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MINING TECHNOLOGY - STATISTICS

1972 AND 1973 DEVELOPMENTS

AMIL DUBNIE

MINING RESEARCH CENTRE

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MINING TECHNOLOGY - STATISTICS 1972 AND 1973 DEVELOPMENTS

by

Amil Dubnie*

SUMMARY

The tonnage of metallic ore mined underground in Canada decreased in 1972 while a corresponding increase took place in the tonnage mined from surface bringing the latter to 72% of the total.

In the non-metallic less coal mine category, tonnages showed only a minor increase. In coal mines, the tonnage derived from surface increased, reaching 79% of the total for the group.

During 1972, about 37% of underground metallic ore was mined by the cut-and-fill method or variations, followed by open stoping at 31%.

The general trend of underground mining costs is up, while productivity has not shown a comparable rise. Costs and productivity in surface mines are holding approximately at previous levels.

Promising advances in underground mining during 1973 were the use of a "roadheader" for mining without drilling and blasting under certain conditions, and the application of large-diameter holes to open stoping.

Key Words: Mining, Stoping, Mines Costs

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LA TECHNOLOGIE MINIÈRE - LES STATISTIQUES DE 1972 ET LES DÉVELOPPEMENTS DE 1973

par

Amil Dubnie*

RÉSUMÉ

En 1972, le tonnage de minerai métallique exploité souterrainement au Canada a diminué pendant qu'une augmentation correspondante s'est produite dans le tonnage de la surface. Cela amène ce dernier à 72% du total.

Dans la catégorie des mines non-métalliques sans compter les mines de charbon, les tonnages ont seulement montré une augmentation mineure. Dans les mines de charbon, le tonnage provenant de la surface a augmenté, atteignant 79% du total pour le groupe.

Pendant 1972, environ 37% du minerai métallique souterrain a été exploité par la méthode par chambre remblayée ou par les variations, suivie par l'abattage par chambre vide se situant à 31%.

La tendance générale des coûts de l'exploitation souterraine augmente pendant que la productivité n'a pas montré d'augmentation comparable. Les coûts et la productivité dans les mines à ciel ouvert restent à peu près aux mêmes niveaux qu'auparavant.

Pendant 1973, il y a eu des progrès prometteurs dans le domaine de l'exploitation souterraine avec l'utilisation d'un "excavateur de voie" pour l'exploitation sans forage et sans abattage à l'explosif sous certaines conditions, et aussi avec l'application des trous à large diamètre à l'abattage par chambre vide.

Mots clefs: Exploitation, Abattage, Coûts miniers.

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The Mines Branch, Department of Energy, Mines and Resources, as well as pursuing research in matters of interest to the mineral industry, gathers information on the trends in mining technology. The purpose of these activities is to assess the effects of new developments and to identify areas into which research efforts can be profitably directed.

The Mines Branch works closely with Statistics Canada in the gathering of production and technical information from statistical and other reports. Information is obtained from Statistics Canada, technical literature and mining companies and associations.

The report that follows presents a series of statistical tables which outline the growth of mining and shows trends in technology. The most recent year for which complete production data are available is 1972; therefore the tables cover this year. Complete data for 1973 will be available early in 1975. A brief summary is given of the technical advances which occurred in 1973.

Preliminary estimates released by Statistics Canada in January, 1974 show that the value of Canadian mineral production reached a new high of $8.24 billion in 1973, compared with the previous high of $6.40 billion in 1972. All sectors of the mineral industry showed substantial increases, led by mineral or fossil fuels which recorded an increase of 37.1%, the non-metals group 14.8% and the structural materials 6.9%. The per cent increase in value generally exceeded the per cent increase in volume owing to rising prices. Figure 1, based on Statistics Canada reports, gives a graphical presentation of the value of mineral production by classes, since 1950.

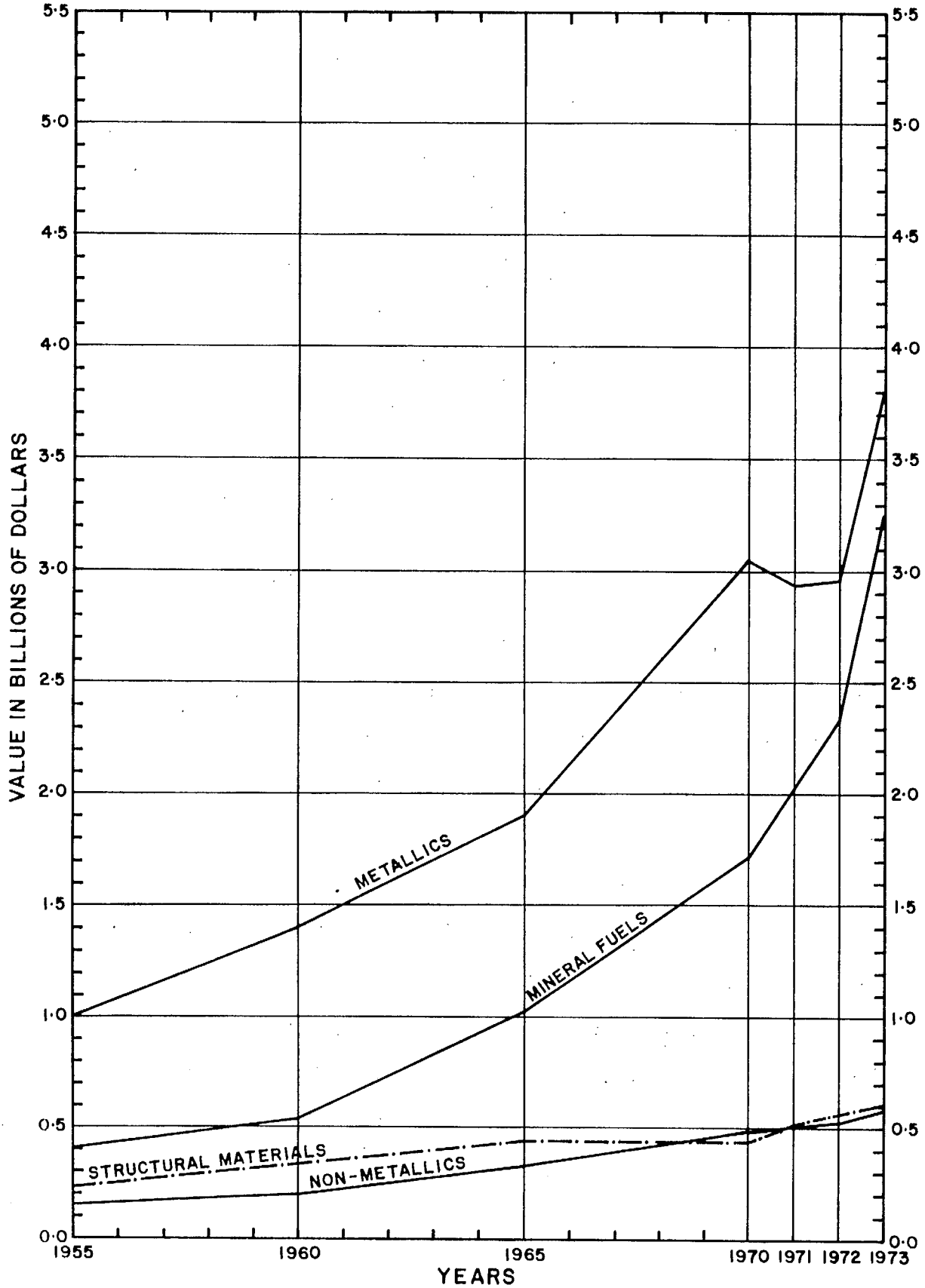

Figure 1. Value of Canadian Mineral Production by Classes, 1950-1973

TABLE 1

TONNAGE OF ORE MINED AND ROCK QUARRIED IN CANADA

Selected Years, 1950 to 1972
(millions of net tons)

Types of Mines	1950	1960	1965	1968	1969	1970	1971	1972
METAL MINES (excluding waste broken)								
Gold - Quartz	17.0	14.7	12.0	9.3	9.0	8.0	7.4	6 7
Uranium[1]	-	-	-	-	-	2.0	3.2	3.2
Iron Ore	4.4	33.0	89.2	100.9	90.9	103.0	100.8	93.6
Copper - Gold - Silver	8.8	14.0	20.0	34.8	33.2	42.3	48.8	72.1
Nickel - Copper	10.8	20.8	24.3	29.5	22.2	34.6	34.2	25.5
Silver - Cobalt	0.7	0.2	0.3	0.3	0.2	0.2	0.3	0.1
Silver - Lead - Zinc	4.8	5.8	10.1	12.6	13.5	14.0	14.4	12.3
Molybdenum[1]	-	-	-	-	-	18.1	12.3	7.1
Misc. Metal Mines	0.2	13.0	10.7	14.5	21.4	4.0[2]	4.1	3.6
Sub-total, Metal Mines[3]	46.7	101.5	166.6	205.0	190.4.	226.4	225.5	224.2
NON-METAL MINES (excluding waste broken)								
Asbestos[4]	12.2	33.2	53.4	31.5	32.5	34.9	36.1	34.3
Gypsum	3.8	5.1	6.1	7.5	6.6	6.2	6.5	8.0
Talc and Soapstone	-	0.1	0.1	0.1	-	0.1	0.1	0.1
Feldspar, Quartz, Neph Syen.	1.1	1.6	2.0	1.8	1.9	1.2	2.1	2 0
Rock Salt	-	1.3	3.4	3.9	3.2	4.4	4.6	4.6
Potash[5]	-	-	-	-	-	13.9	15.6	17.0
Other non-metals	0.5	0.7	5.7	11.3	14.2	0.3	1.1	0.5
Sub-total, Non Metal Mines[3]	17.6	42.0	70.7	56.1	58.4	61.0	66.1	66.5
Stone, all kinds, quarried	18.1	45.4	76.8	75.9	70.1	70.7	73.5	80.2
COAL MINING (excluding waste broken)								
Coal	18.5	10.7	11.4	11.0	10.7	16.6	18.4	20.7
Grand Total, Ore and Rock[3]	100.9	199.6	305.5	348.0	329.6	374.7	383.5	391.6

(1) with miscellaneous metals prior to 1970
(2) excludes uranium and molybdenum as of 1970
(3) may not balance owing to individual rounding
(4) waste included, 1950-1967, inclusive
(5) included with "other non-metals", prior to 1970.

Source: Statistics Canada, Reports.

PRODUCTION ANALYSIS

Tonnage of ore and waste mined

Table 1 shows the tonnages of ore mined and rock quarried in the Canadian mining industry for selected years between 1950 and 1972. Waste material is not included except for asbestos mines where waste broken in surface mines is normally included in Statistics Canada reports. To bring the reports for metals and non-metals to the same standard, waste was excluded by the author for non-metal mines, commencing in 1968. Table 1 shows the changes in the scale of production of metal and non-metal ores. During 1972 the production of most ores decreased in volume. However, the large increase in copper ore over 1971 and substantial increases for potash, gypsum, stone and coal resulted in a net increase of about 2% in total ore. The production of coal showed an increase to 20.71 million tons in 1972 and the preliminary figure for 1973 was 21.96 million tons.

Underground and surface mining

Table 2 gives a comparison of ore produced from underground and surface mines during the period from 1950 to 1972. During 1972 there was a reduction of about 11 million tons in the metallic ore mined from underground which was approximately balanced by an increase in surface ore. Surf .ce mined ore represented 72% of the total ore in metal mines in 1972, an all time high.

Table 2 does not show the large amounts of waste mined in surface mines. In 1971 the waste to ore ratio for producing surface metal mines was 94:100. In 1972 the ratio was 89:100. This includes only the waste which was drilled and blasted. It is estimated that about 55 million tons of waste was excavated in producing surface metal mines without drilling and blasting. There was also an unknown tonnage of waste from mines in the pre-production period. Until a mine reaches production status, no data on waste mined are gathered by federal agencies.

TABLE 2

ORE DISTRIBUTION - SURFACE AND UNDERGROUND

(millions of net tons of ore broken)

	METAL MINES				NON-METAL MINES				COAL MINES			
Year	Underground	Surface	Total	Surface % of Total	Underground	Surface	Total	Surface % of Total	Underground	Surface	Total	Surface % of Total
1950	39.6	6.3	45.9	14	2.3	15.4	17.7	87	13.3	5.8	19.1	30
1960	74.8	26.8	101.6	26	3.5	38.5	42.0	92	6.7	4.3	11.0	39
1965	81.0	85.5	166.5	51	9.8	60.8	70.6	86	6.0	5.6	11.6	48
1966	67.5	94.8	162.3	58	11.1	67.4	78.5	86	6.0	5.4	11.4	47
1967	70.9	115.6	186.5	62	18.2	79.4	97.6	81	5.5	5.9	11.4	52
1968	70.0	135.0	205.0	66	17.9	38.2	56.1(1)	68	4.7	6.3	11.0	57
1969	62.7	127.8	190.5	67	20.2	38.3	58.5	65	4.3	6.4	10.7	60
1970	71.3	155.1	226.4	69	20.8	40.2	61.0	66	4.6	12.0	16.6	72
1971	75.5	149.9	225.4	66	23.0	42.9	65.9	65	4.6	13.8	18.4	75
1972	64.2	160.2	224.4	72	24.2	42.3	66.5	64	4.3	16.4	20.7	79

(1) Waste not included for 1968 and later years.

Source: Statistics Canada reports and author's estimates.

In 1972, an estimated 4.7 million tons of waste were mined in underground metal mines to recover 64.2 million tons of ore. However, there was also a large amount of waste from development work. It is estimated that during 1972, 145 miles of lateral development and 58 miles of raises were driven in Canadian underground mines.

In surface mining of industrial minerals, the waste to ore ratio for 1972 is estimated at 1.14:1 against 1.05:1 in 1971. The ratio fluctuates depending on the opening of new mines and implementation of short-term major stripping programs in established mines. The smaller number of industrial mineral mines compared with metal mines, tends to accentuate the effect of major stripping programs on the waste to ore ratio for the group. Less than a million tons of waste were mined in underground industrial mineral mines with potash accounting for the largest volume.

During 1972, surfaced-mined coal accounted for 79% of the totalcoal. Tonnage in this report refers to clean coal. Not shown in Table 2 is the rock waste drilled and blasted before coal can be removed in some western Canadian surface mines. For 1972, it is estimated that approximately 50 million tons of waste rock was stripped.

If waste (tailings) rejected during processing is taken into account, it can be readily seen that the final saleable product from mines represents only a small part of the volume actually mined. For example, for asbestos mining in 1972, about 34.3 million tons of ore were mined and 44.9 million tons of waste rock were stripped for a total of 79.2 million tons. The fibre actually shipped amounted to 1.7 million tons or 2.1% of the ore and waste mined. In addition, the asbestos mining companies excavated 34.4 million tons of overburden without blasting, which is not included in the estimates. In base metal mining, a greater percentage of the product is shipped owing to the different degree to which the ore is concentrated; however, tons shipped may be 10 to 15% of that mined.

TABLE 3

METHODS USED IN MINING OF CANADIAN ORES - 1969

(millions of net tons of ore broken)

Ore Mined	Total No. of Mines	Tons Broken	UNDERGROUND MINES								SURFACE MINES	
			Stoping Methods									
			Shrinkage	Cut & Fill Sg. Set. Stulls	Longholes Open Stopes Sublevel	Shortholes Open Stopes Sills	Room & Pillar Panel	Caving -block -sublevel	Number of mines	Tons Ore Broken	Number of mines	Tons Ore Broken
METAL MINES												
Gold - Quartz	32	9.03	2.46	3.33	2.59	0.65	-	-	32	9.03	nil	-
Copper - Gold	54	33.14	2.06	4.40	5.86	1.71	1.19	1.10	43	16.32	11	16.82
Nickel - Copper	28	22.16	1.53	10.31	3.99	0.06	-	4.00	24	19.89	4	2.27
Silver - Cobalt	7	0.22	0.22	-	-	-	-	-	7	0.22	nil	-
Silver - Lead - Zinc	21	13.51	0.61	0.99	4.15	0.11	2.80	-	18	8.66	3	4.85
Uranium	4	3.06	-	0.44	-	-	2.60	-	3	3.04	n/a	n/a
Iron Ore	18	90.88	-	-	2.21	-	1.34	-	3	3.55	15	87.33
All Other Metals	13	18.43	0.38	0.12	1.28	-	0.17	-	6	1.95	7	16.48
Total Metals (1)	177	190.43	7.26	19.59	21.18	2.43	8.10	5.10	136	62.66	40	127.75
NON-METAL MINES												
Asbestos	13	32.54	-	-	-	-	-	n/a	2	n/a	11	30.63
Gypsum	12	6.56	-	-	-	-	0.71	-	3	0.71	9	5.85
Salt	3	3.21	-	-	-	-	3.21	-	3	3.21	nil	-
Barite	2	n/a	-	n/a	-	-	-	n/a	2	n/a	nil	-
Feldspar, Qtz, Neph-syen.	12	1.73	-	-	-	-	-	-	nil	-	12	1.73
Potash	8	13.84	-	-	-	-	13.84	-	8	13.84	nil	-
Talc and Pyrophyllite	3	0.05	n/a	-	-	-	-	-	2	n/a	1	n/a
Fluorspar and Misc.	2	0.27	-	0.20	0.07	-	-	-	2	0.27	nil	-
Total Non-Metals (1)	55	58.45	n/a	0.26	0.07	-	17.76	2.06	22	20.17	33	38.28
FUELS												
Coal	43	10.67	-	-	mined by longwall and room and pillar methods				18	4.27	25	6.40
Total, all ores (1)	275	259.55	7.28	19.85	21.25	2.43	27.44	7.16	176	87.10	99	172.45

(1) Totals may not balance due to individual rounding and to absence of data (noted n/a) which could not be published under the Statistics Act.

Source: Statistics Canada and author's estimates.

TABLE 4

METHODS USED IN MINING OF CANADIAN ORES - 1970

(millions of net tons of ore broken)

Ore Mined	Total No. of Mines	Total Tons Broken	UNDERGROUND MINES									SURFACE MINES	
			Stoping Methods										
			Shrinkage	Cut & Fill Undercut & Fill	Open Stoping	Room and Pillar	Sublevel Caving	Caving, Other	Other Methods	No. of Mines	Tons Ore Broken	No. of Mines	Tons Ore Broken
METAL MINES													
Gold - Quartz	29	8.01	2.00	2.87	1.44	0.13	0.22	1.09	0.27	29	8.01	nil	-
Uranium	4	1.96		0.33		1.63				4	1.96	1	n/a
Iron Ore	15	102.96	-	-	-	-	-	-	-	2	n/a	14	99.52
Copper - Gold - Silver	50	42.43	2.78	3.61	7.96	0.43	1.98	0.52		36	17.28	14	25.16
Nickel - Copper	29	34.64	2.96	11.59	2.52	-	8.17	5.52	0.31	24	31.07	5	3.59
Silver - Cobalt	7	0.25	0.22	-	-	-	-	-	-	6	0.22	1	n/a
Silver - Lead - Zinc	26	13.96	0.47	0.55	5.51	.23	-	.03	0.20	22	6.98	4	6.98
Molybdenum	7	18.10	0.66	-	0.68	-	-	-	-	4	1.34	3	16.76
Other Metals	6	4.05	-	0.18	0.71	0.16	-	-	-	3	1.05	3	3.00
Total Metals[1]	173	226.36	9.09	19.13	18.82	2.58	10.37	7.16	0.78	130	67.93	45	155.01
NON-METAL MINES													
Asbestos	13	34.93	-	-	-	-	-	n/a	-	2	n/a	11	33.14
Gypsum	10	6.18	-	-	-	0.34	-	-	-	3	0.34	7	5.84
Talc-Soapstone-Pyrophyllite	4	0.03	n/a	-	n/a	-	-	n/a	-	2	n/a	2	n/a
eldspar and Quartz	9	1.16	-	-	-	-	-	-	-	nil	-	9	1.16
lt (mined only)	3	4.37	-	-	-	4.37	-	-	-	3	4.37	nil	-
otash	9	13.93	-	-	-	13.93	-	-	-	9	13.93	nil	-
Other non-metals	4	0.33	-	0.20	.03	-	-	0.11	-	3	0.33	1	n/a
Total, Non-Metals	52	60.93	-	0.20	0.03	18.64	-	0.11		22	18.97	30	39.14
FUELS													
Coal	29[2]	16.60	Underground coal mined by longwall and room and pillar, not included in totals below.							15	4.62	14	11.98
Total, all ores[1]	254	303.89	9.09	19.33	18.85	21.22	10.37	7.27	0.78	167	91.52	89	206.13

(1) Totals may not balance due to individual rounding and to absence of data (noted n/a) which cannot be published under the Statistics Act.

(2) Includes only mines producing 25,000 tons per year or more, but total tons produced is from all mines.

Source: Statistics Canada and author's estimates.

TABLE 5

METHODS USED IN MINING OF CANADIAN ORES, 1971

(millions of net tons of ore broken)

Ore Mines	Total No. of Mines	Total Tons Broken	UNDERGROUND MINES									SURFACE MINES	
			Stoping Methods										
			Shrinkage	Cut & Fill Undercut & Fill	Open Stoping	Room and Pillar	Sublevel Caving	Caving Other	Other Methods	No. of Mines	Tons Ore Broken	No. of Mines	Tons Ore Broken
METAL MINES													
Gold - Quartz	27	7.38	1.89	3.29	1.57	-	.12	-	.09	27	7.38	nil	-
Uranium	4	3.17	-	.21	-	2.95	-	-	-	3	3.16	1	.01
Iron Ore	17	100.75	-	-	1.09	.08	1.54	1.5	-	3	4.21	14	96.55
Copper - Gold - Silver	52	48.73	3.00	3.04	10.00	.30	5.0	-	.30	38	21.95	14	26.78
Nickel - Copper	10	34.23	4.04	16.53	2.22	.01	6.49	1.00	.53	8	30.81	2	3.42
Silver - Cobalt	7	.26	.21	-	.05	-	-	-	-	7	.26	nil	-
Silver - Lead - Zinc	19	14.40	.44	1.70	4.01	.03	-	.01	.17	15	6.36	4	8.04
Molybdenum	8	12.32	.09	-	.58	-	-	-	-	4	.67	4	11.65
Other Metals	6	4.11	-	.12	.35	.16	-	-	.07	3	.70	3	3.41
Total Metals[1]	150	225.35	9.67	24.89	19.87	3.53	13.15	2.51	1.16	108	75.50	42	149.86
NON-METAL MINES													
Asbestos	13	36.06	-	-	-	-	-	n/a	-	2	n/a	11	34.24
Gypsum	11	6.46	-	-	-	.81	-	-	-	3	.81	8	5.65
Talc - Soapstone - Pyrophyllite	4	.07	n/a	-	-	-	n/a	n/a	-	2	n/a	2	n/a
Feldspar & Quartz	12	2.08	-	-	-	-	-	-	-	nil	-	12	2.08
Salt	3	4.58	-	-	-	4.58	-	-	-	3	4.58	nil	-
Potash	8	15.60	-	-	-	15.60	-	-	-	8	15.60	nil	-
Other, Non-Metals	10	1.08	-	.13	.01	-	-	.04	-	2	.18	8	.90
Total Non-Metals[1]	61	65.93		.13	.01	20.99		.04		20	23.02	41	42.91
FUELS													
Coal	26[2]	18.43	Underground coal mined by longwall, room and pillar and hydraulicking, not included in totals below.							13	4.62	13	13.81
Total, All Ores[1]	237	309.71	9.68	25.02	19.88	24.52	13.16	4.38	1.16	141	103.14	96	206.58

(1) Totals may not balance owing to individual rounding and to absence of data (noted n/a) which cannot be published under The Statistics Act

(2) Includes only mines producing 25,000 tons per year or more, but total tons produced is from all mines.

Source: Statistics Canada and author's estimates.

TABLE 6

METHODS USED IN MINING OF CANADIAN ORES, 1972

(millions of net tons of ore broken)

Ore Mines	Total No. of Mines	Total Tons Broken	UNDERGROUND MINES — Stoping Methods: Shrinkage	Cut & Fill Undercut & Fill	Open Stoping	Room and Pillar	Sublevel Caving	Caving Other	Other Methods	No. of Mines	Tons Ore Broken	SURFACE MINES: No. of Mines	Tons Ore Broken
METAL MINES													
Gold - Quartz	21	6.74	1.47	2.65	1.28	-	.56	.29	.31	21	6.74	nil	-
Uranium	3	3.20	.10	.10	-	2.67	-	-	.33	3	3.20	nil	-
Iron Ore	17	93.60	-	-	4.17	.12	.11	-	-	3	4.39	14	89.20
Copper - Gold - Silver	53	72.12	.95	4.49	6.73	2.11	4.27	.95	.53	36	20.02	17	52.10
Nickel - Copper	13	25.46	.18	16.31	2.86	-	1.68	1.00	.95	9	22.97	4	2.49
Silver - Cobalt	4	0.13	.13	-	-	-	-	-	-	4	0.13	nil	-
Silver - Lead - Zinc	15	9.44	.46	.15	4.85	-	-	-	.08	12	5.41	3	4.02
Molybdenum	4	7.14	.18	.02	-	-	-	-	-	2	.21	2	6.93
Other Metals	8	3.62	.60	.12	.03	.36	-	-	-	5	1.12	3	2.50
TOTAL METALS	138	221.45	4.07	23.84	19.94	5.26	6.62	2.24	2.20	95	64.19	43	157.24
NON-METAL MINES													
Asbestos	13	34.26	-	-	-	-	-	1.29	-	2	n/a	11	32.97
Gypsum	10	8.04	-	-	-	.88	-	-	-	3	.88	7	7.16
Talc - Soapstone - Pyrophy	4	.09	n/a	-	-	-	n/a	n/a	-	2	n/a	2	n/a
Feldspar & Quartz	12	1.99	-	-	-	-	-	-	-	nil	-	12	1.99
Salt	3	4.62	-	-	-	4.62	-	-	-	3	4.62	nil	-
Potash	8	16.99	-	-	-	16.99	-	-	-	8	16.99	nil	-
Other, Non-Metals	8	.52	-	.24	.15	-	-	-	-	3	.40	5	.12
TOTAL NON-METALS	58	66.51	.01	.24	.15	22.49	.01	1.30	-	21	24.22	37	42.29
FUELS													
Coal	29	20.70	Underground coal mined by longwall, room & pillar, & hydraulicing, not included in totals below									20	16.40
TOTAL, ALL ORES	225	308.66	4.08	24.08	20.09	27.75	6.64	3.54	2.20	116	88.41	100	215.93

Mining methods used in breaking Canadian ores

Tables 3 to 6 show the mining methods used in breaking Canadian ores from 1969 to 1972 inclusive. During the compilation of these tables, it was difficult to classify some underground mines owing to the variations of recognized mining methods. However, the tonnage mined was distributed as impartially as possible among the headings which represent the recognized methods.

An example of the difficulty of classifying mining methods is illustrated by open stoping whereby the ore may be drilled off with either long or short holes. The sublevel caving method sometimes does not rely on "caving" for breaking the ore, in which case it could be considered as open stoping. Again, a mining company may rely largely on caving, yet may induce caving by doing some drilling and blasting.

Since 1970, mining methods have been reclassified to exclude "blasthole stoping" which is a term inconsistent with the normal classification according to the method of support. Long holes may be used for shrinkage, open or other stoping.

Tables 3 to 6 show that cut-and-fill stoping or variations of it are most widely used in underground metal mining, followed by open stoping with long holes. There appears to be a sharp drop for 1972 in the use of sublevel caving. This is believed partly due to one substantial mine which formerly reported using sublevel caving but now reports open stoping with long holes, and to the rapid rise in post-pillar cut-and-fill stoping in one major mining district.

The room-and-pillar method dominates in underground mining of industrial minerals inasmuch as the method is ideally suited to Canadian deposits of potash, salt and gypsum.

TABLE 7

ROCK BREAKING ANALYSIS, CANADIAN MINERAL MINES

(average of years 1968 and 1969)

Type of Mining	UNDERGROUND MINES								SURFACE MINES			
	LONGHOLE DRILLING				SHORTHOLE DRILLING				LONGHOLE DRILLING			
	Tons ore & waste broken	Feet drilled	Most common bit diam.	Tons per foot drilled	Tons ore & waste broken	Feet drilled	Most common bit diam.	Tons per foot drilled	Tons ore & waste broken	Feet drilled	Most common bit diam.	Tons per foot drilled
	(millions)		(in.)		(millions)		(in.)		(millions)		(in.)	
METAL MINES												
Gold-Quartz	2.4	2.4	1 5/8	1.0	7.0	21.6	1 1/4	0.33	nil	-	-	-
Copper - Gold	7.1	6.0	1 3/4	1.2	10.2	24.9	1 1/4	0.41	49.0	2.3	9 7/8	21.2
Nickel - Copper	10.1	5.6	2 1/8	1.8	14.3	31.7	1 3/8	0.45	7.7	0.4	9 7/8	20.8
Silver - Cobalt	nil	-	-	-	0.3	1.4	1 1/4	0.20	nil	-	-	-
Lead - Zinc	4.4	4.2	2	1.1	4.8	11.3	1 1/4	0.43	8.4	0.4	9	20.5
Uranium	nil	-	-	-	3.4	9.2	1 3/8	0.36	nil	-	-	-
Iron Ore	3.9	1.7	2 1/8	2.2	nil	-	-	-	139.0	4.8	9 7/8 12 1/4	28.8
Other Metals	1.2	1.3	1 5/8	1.0	0.6	2.9	1 1/4	0.21	21.7	1.2	9	16.8
Total Metals	29.1	21.2	-	1.4	40.6	103.0	-	0.40	225.8	9.1	-	24.7
NON-METAL MINES												
Asbestos	-	-	-	-	1.9	0.8	1 3/8	2.35	81.1	7.0	4 6 1/2	11.7
Gypsum	-	-	-	-	0.7	0.9	1 3/4	0.76	8.5	1.5	2 1/8	5.8
Salt	-	-	-	-	4.3	5.3	1 7/8	0.80	nil	-	-	/-
Barite	-	-	-	-	0.2	0.3	2 1/8	0.71	nil	-	-	-
Feld. Qtz., N.Syen.	-	-	-	-	nil	-	-	-	1.7	0.3	3	5.4
Potash	Boring machines mostly used - little drilling and blasting								nil	-	-	-
Pyrophyllite and Talc	-	-	-	-	0.04	0.06	1 1/4	0.67	0.2	0.01	2 1/2	20.0
Fluorspar and Misc.	0.9	0.9	1 7/8	1.0	0.18	0.25	1 1/4	0.72	nil	-	-	-
Total Non-Metals	0.9	0.9	-	1.0	7.3	7.6	-	0.96	91.5	8.8	-	10.4

Source: Statistics Canada and author's estimates.

TABLE 8

ROCK BREAKING ANALYSIS, CANADIAN MINERAL MINES, 1970

ORE MINED	UNDERGROUND MINES								SURFACE MINES			
	LONGHOLE DRILLING				SHORTHOLE DRILLING				LONGHOLE DRILLING			
	Tons ore & waste broken	Feet drilled	Common bit diameter	Tons per foot drilled	Tons ore & waste broken	Feet drilled	Common bit diameter	Tons per foot drilled	Tons ore & waste broken	Feet drilled	Common bit diameter	Tons per foot drilled
	(millions)		(inches)		(millions)		(inches)		(millions)		(inches)	
METAL MINES												
Gold - Quartz	1.2	0.9	1 5/8	1.35	7.2	18.0	1 1/4	0.40	nil	-	-	-
Uranium	n/a	n/a	n/a	n/a	2.2	10.0	1 3/8	0.22	n/a	n/a	n/a	n/a
Iron Ore	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	141.7	4.0	7 7/8 to 12 1/4	35.4
Copper - Gold - Silver	10.1	7.8	1 7/8	1.36	8.8	18.0	1 1/4	0.49	70.6	3.3	9	21.6
Nickel - Copper	11.3	5.7	2 1/8	1.99	21.5	30.7	1 3/8	0.70	10.4	0.3	9 7/8	33.9
Silver - Cobalt	-	-	-	-	0.2	1.0	1 1/4	0.20	n/a	n/a	n/a	n/a
Silver - Lead - Zinc	5.6	2.3	2 1/4	2.39	1.8	6.0	1 1/4	0.30	24.7	1.0	9	25.2
Molybdenum	0.7	0.6	-	1.28	0.7	2.5	1 1/4	0.28	21.8	1.0	9	21.6
Other Metal Mines	n/a	n/a	n/a	n/a	0.4	1.1	1 5/8	0.36	5.8	0.2	6 1/2	31.8
Total Metals	28.9	17.3		1.67	42.8	87.3		0.49	275.0	9.8		28.1
NON-METAL MINES												
Asbestos	nil	-	-	-	n/a	n/a	1 3/8	1.92	88.7	6.2	2 to 9	14.3
Gypsum	nil	-	-	-	0.3	0.5	1 1/2	0.60	7.5	1.5	4	5.1
Talc - Soapstone - Pyrophyllite	nil	-	-	-	0.03	0.01	1 1/4	2.66	n/a	n/a	2 1/2	23.2
Feldspar and Quartz	nil	-	-	-	nil	-	-	-	1.3	0.2	3	5.6
Salt	nil	-	-	-	5.3	5.4	1 7/8	0.99	nil	-	-	-
Potash	Cutting machines used - little drilling and blasting								-	-	-	-
Other Non-Metals	-	-	-	-	0.3	0.7	1 3/8	0.42	n/a	n/a	n/a	n/a
Total, Non-Metals					5.9	6.6		0.89	97.5	7.9		12.3

Source: Statistics Canada reports and author's estimates.

n/a - not available

TABLE 9

ROCK BREAKING ANALYSIS, CANADIAN MINERAL MINES, 1971

ORE MINED	UNDERGROUND MINES								SURFACE MINES			
	LONGHOLE DRILLING				SHORTHOLE DRILLING				LONGHOLE DRILLING			
	Tons ore & waste broken	Feet drilled	Common bit diameter	Tons per foot drilled	Tons ore & waste broken	Feet drilled	Common bit diameter	Tons per foot drilled	Tons ore & waste broken	Feet drilled	Common bit diameter	Tons per foot drilled
	(millions)		(inches)		(millions)		(inches)		(millions)		(inches)	
METAL MINES												
Gold - Quartz	0.4	0.4	2	1.00	7.2	14.0	1 1/4	0.51	nil	-	-	-
Uranium	n/a	n/a	n/a	n/a	3.42	8.0	1 3/8	0.43	n/a	n/a	n/a	n/a
Iron Ore	4.2	1.2	2 1/8	3.50	-	-	-	-	151.2	3.2	7 7/8 to 12 1/4	47.25
Copper - Gold - Silver	6.3	3.2	2	1.97	15.0	25.2	1 1/4	0.60	77.8	2.6	9 7/8	29.80
Nickel - Copper	8.7	3.5	2 1/4	2.49	25.4	43.7	1 1/4	0.58	9.7	n/a	n/a	-
Silver - Cobalt	-	-	-	-	0.3	0.4	1 1/4	0.75	n/a	n/a	n/a	-
Silver - Lead - Zinc	3.7	2.0	2	1.85	2.5	5.1	1 3/8	0.49	25.1	1.0	9	25.1
Molybdenum	n/a	n/a	n/a	n/a	0.6	0.6	1 1/4	1.00	20.7	1.0	2 3/4 & 9	20.7
Other Metal Mines	n/a	n/a	n/a	n/a	0.4	0.5	1 5/8	0.8	5.7	0.3	6 1/2 & 3 1/2	19.0
Total Metals[1]	23.0	10.7		2.15	54.82	97.5		0.56	290.2	8.1		36.0
NON-METAL MINES												
Asbestos	nil	-	-	-	n/a	n/a	1 3/8	n/a	82.4	5.1	2 1/2 to 9	16.15
Gypsum	nil	-	-	-	0.8	1.8	n/a	0.44[3]	7.8	1.3	4	6.00[3]
Talc - Soapstone - Pyrophylite	nil	-	-	-	0.04	0.01	1 1/4	4.0	n/a	n/a	2 to 2 1/2	-
Feldspar and Quartz	nil	-	-	-	nil	-	-	-	2.2	0.2	1 1/2 to 4 1/2	11.0
Salt	nil	-	-	-	5.3	5.6	1 7/8	0.95	nil	-	-	-
Other Non-Metals[2]	nil	-	-	-	0.2	0.2	1 3/8	1.0	1.2	n/a	n/a	-
Total, Non-Metals[1]					8.14	7.11		1.01	93.6	5.8		16.14

(1) Totals may not balance owing to absence of data (shown n/a) which could not be published.
(2) Excluding potash.
(3) Revised.

n/a - not available

TABLE 10

ROCK BREAKING ANALYSIS, CANADIAN MINERAL MINES, 1972

ORE MINED	UNDERGROUND MINES								SURFACE MINES			
	LONGHOLE DRILLING				SHORTHOLE DRILLING				LONGHOLE DRILLING			
	Tons ore & waste broken	Feet drilled	Common bit diameter	Tons per foot drilled	Tons ore & waste broken	Feet drilled	Common bit diameter	Tons per foot drilled	Tons ore & waste broken	Feet drilled	Common bit diameter	Tons per foot drilled
	(millions)		(inches)		(millions)		(inches)		(millions)		(inches)	
METAL MINES												
Gold Quartz	1.3	0.9	2	1.40	5.8	13.9	$1\frac{1}{4}$	0.42	-	-	-	-
Uranium	-	-	-	-	3.5	8.4	$1\frac{5}{8}$	0.42	-	-	-	-
Iron-Ore	4.5	1.8	$2\frac{1}{2}$	2.50	-	-	-	-	121.4	3.2	7 to $12\frac{1}{4}$	37.80
Copper - Gold - Silver	10.9	6.9	$2\frac{5}{8}$	1.60	10.2	14.4	$1\frac{1}{4}$	0.71	140.8	8.5	$2\frac{3}{4}$ to $12\frac{1}{4}$	16.50
Nickel - Copper	2.7	0.9	$2\frac{1}{4}$	3.00	22.1	42.6	$1\frac{1}{4}$	0.52	4.6	0.4	n/a	11.50
Silver - Cobalt	-	-	-	-	0.1	0.4	$1\frac{1}{4}$	0.25	-	-	-	-
Silver - Lead - Zinc	4.3	2.3	2	1.90	1.3	4.3	$1\frac{5}{8}$	0.30	20.3	0.9	9	22.60
Molybdenum	nil	n/a	n/a	n/a	0.2	n/a	n/a	n/a	11.7	0.5	9	23.30
Other Metal Mines	n/a	n/a	n/a	n/a	1.2	2.6	$1\frac{1}{4}$	0.46	4.1	0.3	$3\frac{1}{2}$ to $6\frac{1}{2}$	13.60
TOTAL METALS(1)	23.7	12.8		1.85	44.4	86.6		0.51	282.9	13.8		20.50
NON-METAL MINES												
Asbestos	nil	-	-	-	n/a	n/a	$1\frac{5}{8}$	n/a	78.9	5.3	4 to 9	14.80
Gypsum	nil	-	-	-	0.9	1.9	$1\frac{1}{2}$	0.48	10.2	1.6	4	6.40
Talc - Soapstone - Pyroph	nil	-	-	-	0.04	.01	$1\frac{1}{4}$	4.00	n/a	n/a	2	n/a
Feldspar and Quartz	nil	-	-	-	nil	-	-	-	2.2	0.5	$1\frac{1}{2}$ to $4\frac{1}{2}$	4.40
Salt	-	-	-	-	5.6	4.6	$1\frac{7}{8}$	1.21	nil	-	-	-
Other Non-Metals(2)	0.2	0.1	$1\frac{7}{8}$	2.00	0.2	0.4	$1\frac{5}{8}$	0.50	0.1	n/a	n/a	n/a
TOTAL NON-METALS(1)	0.2	0.1		2.00	8.4	7.0		1.20	91.4	7.4		12.20

(1) Totals may not balance owing to absence of data (shown n/a) which could not be published.
(2) Excluding potash.

n/a = not available.

Rock breaking analysis

Tables 7 to 10 give estimates of the amount of drilling required to break rock between 1968 and 1972. It is apparent from the tables that long hole drilling produces over three times as much broken rock per foot of hole as short hole drilling. There is also a correlation between the tons broken per foot drilled and stoping method. Where larger-scale stoping methods are in use, the yield per foot drilled is high, whereas the converse also holds. This is illustrated in Table 10 by the higher yields in mining of iron ore, nickel, copper and lead-zinc compared with uranium, gold-quartz and silver-cobalt.

The large tonnage broken per foot of drilling in surface mining is to be expected owing to the large hole diameter. During 1972, the yield in iron ore mining was 37.80 tons per foot drilled; the yield for asbestos mining was 14.80 tons per foot but the average for all surface industrial minerals (12.20 tons per foot) was less because of low yields for gypsum and quartz.

Employment in producing mines

Tables 11 to 14 show total employment, cost of labour and labour productivity in Canadian mines for 1969 to 1972. The final tabulation is affected by the different policies of mining companies in distributing operating costs. It might be assumed from them that iron ore companies are less productive but this is due to the inclusion of personnel in the extensive port materials-handling facilities.

From available data, it is concluded that productivity is highest in the surface mines of copper, molybdenum, lead-zinc and iron ore. Productivity in surface industrial mineral mines follows the pattern of previous years. The

TABLE 11

SUMMARY OF EMPLOYMENT - CANADIAN PRODUCING MINES, 1969

TYPE OF MINING	ORE MILLED			Total Ore & Waste Broken	EMPLOYEES				Total Paid Manhours	Total salaries & wages Paid	LABOUR COST		Tons O & W broken per Manhour
	Under-ground	Surface	Total		Admin.	Mine	Mill	Total			Per Ton Milled	Per Ton O & W Broken	
	(millions of short tons)					(thousands)			(millions $)		($)	($)	
METAL MINES													
Gold - Quartz	9.3	-	9.3	9.3	1.2	6.0	1.2	8.4	17.9	51.5	5.55	5.52	0.52
Copper - Gold	16.1	16.5	32.6	68.1	2.4	6.9	3.6	12.9	26.5	92.5	2.84	1.36	2.57
Nickel - Copper	19.8	2.2	22.0	27.9	2.9	11.9	1.1	15.9	31.1	127.8	5.80	4.58	0.90
Silver - Cobalt	0.3	-	0.3	0.2	0.1	0.3	0.1	0.5	1.1	3.2	9.13	12.70	0.24
Lead - Zinc	8.0	4.8	12.8	18.5	1.1	3.5	1.1	5.7	11.9	42.6	3.33	2.30	1.55
Uranium - Rock Mining	3.1	-	3.1	3.5	0.6	1.3	0.5	2.4	5.1	20.7	6.75	6.03	0.68
Iron Ore	3.6	82.3	85.9	136.5	2.7	3.7	4.1	10.5	22.3	101.3	1.18	0.75	6.12
All Other Metals	1.9	14.5	16.4	24.8	0.4	1.4	0.3	2.1	4.7	16.5	1.01	0.67	5.33
NON-METAL MINES													
Asbestos	1.9	23.1	25.0	88.0	1.4	2.3	3.6	7.3	17.1	59.1	2.36	0.67	5.14
Gypsum and Anhydrite	0.7	5.9	6.6	9.6	0.1	0.5	0.03	0.6	1.5	3.9	0.60	0.41	6.60
Salt (Rock Salt)	2.8	-	2.8	3.9	0.1	0.3	0.1	0.5	1.1	3.2	1.15	0.82	3.48
Barite	0.2	-	0.2	0.2	0.02	0.10	0.01	0.1	0.3	0.8	4.18	3.76	0.77
Feldspar, Quartz, Neph. Syenite	-	1.3	1.3	1.8	0.1	0.1	0.2	0.4	0.9	2.5	1.85	1.38	2.05
Potash	13.6	-	13.6	13.8	0.6	1.1	1.0	2.7	5.7	22.1	1.62	1.60	2.44
Pyrophyllite and Talc	0.02	0.03	0.05	0.05	0.02	0.06	0.01	0.1	0.2	0.4	7.47	8.12	0.27
Fluorspar and Misc.	0.3	-	0.3	0.3	0.1	0.3	0.1	0.5	1.1	3.2	10.20	11.18	0.27

Source: Statistics Canada and author's estimates.

TABLE 12

SUMMARY OF EMPLOYMENT - CANADIAN PRODUCING MINES, 1970

ORE MINED	ORE MILLED			Total Ore & Waste Broken	EMPLOYEES				Total Paid Manhours	Total Wages and Salaries	LABOUR COST		Tons O & W broken per Manhour
	Underground	Surface	Total		Admin.	Mine	Mill	Total			Per Ton Milled	Per Ton O & W Broken	
	(millions of net tons)					(thousands)			(millions)	(million$)	$	$	
METAL MINES													
Gold - Quartz	8.01	-	8.01	8.49	1.18	4.77	1.06	7.01	14.64	44.86	5.60	5.28	0.58
Uranium	1.96	n/a	1.96	2.28	0.51	1.09	0.57	2.18	4.46	18.80	9.60	8.35	0.51
Iron Ore, Underground	3.43	-	3.43	3.81	0.16	0.20	0.23	0.59	1.39	6.09	1.77	1.60	2.54
Surface	-	99.52	99.52	141.77	1.65	3.03	3.31	7.99	16.89	79.42	0.80	0.56	8.42
Copper - Gold - Silver, Underground	17.27	-	17.27	18.87	2.16	5.56	2.31	10.03	21.35	83.67	4.85	4.44	0.88
Surface	-	25.16	25.16	70.59	0.46	0.89	0.97	2.32	4.87	20.14	0.80	0.29	14.50
Nickel - Copper	31.05	3.59	34.64	43.19	3.26	15.27	1.42	19.95	42.42	190.20	5.49	4.41	1.02
Silver - Cobalt	0.22	-	0.22	0.24	.07	0.29	0.06	0.42	0.81	2.70	12.27	11.24	0.30
Silver - Lead - Zinc, Underground	6.98	-	6.98	7.41	0.71	2.58	0.79	4.06	7.94	31.64	4.57	4.27	0.93
Surface	6.98	-	6.98	24.71	0.20	0.60	0.35	1.24	2.46	12.91	1.85	0.52	10.40
Molybdenum, Undergound	1.34	-	1.34	1.41	0.13	0.66	0.03	0.82	1.73	5.33	3.98	3.78	0.82
Surface	-	16.76	16.76	21.78	0.17	0.41	0.22	0.80	1.74	7.01	0.42	0.32	12.52
Other Metal Mines	1.05	3.00	4.05	6.96	0.18	0.50	0.08	0.76	1.67	6.43	1.59	0.93	4.17
NON-METAL MINES													
Asbestos	1.79	33.14	34.93	90.50	1.41	2.60	3.74	7.74	18.18	65.19	1.87	0.72	4.98
Gypsum	0.34	5.84	6.18	7.81	0.11	0.50	0.02	0.64	1.42	3.99	0.65	0.51	5.50
Talc, Soapstone, Pyrophyllite	0.03	0.04	0.07	0.41	0.02	0.06	0.02	0.10	0.21	0.52	7.43	1.27	1.95
Feldspar and Quartz	-	1.16	1.16	1.29	0.04	0.08	0.12	0.24	0.57	1.53	1.32	1.19	2.27
Salt	4.37	-	4.37	5.32	0.09	0.44	0.09	0.62	1.32	4.78	1.09	0.90	4.06
Potash	13.93	-	13.93	13.93	0.75	1.06	0.95	2.75	5.70	22.46	1.97	1.97	2.44
Other Non-Metals	0.33	0.004	0.33	0.33	0.05	0.39	0.03	0.47	0.99	2.88	8.73	8.73	.33

Source: Statistics Canada and author's estimates.

TABLE 13

SUMMARY OF EMPLOYMENT - CANADIAN PRODUCING MINES, 1971

TYPE OF MINING	ORE MILLED			Total Ore & Waste Broken	EMPLOYEES				Total Paid Man-hours	Total Wages and Salaries	LABOUR COST		Tons O & W Broken per Manhour
	Under-ground	Surface	Total		Admin.	Mine	Mill	Total			Per Ton Milled	Per Ton O & W Broken	
	(millions of short tons)					(thousands)				(millions $)	($)	($)	
	METAL MINES												
Gold - Quartz	7.40	-	7.40	7.60	0.97	4.46	0.72	6.15	12.28	39.98	5.40	5.26	0.62
Uranium	3.20	n/a	3.20	3.42	0.48	1.04	0.52	2.04	3.92	17.81	5.56	5.21	0.87
Iron Ore - Underground	4.20	-	4.20	4.20	0.17	0.54	0.16	0.87	1.85	8.48	2.01	2.01	2.27
Surface	-	96.55	96.55	151.20	2.32	2.53	3.88	8.73	17.68	94.40	0.97	0.62	8.55
Copper - Gold - Silver													
Underground	21.95	-	21.95	23.00	2.44	6.06	2.61	11.11	22.76	100.81	4.59	4.38	1.01
Surface	-	26.78	26.78	77.80	0.60	1.19	1.21	3.00	6.12	26.27	0.98	0.34	12.71
Nickel - Copper	30.81	3.42	34.23	43.80	4.25	15.94	1.57	21.76	38.47	214.04	6.25	4.89	1.14
Silver - Cobalt	0.26	-	0.26	0.30	0.07	0.31	0.08	0.46	1.11	4.19	16.12	13.97	0.27
Silver - Lead - Zinc -													
Underground	6.36	-	6.36	6.60	0.63	2.36	0.68	3.67	7.58	32.94	5.18	4.99	0.87
Surface	-	8.04	8.04	25.10	0.24	0.56	0.31	1.11	2.16	13.02	1.62	0.52	11.62
Molybdenum - Underground	0.67	-	0.67	0.70	0.01	0.35	0.15	0.51	0.68	2.84	4.24	4.06	1.03
Surface		11.65	11.65	20.70	0.17	0.21	0.33	0.71	1.50	6.95	0.60	0.34	13.80
Other Metal Mines	0.70	3.41	4.11	6.10	0.19	0.38	0.03	0.58	1.51	6.50	1.58	1.07	4.06
	NON-METAL MINES												
Asbestos	1.82	34.24	36.06	84.20	1.43	2.52	3.89	7.84	16.13	69.19	1.92	0.82	5.22
Gypsum	0.81	5.65	6.46	8.60	0.10	0.47	0.03	0.60	1.31	4.21	0.65	0.49	6.56
Talc - Soapstone - Pyrophyllite	0.03	0.04	0.07	0.34	0.02	0.04	0.02	0.08	0.19	0.49	7.00	1.44	1.79
Feldspar & Quartz	-	2.08	2.08	2.20	0.11	0.11	0.25	0.47	0.82	3.18	1.53	1.46	2.68
Salt	4.58	-	4.58	5.50	0.21	0.44	0.43	1.08	2.25	8.71	1.90	1.58	2.44
Potash	15.60	-	15.60	15.60	0.64	0.90	0.95	2.49	5.36	22.62	1.45	1.45	2.91
Other Non-Metals	0.18	0.90	1.08	1.40	0.06	0.24	0.18	0.48	0.92	3.61	3.34	2.58	1.52

Source: Statistics Canada and author's estimates.

TABLE 14

SUMMARY OF EMPLOYMENT - CANADIAN PRODUCING MINES, 1972

TYPE OF MINING	ORE MILLED			Total Ore & Waste Broken	EMPLOYEES				Total Paid Man-hours	Total Wages and Salaries	LABOUR COST		Tons O & W Broken per Manhour
	Under-ground	Surface	Total		Admin.	Mine	Mill	Total			Per Ton Milled	Per Ton O & W Broken	
	(millions of short tons)					(thousands)			(millions $)		($)	($)	
METAL MINES													
Gold - Quartz	6.74	-	6.74	7.08	0.84	3.77	0.61	5.63	10.67	40.50	6.00	5.70	0.62
Uranium	3.20	n/a	3.20	3.48	0.45	1.28	0.21	1.95	3.81	19.69	6.20	5.70	0.91
Iron Ore - U/G	4.39	-	4.39	4.45	0.18	0.57	0.15	0.90	1.60	9.52	2.17	2.13	2.78
- Surface	-	89.20	89.20	121.37	1.98	2.54	2.96	7.48	14.63	85.14	0.96	0.70	8.30
Copper - Gold - Silver													
- U/G	20.02	-	20.02	21.97	2.17	6.22	2.11	10.73	21.03	101.32	5.05	4.60	1.02
- Surface	-	52.10	52.10	140.78	0.91	2.05	1.65	4.62	8.53	47.30	0.91	0.33	16.50
Nickel - Copper	22.97	2.49	25.46	29.35	2.98	14.36	1.54	19.02	31.40	189.27	7.46	6.48	1.03
Silver - Cobalt	0.13	-	0.13	0.15	0.05	0.15	0.04	0.24	0.46	1.83	14.10	12.20	0.33
Silver - Lead - Zinc													
- U/G	5.41	-	5.41	5.63	0.64	2.26	0.34	3.25	6.08	28.93	5.34	5.13	1.04
- Surface	-	6.93	6.93	20.33	0.22	0.57	0.23	1.01	2.21	10.30	1.54	0.52	9.20
Molybdenum	0.21	6.93	7.14	11.90	0.14	0.37	0.10	0.63	1.22	5.49	0.77	0.46	9.80
Other Metal Mines	1.11	2.50	3.62	5.33	0.25	0.53	0.12	0.90	1.79	9.07	2.50	1.80	2.97
NON-METAL MINES													
Asbestos	1.29	32.97	34.26	79.17	1.47	2.40	3.85	7.84	16.92	74.41	2.17	0.94	4.90
Gypsum	0.88	7.16	8.04	11.06	0.10	0.53	0.04	0.67	1.47	5.19	0.64	0.47	7.55
Talc - Soapstone - Pyroph	0.04	0.05	0.09	0.09	0.03	0.04	0.02	0.09	0.19	0.55	6.10	6.10	0.47
Feldspar & Quartz	-	1.99	1.99	2.18	0.10	0.11	0.25	0.45	0.95	3.54	1.78	1.62	2.30
Salt (1)	4.62	-	4.62	5.58	0.08	0.46	0.07	0.61	0.93	5.79	1.25	1.02	6.00
Potash(1)	16.99	-	16.99	16.99	0.61	0.96	0.98	2.57	4.95	24.49	1.44	1.44	3.43
Other Non-Metals	0.40	0.12	0.52	0.68	0.07	0.40	0.18	0.68	1.28	5.14	9.89	7.55	0.53

(1) Does not include brining operations.

Note: Totals may not balance owing to rounding and absence of some data (shown n/a) which could not be published.

Source: Statistics Canada and author's estimates.

lowest productivity occurs in mines where small-scale underground operations were in effect (silver-cobalt) or where the mines are generally old and deep (gold-quartz).

Operating costs

Tables 15, 16, 17 and 18 give an analysis of mine operating costs for 1969 to 1972 according to type of ore and principal mining method. Many mining companies use several mining methods and operating costs are not usually broken down by method. Unless one method dominates in a specific mine, it is not included in the tables. Further, where both underground and surface methods are used in a specific mine, the operation is also excluded. The analysis is therefore incomplete.

Individual costs are shown as a weighted average for mining ore and waste, and not on the basis of tons milled. This tends to show unusually low processing costs in some operations. It also tends to show lower costs at surface mining locations where large volumes of waste are drilled and blasted prior to ore mining. The tons of overburden removed without drilling and blasting in surface mines are not included, but the costs of stripping cannot be separated so they are absorbed in the mining costs. Allowances have been made to account for these factors in efforts to obtain more accurate costs.

Costs of underground mining for all methods continue to increase, however, cut-and-fill stoping appears to have risen the least. Surface mining of industrial minerals appears to be holding to previous levels. Data for 1972 show a marked drop in costs of iron ore mining. Review of old data indicates that one of the largest (and lowest cost) iron ore mining companies could not have been included in previous years. Inclusion of this producer has since depressed the weighted average cost. In addition, expenditures for some major expansion programs were reduced in 1972, thereby further affecting

TABLE 15

ANALYSIS OF OPERATING COSTS OF SELECTED MINES

year 1969

Type of Mine	Number of Mines Analyzed	Tons O & W Broken Per Foot of Drilling	OPERATING COSTS PER TON OF ORE AND WASTE BROKEN								
			Expl. and Devel.	Mining	Sub-Total	Milling	Gen'l	Dep'n	Grand Total	Labour - Salaries and Wages	Labour - Percent of Total
SHRINKAGE STOPING											
Copper	5	0.44	0.60	3.50	4.10	1.70	2.80	1.20	9.80	3.95	40
Gold	6	0.48	1.10	4.10	5.20	2.00	1.20	0.30	8.70	4.05	47
Silver	6	0.20	3.20	6.00	9.20	3.60	2.00	0.40	15.20	9.10	60
CUT AND FILL STOPING											
Copper	8	0.36	1.00	5.90	6.90	1.80	2.50	1.50	12.70	5.90	47
Nickel	8	0.41	2.50	7.70	10.20	2.80	1.60	2.00	16.60	8.15	49
Lead - Zinc	4	0.34	2.10	8.30	10.40	2.50	2.50	2.50	17.90	7.55	42
Gold	12	0.30	1.50	9.50	11.00	2.50	2.20	0.40	16.10	9.40	58
OPEN STOPING (with longholes)											
Copper	6	1.06	0.45	2.50	2.95	1.20	2.20	1.50	7.85	2.85	36
Gold	6	0.49	0.40	3.00	3.40	1.30	1.15	0.65	6.50	3.05	47
Lead - Zinc	4	0.93	0.90	3.35	4.25	1.80	1.30	1.30	8.65	3.95	46
ROOM AND PILLAR MINING											
Lead - Zinc	3	0.6	0.40	3.90	4.30	1.30	0.70	0.30	6.60	3.20	48
BLOCK CAVING AND SUB-LEVEL CAVING											
This mining method is used in mining of asbestos, copper, and nickel. Data from an insufficient number of mines were available for publication.											
SURFACE MINING											
Asbestos	9	11.7	0.10	0.35	0.45	0.50	0.40	0.15	1.50	0.55	37
Molybdenum	3	18.5	0.10	0.55	0.65	0.90	0.50	0.55	2.60	0.55	21
Copper	7	21.0	0.10	0.60	0.70	0.55	0.40	0.30	1.95	0.50	26
Iron	12	29.0	0.20	0.90	1.10	0.85	0.35	0.30	2.60	0.75	29
Lead - Zinc	3	20.5	0.15	1.10	1.15	0.95	0.20	0.60	2.90	0.90	31

Source: Statistics Canada and author's estimates.

TABLE 16

ANALYSIS OF OPERATING COSTS OF SELECTED MINES

year 1970

Ore Mined	Number of Mines Analyzed	Tons O & W Broken Per Foot of Drilling	OPERATING COSTS PER TON OF ORE AND WASTE BROKEN ($)							Labour - Salaries and Wages	Labour - Percent of Total
			Expl. and Devel.	Mining	Sub-Total	Milling	Gen'l	Dep'n	Grand Total	(million $)	
SHRINKAGE STOPING											
Gold - Quartz	4	0.61	1.01	3.74	4.74	2.00	1.28	0.25	8.27	4.3	45
Silver - Cobalt	3	0.22	5.21	6.82	12.03	2.80	1.64	1.54	18.01	1.3	48
Other Metal Mines	8	0.36	1.81	5.01	6.82	1.59	1.84	1.10	11.35	14.3	49
CUT AND FILL STOPING											
Gold - Quartz	7	0.32	0.94	6.95	7.89	2.02	2.43	0.42	12.76	18.1	68
Other Metals	15	0.55	2.37	6.96	9.33	2.17	2.59	1.43	15.52	57.2	43
OPEN STOPING (with longholes)											
Gold - Quartz	3	0.75	0.32	2.88	3.20	1.10	0.56	0.13	4.99	4.6	56
Copper	9	1.43	0.90	2.63	3.53	1.27	2.08	1.66	8.54	19.4	36
Lead - Zinc	4	2.71	0.64	2.89	3.53	2.26	1.01	0.96	7.76	8.0	32
Other Metals	5	1.82	0.72	4.38	5.10	1.56	0.58	0.71	7.95	13.6	52
ROOM AND PILLAR											
Metals	4	0.51	0.68	3.82	4.50	3.04	2.48	0.75	10.77	8.5	40
Potash	5	-	-	1.67	1.67	1.94	3.10	1.64	8.35	14.3	23
CAVING											
Copper	3	0.70	0.29	2.84	3.13	0.91	1.32	0.73	6.09	6.4	38
SURFACE MINES											
Asbestos	10	14.85	0.10	0.61	0.71	0.63	0.54	0.14	2.03	61.5	34
Iron Ore	10	32.70	0.19	1.31	1.50	1.02	0.37	1.36	4.25	55.3	13
Other Metals	9	34.00	0.08	0.37	0.45	0.44	0.18	0.23	1.30	33.8	26

Source: Statistics Canada and author's estimates.

TABLE 17

ANALYSIS OF OPERATING COSTS OF SELECTED MINES

year 1971

Ore Mined	Number of Mines Analyzed	Tons O & W Broken Per Foot of Drilling	OPERATING COSTS PER TON OF ORE AND WASTE BROKEN ($)							Labour - Salaries and Wages	Labour - Percent of Total
			Expl. and Devel.	Mining	Sub-Total	Milling	Gen'l	Dep'n	Grand Total[1]		
			SHRINKAGE STOPING							(million $)	
Gold - Quartz	5	0.56	0.90	3.74	4.63	1 75	1.13	0 36	7.90	6.9	53
Copper	7	0.48	0.50	2.92	3.44	1.35	3.97	1.91	10.65	7.7	36
Silver - Cobalt	4	0.34	3.83	8.15	11.95	2.46	2.64	1.15	18.69	1.9	54
Other Metal Mining	3	0.50	0.28	5.20	5.48	1.84	2.15	3.39	12.83	2.5	38
			CUT AND FILL STOPING								
Gold - Quartz	10	0.36	0 70	8.60	9.30	1.63	2 34	0.40	13.67	21.6	63
Other Metals	19	0.55	2.19	6.60	8.80	2.55	3.04	1.71	16.07	78.8	51
			OPEN STOPING (with longholes)								
Gold - Quartz	3	0.58	0.29	2.93	3.22	1.38	0 66	0.12	5.38	5.3	60
Copper	11	1.18	0.89	3.05	3.92	1.66	2.52	1.73	9.85	20.8	28
Lead - Zinc	3	3.20	0.62	3.78	4.40	2.43	1.26	1.07	9.17	4.1	35
Other Metal Mines	4	2.95	0.35	1.46	1.81	2.04	0.56	0.62	5.04	10 6	42
			ROOM AND PILLAR								
Metal Mines	5	0 54	0.63	4.31	4.94	2.97	1.31	0.88	10.09	19 8	39
Potash	7	-	-	1.16	1.16	1.57	1.99	1.40	6.12	19.7	22
			SUB-LEVEL CAVING								
Metal Mines	3	0.68	0.19	3.50	3 70	1.55	0.96	1.92	8.13	14.1	42
			CAVING								
Non-metal Mines	3	2.06	0.07	2.90	2.97	2.42	1.32	0.69	7.40	7 6	54
			SURFACE MINES								
Asbestos	10	13 54	0.12	0.72	0.83	0 76	0.60	0.16	2.36	61.5	35
Iron Ore	13	33.80	0.22	1.26	1.48	1.43	0.34	1.12	4.37	68.1	13
Other Metal Mines	9	30.90	0.10	0.44	0 54	0.39	0 20	0 22	1.34	36.5	26

(1) Totals may not balance owing to individual rounding.

Source: Statistics Canada and author's estimates.

TABLE 18

ANALYSIS OF OPERATING COSTS OF SELECTED MINES

year 1972

Ore Mines	Number of Mines Analyzed	Tons O & W Broken Per Foot of Drilling	OPERATING COSTS PER TON OF ORE AND WASTE BROKEN ($)							Labour - Salaries and Wages	Labour - Percent of Total
			Expl. and Devel.	Mining	Sub-Total	Milling	General	Dep'n.	Grand[1] Total		
			SHRINKAGE STOPING							(million $)	
Gold - Quartz	5	0.42	1.10	6.47	7.57	2.35	1.02	0.26	11.20	7.5	54
Copper	7	0.49	1.30	5.24	6.54	1.60	6.12	2.55	16.80	5.9	56
Silver - Cobalt	3	0.32	11.25	4.14	15.39	2.03	0.60	0.22	18.25	1.3	60
Other Metal Mines	3	0.42	1.28	4.94	6.22	1.68	3.02	1.05	11.96	3.5	45
			CUT AND FILL STOPING								
Gold - Quartz	8	0.40	0.69	7.01	7.70	1.99	3.29	0.40	13.38	18.3	52
Other Metal Mines	10	0.24	2.18	6.50	8.68	2.27	2.51	1.23	14.69	89.1	64
			OPEN STOPING (with longholes)								
Gold - Quartz	3	0.84	0.18	3.80	3.98	1.63	0.90	0.15	6.67	6.5	61
Copper	10	0.83	3.43	2.06	5.49	1.17	0.91	0.77	8.33	22.5	43
Other Metal Mines	5	2.35	0.37	1.85	2.22	1.68	0.93	0.70	5.52	11.79	44
			OPEN STOPING (with shortholes)								
Metal Mines	6	0.53	0.89	4.90	5.79	2.32	1.95	1.56	11.80	6.2	46
			ROOM AND PILLAR								
Metal Mines	4	0.43	0.88	3.84	4.72	2.84	4.48	1.04	13.09	17.95	39
Potash	8	-	-	1.26	1.26	1.71	1.71	1.61	6.28	24.49	23
			SUB-LEVEL CAVING								
Metal Mines	3	0.78	1.11	4.45	5.56	1.52	1.84	1.73	10.66	12.04	36
			CAVING (other)								
Metal and Non-Metal Mines	4	10.5	0.83	4.62	0.50	3.26	2.66	0.66	12.03	13.9	36
			SURFACE MINES								
Asbestos	8	17.93	0.13	0.61	0.74	0.91	0.40	0.30	2.35	48.7	45
Iron Ore	12	35.00	0.09	0.68	0.77	0.84	0.42	0.29	2.31	70.2	29
Other Metal Mines	15	26.70	0.06	0.35	0.41	0.41	0.18	0.16	1.15	41.5	29

(1) Totals may not balance owing to individual rounding

Source: Statistics Canada and author's estimates.

the result. Therefore, the data for iron mining in 1972 as shown in Table 18 is not comparable with that for 1970 or 1971.

Total estimated costs of mining and processing in the Canadian mineral industry during 1972, excluding petroleum, natural gas, sand and gravel, lime and sodium sulphate, were $1,095 and $1,598 million respectively. The lower figure shown for mining compared with 1971 is believed caused by reduction in tons mined by underground methods, and by a revised method of estimating believed to be more accurate. The values for 1972 are thus not directly comparable with those of previous years.

MINING TECHNOLOGY

Underground mining

Post-pillar cut-and-fill stoping has made further headway against alternate stope and pillar arrangements. The main benefit of the method appears to be the elimination of more costly pillar recovery which would normally result from conventional stope and pillar mining.

Favourable results have been reported by one company experimenting with a Dosco roadheader for mining a replacement-type zinc-lead orebody in sedimentary rocks. This development is significant as it could lead to continuous mining at the face and automated ore transport where conditions are favourable.

Progress was made in developing an automation-control strategy for a raise borer. Work on this is a joint effort by a major mining company and the Mining Research Centre and is closely related to similar work completed on a laboratory-scale diamond drill.

Further advances have been made in applying large diameter holes to open stoping and at least two major companies are known to be increasing their use. In one location, down-the-hole drills provide 6-in. diam. holes drilled parallel on a 13 ft by 13 ft pattern and about 180 ft deep. The large diameter holes are also used for widening a 7-ft diam., bored slot raise, eliminating the need for smaller-scale slot cutting. Major advantages of the method over that previously used for drilling of 2-in. diam. holes are the reduction in stope development requirements and greater utilization of the holes drilled. Rotary holes of 7 7/8 in. diam. have been used in another location.

Application of blasting slurries has progressed from the test stage to its increasing use in underground production blasts. The major explosives manufacturers can now provide pumps for bulk-loading slurries, or pneumatic cartridge loaders recently permitted into Canada for use with insensitive products.

Use of load-haul-dump (LHD) vehicles continues to increase in Canadian underground mines. The largest supplier of this equipment has reported that about 700 units have been sold to the industry. Two developments have been the application of LHD units to steeper grades than formerly envisaged and use of the equipment at distances felt more suitable for trucks. Improved braking systems and a wider variety of low-profile haulage trucks for longer hauls have resulted. Conventional rubber-tyred front end loaders have also been applied in conjunction with trucks.

Among activities within the Mines Branch related to underground mining are those in the areas of ground control, environmental control and systems engineering. Particular emphasis is being placed on studies of spontaneous combustion and methane emission in coal mining.

Surface mining

Canadian surface mines have apparently experienced a period of consolidation in the use of large equipment. The largest drill hole diameter in metal mines remains at $12\frac{1}{4}$ in. while 7 7/8-in. diam. rotary-drilled holes were tested and proven successful in an asbestos mine. Mining companies in this area have usually used percussion-drilled holes from 2 to 4 in. in diam., except for one instance where $6\frac{1}{2}$-in. diam. holes were drilled with a down-the-hole drill.

It has been found that maintaining the interiors of some surface drills in iron ore mining under a positive air pressure has eliminated grit from working parts of compressors and other machinery. The costs of these modifications were reported to be more than compensated for by reduced maintenance costs.

Slope stability studies, sponsored by the Mining Research Centre, Mines Branch, are now in their third year. The interest generated in the subject is evident from the increase in published papers on related subjects.

Reclamation of land disturbed during surface mining and revegetation of tailings dumps have become accepted phases of the mining cycle. Mines Branch research in this area has involved methodology for the determination of the most suitable plants for particular soil, weather, surface wind and sun exposure conditions and the methodology for determining optimum fertilizer and moisture treatment.

The publications listed below may be obtained from:

Publications Distribution Office, Mines Branch,
Department of Energy, Mines & Resources,
555 Booth Street,
Ottawa, Ontario. K1A OG1.

All requests should be accompanied by a cheque or money order made payable to: Receiver General of Canada.

R = Research Report
IC = Information Circular
TB = Technical Bulletin
RS = Reprint Series

Cochrane, T.S., Knight, G., Richards, L.C. and Stefanich, W., "Comparison of Dust Sampling Instruments", R 250, 1971. $1.25.

Gray, W.M. and Toews, N.A., "Analysis of Accuracy in the Determination of the Ground-Stress Tensor by Means of Borehole Devices", RS 109, 1972. $0.25.

Gray, W.M. and Barron, K., "Stress Determination from Strain Relief Measurements on the Ends of Boreholes; Planning, Data Evaluation and Error Assessment", RS 110, 1972. $0.25.

Coates, D.F. and Yu, Y.S., "Analysis of Grading Effects on Hydraulic and Consolidated Fill", and
Gyenge, M. and Coates, D.F., "Mine Fill System Design based on Optimization", RS 113, 1972, $0.25.

Dubnie, A., "Northern Mining Problems with Particular Reference to Unit Operations in Permafrost", TB 148, June 1972. $0.75.

Dubnie, A., "Surface Mining Practice in Canada", Mines Branch Information Circular 292, 1972. $3.00.

Yu, Y.S. and Coates, D.F., "Analysis of Rock Slopes Using the Finite Element Method", R 229, October 1970. $1.25.

Dubnie, A., "Problems miniers dans le nord avec reference particuliere aux chantiers d'exploitation dans le pergelisol", TB 148F, September 1972. $0.75.

Murray, D.R., "Vegetation of Mine Waste Embankments in Canada", IC 301, January 1973. $1.00.

Sage, R. and Coates, D.F., "Survey of Physical-Mineralogical Characteristics of Underground Mines in Canada", IC 306, May 1973. $0.75.

Norris, D.K. and Barron, K., "Structural Analysis of Features on Natural and Artificial Faults", RS 120, 1973, $0.25.

Bielenstein, H.V. and Barron, K., "In Situ Stresses", RS 120, 1973. $0.25.

Tervo, R.O. and Everell, M.D., "Communication Methods in Underground Mines", RS 121, 1973. $0.25.

Coates, D.F. and Dickhout, M., "Elements of Planning in Deep Mining", RS 122, 1973. $0.25.

Hedley, D.G.F. and Grant, F., "Stope-and-Pillar Design for the Elliot Lake Uranium Mines", RS 122, 1973. $0.25.

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