3 773.4
Repair											
Construction	108.5	119.8	137.2	149.5	139.4	192.5	230.8	302.7	368.9	376.0	408.6
Machinery	228.9	244.6	342.6	376.7	394.4	489.1	612.7	699.5	830.7	886.4	923.1
Total	337.4	364.4	479.8	526.2	533.8	681.6	843.5	1 002.2	1 199.6	1 262.4	1 331.7
Total capital and repair	1 411.4	1 541.6	1 828.3	2 287.7	2 154.1	2 362.3	2 878.9	3 614.2	4 640.5	5 297.7	5 105.1

[1] Does not include cement, lime and clay products (domestic clays) manufacturing, smelting and refining. [2] Includes coal mines, asbestos, gypsum, salt, potash, miscellaneous nonmetals, quarrying and sand pits.
[p] Preliminary; [f] Forecast.

Table 69. Canada, capital and repair expenditures in the mineral manufacturing industries[1], 1968-78

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977[p]	1978[f]
					($ million)						
Primary metal industries[2]											
Capital											
Construction	77.5	71.5	114.0	89.0	95.3	75.8	148.0	200.5	144.8	188.4	202.9
Machinery	157.9	221.4	311.2	312.4	276.6	328.5	549.7	614.4	496.1	529.3	571.4
Total	235.4	292.9	425.2	401.4	371.9	404.3	697.7	814.9	640.9	717.7	774.3
Repair											
Construction	27.7	22.6	28.6	28.4	35.3	38.8	51.6	65.8	63.2	62.1	66.9
Machinery	281.4	267.9	324.6	343.5	383.2	420.1	507.3	563.4	632.4	625.7	707.0
Total	309.1	290.5	353.2	371.9	418.5	458.9	558.9	629.2	695.6	687.8	773.9
Total capital and repair	544.5	583.4	778.4	773.3	790.4	863.2	1 256.6	1 444.1	1 336.5	1 405.5	1 548.2
Nonmetallic mineral products[3]											
Capital											
Construction	19.6	37.1	30.7	21.8	30.7	37.6	29.5	41.1	46.6	67.4	56.8
Machinery	66.5	84.0	104.3	58.5	99.2	151.1	144.7	158.0	195.4	217.1	198.6
Total	86.1	121.1	135.0	80.3	129.9	188.7	174.2	199.1	242.0	284.5	255.4
Repair											
Construction	7.2	7.2	5.4	7.0	8.5	7.5	11.3	14.4	15.4	15.0	17.1
Machinery	73.8	72.1	77.1	80.4	85.7	112.0	130.9	151.8	164.9	148.9	168.7
Total	81.0	79.3	82.5	87.4	94.2	119.5	142.2	166.2	180.3	163.9	185.8
Total capital and repair	167.1	200.4	217.5	167.7	224.1	308.2	316.4	365.3	422.3	448.4	441.2
Petroleum and coal products											
Capital											
Construction	99.0	116.9	213.7	211.3	214.0	229.7	321.7	337.5	255.9	278.5	209.9
Machinery	28.8	12.9	17.4	20.1	29.8	89.1	107.8	112.9	88.3	98.9	83.5
Total	127.8	129.8	231.1	231.4	243.8	318.8	429.5	450.4	344.2	377.4	293.4
Repair											
Construction	46.6	52.1	51.0	51.3	61.3	71.1	83.8	96.1	101.2	124.5	140.0
Machinery	8.6	6.8	9.2	9.8	14.6	17.3	27.0	37.0	35.8	43.2	45.4
Total	55.2	58.9	60.2	61.1	75.9	88.4	110.8	133.1	137.0	167.7	185.4
Total capital and repair	183.0	188.7	291.3	292.5	319.7	407.2	540.3	583.5	481.2	545.1	478.8

Table 69. (concl'd)

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977[p]	1978[f]
						($ million)					
Total mineral manufacturing industries											
Capital											
Construction	196.1	225.5	358.4	322.1	340.0	343.1	499.2	579.1	447.3	534.3	469.6
Machinery	253.2	318.3	432.9	391.0	405.6	568.7	802.2	885.3	779.8	845.3	853.5
Total	449.3	543.8	791.3	713.1	745.6	911.8	1 301.4	1 464.4	1 227.1	1 379.6	1 323.1
Repair											
Construction	81.5	81.9	85.0	86.7	105.1	117.4	146.7	176.3	179.8	201.6	224.0
Machinery	363.8	346.8	410.9	433.7	483.5	549.4	665.2	752.2	833.1	817.8	921.1
Total	445.3	428.7	495.9	520.4	588.6	666.8	811.9	928.5	1 012.9	1 019.4	1 145.1
Total capital and repair	894.6	972.5	1 287.2	1 233.5	1 334.2	1 578.6	2 113.3	2 392.9	2 240.0	2 399.0	2 468.2

[1]Industry groups are the same as in Table 28. [2]Includes smelting and refining. [3]Includes cement, lime and clay products manufacturing.
[p]Preliminary; [f]Forecast.

Table 70. Canada, capital expenditures in the petroleum, natural gas and allied industries[1], 1967-78

	Petroleum and Natural Gas Extraction[2]	Transportation, Including Rail, Water and Pipelines	Marketing (chiefly outlets of oil companies)	Natural Gas Distribution	Petroleum and Coal Products Industries	Natural Gas Processing Plants	Total Capital Expenditures
				($ million)			
1967	385.1	204.9	86.8	76.4	100.2	89.7	943.1
1968	374.3	247.9	87.6	117.4	127.6	91.1	1 045.9
1969	438.1	220.6	103.6	117.0	129.8	103.8	1 112.9
1970	449.3	246.5	100.0	100.4	231.1	189.5	1 316.8
1971	489.6	352.0	99.2	115.2	231.4	251.1	1 538.5
1972	690.2	440.9	111.8	141.7	243.8	130.3	1 758.7
1973	864.8	390.9	128.0	146.3	318.8	70.3	1 919.1
1974	1 087.8	262.4	144.7	191.7	429.5	138.4	2 254.4
1975	1 427.2	361.9[r]	152.8	192.7	450.4	147.5	2 732.5[r]
1976	1 998.8	337.3	164.9	182.3	344.2	163.3	3 190.8
1977[p]	2 429.0	380.4	149.6	216.2	377.4	207.1	3 759.7
1978[f]	2 399.6	371.7	164.3	220.7	293.4	324.3	3 774.0

[1]The petroleum and natural gas industries in this table include all companies engaged in whole or in part in oil and gas activities. [2]Includes capital expenditures by oil and gas drilling contractors since 1967. Does not include expenditures for geological and geophysical operations. See also Footnote 3 to Table 67.

[p] Preliminary; [r] Revised; [f] Forecast.

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