Department of

ENERGY, MINES AND RESOURCES

ANNUAL REPORT 1973-74

Energy, Mines and Resources Canada

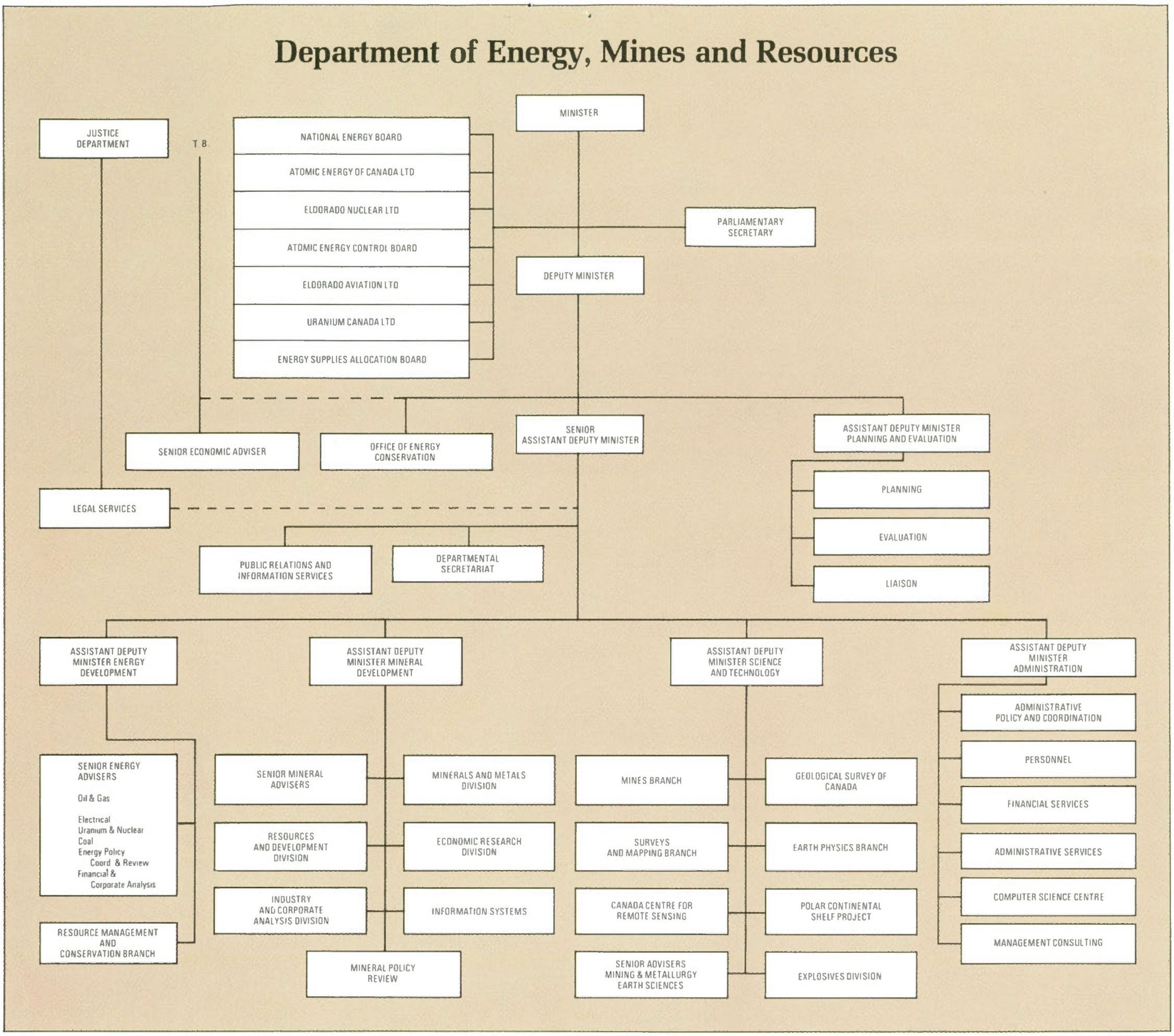
Donald S. Macdonald, Minister
T. K. Shoyama, Deputy Minister

Contents

Left: Grading Mackenzie Highway, near Fort Simpson, Northwest Territories. Members of EMR's Geological Survey of Canada are acting as advisers on this important construction project.

Center: Member of EMR's Earth Physics Branch uses portable core drill to obtain rock sample for paleomagnetic research. Takiyuak Lake, Northwest Territories.

Right: Two suns seem to be shining on this camp of the Polar Continental Shelf Project. One (left) is what is known as a "sun dog," a reflection of the sun.



INTRODUCTION

A single economic development with far-reaching social and political implications dominated the concerns of the Department of Energy, Mines and Resources in the fiscal year 1973–74. This was the crisis in the supply of petroleum, which broke upon the world, and Canada, in the fall of 1973. EMR, being charged with collecting and analyzing information on the energy situation in Canada and abroad, and with providing policy advice on energy management to Cabinet, found itself in the public limelight throughout the year.

This large measure of public attention was due not only to the crisis itself but also the publication, in June 1973, of the long-awaited Phase I of "An Energy Policy for Canada." Phase I was the energy analysis which was intended to lead to Phase II—an assemblage of concrete policies to be worked out in consultation with all the interested parties in the country. In the meantime, a number of the postulates in Phase I have been overtaken by the consequences of the fuel crisis, and various emergency measures had to be devised to ward off the most immediate and most serious shortages and/or price increases in gasoline and heating oil. Thus, for example, the

EMR budget was suddenly inflated to almost triple its normal size by the inclusion of $157 million for payment of oil subsidies.

More detail on this and other activities of EMR's Energy Sector will be found in the pages that follow.

Long-term policy considerations were also the uppermost concern of the Mineral Development Sector, which bears a responsibility similar to that of the Energy Sector in respect of all of Canada's metals and industrial minerals, their processing and factors governing their exportation and importation.

Early in the fiscal year the ten provincial mines ministers and the Minister of Energy, Mines and Resources announced objectives for a national mineral policy, incorporating many of the recommendations of departmental experts. Continuing intensive discussions among Ottawa, the provinces and private companies have focused on assigning priorities to the objectives, with emphasis to be placed on increasing mineral-based manufacturing and mineral processing in this country. Most mineral commodities increase their value manifold, and generate a large range of economic benefits, if processed to manufactured products in the country of origin. On the other hand, most nations now importing Canadian minerals have set up tariff and other barriers to manufactured products. An effective mineral policy must seek to increase the one factor while reducing the other.

The sudden attention forced upon energy and mineral commodities has not diminished the relative importance of the work of EMR's Science and Technology Sector, whose staff engages mainly in the accumulation, interpretation and diffusion of geological, geophysical, metallurgical, mining, topographical, remote sensing and other information. On the contrary: the crisis in the commodity field cannot be solved without the contributions of the sciences and technologies indicated above. For example, if natural gas were to be discovered in large quantities in the Arctic, a pipeline to Ontario and Quebec markets could be built successfully only if exact, reliable information were available on the terrain to be traversed, including such factors as permafrost, topography, sea-ice patterns, etc.: such information is now being collected and analyzed by the Canada Centre for Remote Sensing, the Surveys and Mapping Branch, the Geological Survey of Canada, the Earth Physics Branch, and the agencies supported by the Polar Continental Shelf Project—all parts of EMR. If a petroleum and/or gas discovery occurs, this will be due in large measure to the basic surveys carried out over many years by the Geological Survey and the Earth Physics Branch. Furthermore, only special types of pipe, manufactured from special steels and welded by special methods, will stand up to the rigors of the Arctic. Research on such metallurgical problems is being carried out in EMR's Mines Branch. The larger questions of financing a pipeline and of marketing its throughput are being considered and advised on by the Energy Sector.

This is just one example of the intertwining of the activities engaged in by the various components that make up EMR. Such multi-disciplinary approaches are more and more common in EMR—and this itself is one of the most significant new developments in the department's history.

An important new data-base system was inaugurated by the Surveys and Mapping Branch, which uses a computer bank of mapping information. The information, which can rapidly be processed into a variety of map types, is accessible to all interested agencies.

Most of the field activities of the Geological Survey of Canada now concern the Canadian North, where geological rock and sediment types indicate a potential for mineral wealth that is as great as the known mineral resources of more southerly parts of the Canadian Shield and the Prairies. Also, the growing impact of man's industrial activity in the Arctic has prompted a large range of terrain studies aimed at preventing unnecessary damage both to the environment and to northern societies.

Broad human concerns were also in evidence in the research of the Mines Branch, much of which was directed toward finding more effective and less polluting ways of combustion and ore treatment, or of finding new uses for the large heaps of waste material that are often an undesirable feature at mine sites.

Improvements were made at the Earth Physics Branch's seismic array at Yellowknife, which allow "seismic events" (earthquakes or underground nuclear explosions) to be computer-processed as they happen. A telephone connection between computers in Ottawa and the Yellowknife equipment, to be established soon, will make the processed information available in Ottawa within 24 hours.

The fiscal year 1973–74 was the first full year of operation of the Earth Resources Technology Satellite (ERTS), imagery from which is received, processed and distributed by EMR's Canada Centre for Remote Sensing and the National Air Photo Library. A novel and potentially significant experiment in remote sensing was the transmission of imagery of Arctic sea ice to ships plying the Arctic sea lanes.

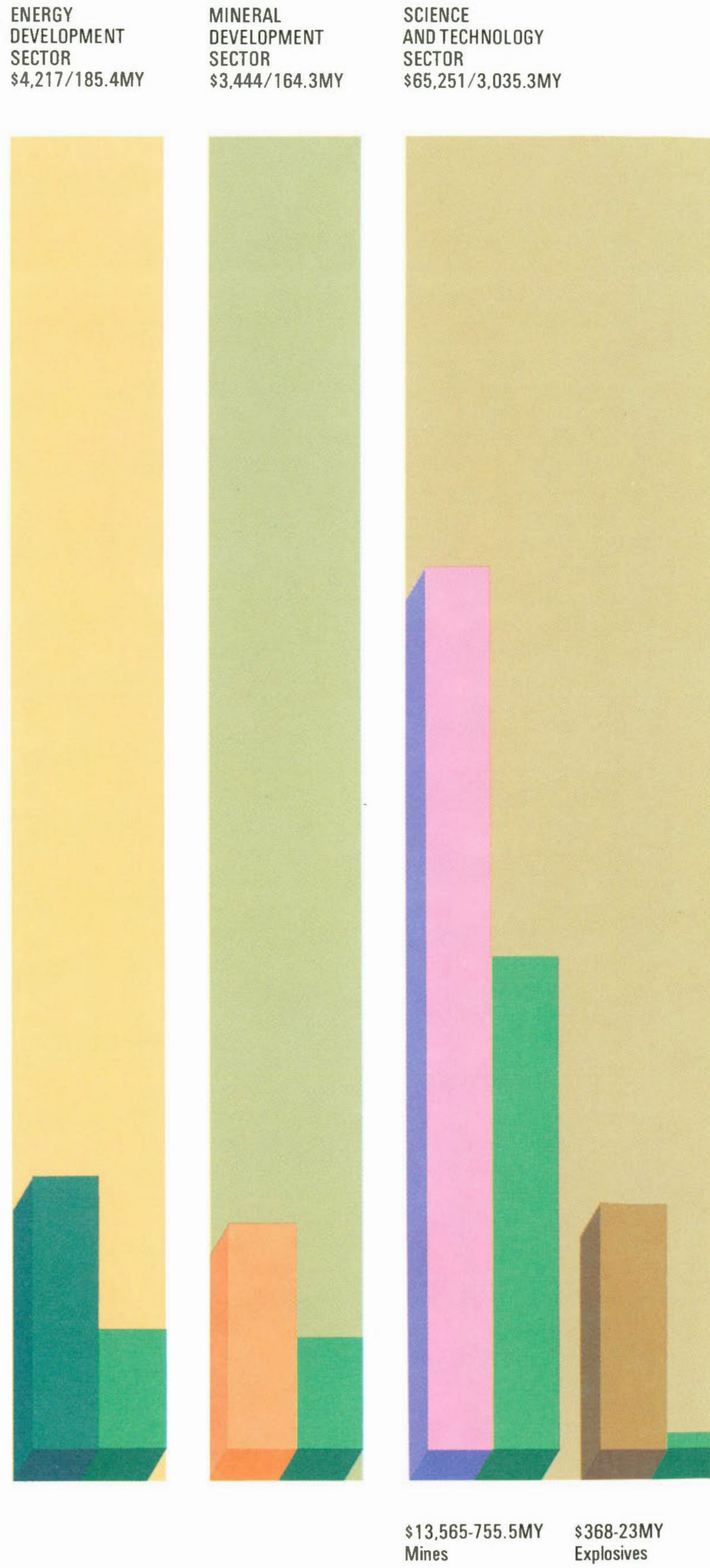
The Polar Continental Shelf Project again supported a wide range of scientific and technical researches in the Canadian Arctic. A number of appointments were made at the senior-management level of EMR, as follows: G. M. MacNabb, former Assistant Deputy Minister, Energy Development, was named Senior Assistant Deputy Minister; J. T. Lyon was named Legal Advisor to the department; John Convey, former Director of the Mines Branch, was named Senior Advisor Mining and Metallurgy; W. H. Hopper was named Assistant Deputy Minister, Energy Development; and A. T. Prince was named Assistant Deputy Minister, Planning and Evaluation.

Several branches of the department were given new directors; appointments are noted in the relevant sections of the report.

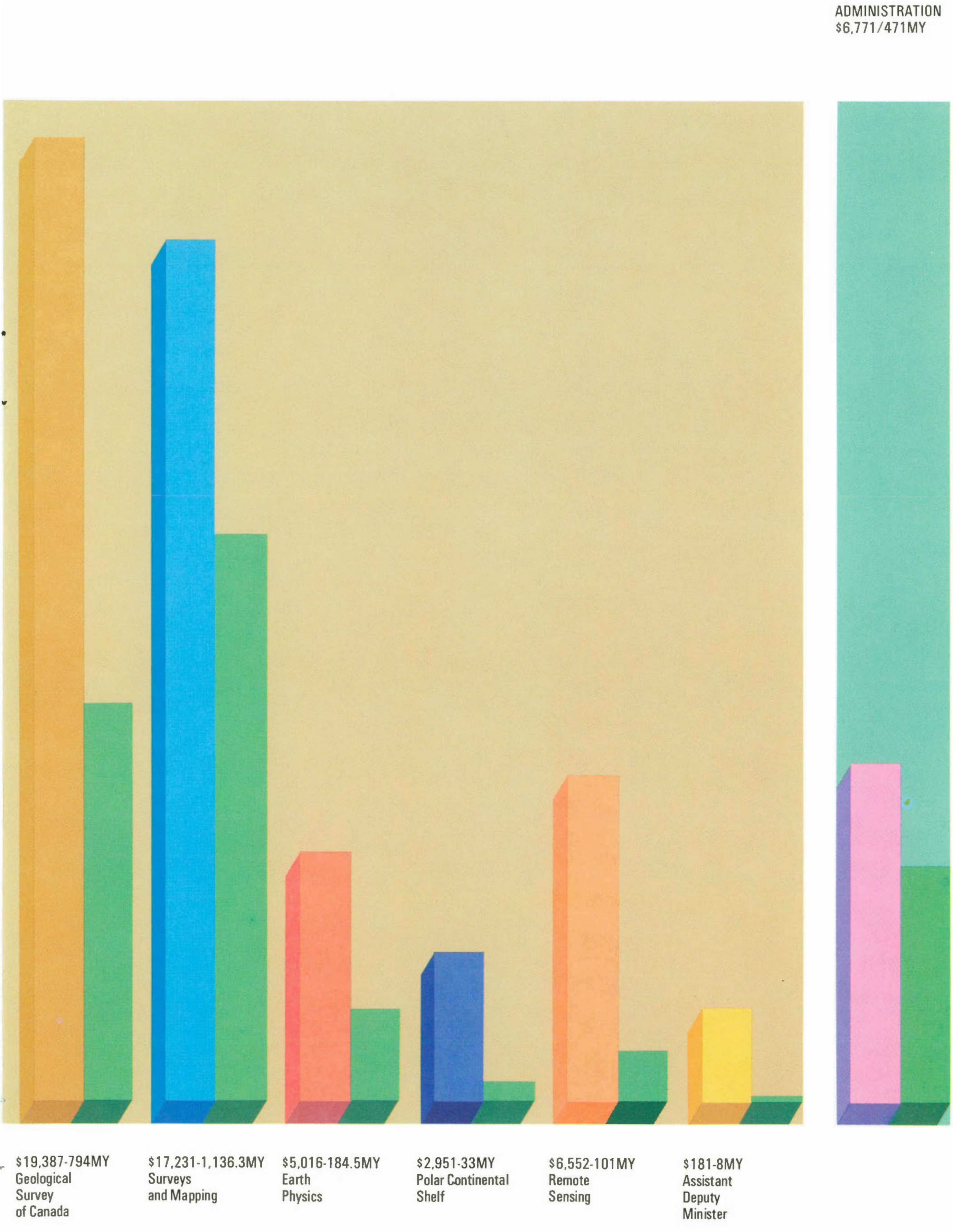
Details about some of the more significant and interesting projects undertaken during the past year by EMR's components will be found in the following pages. It should be noted here that in view of the tremendous number and variety of projects no attempt was made at comprehensive coverage. Readers interested in detailed, professional information are urged to apply directly to the sectors or branches concerned, all of which publish professional reports of their activities.

Department of Energy, Mines and Resources

1973-1974 Estimates in thousands of dollars and man years.
Total for department: $237,042*
3,856 man years (MY)



*Oil Subsidies $157,359



ADMINISTRATION
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$19,387-794MY
Geological
Survey
of Canada
$17,231-1,136.3MY
Surveys
and Mapping
$5,016-184.5MY
Earth
Physics
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Polar Continental
Shelf
$6,552-101MY
Remote
Sensing
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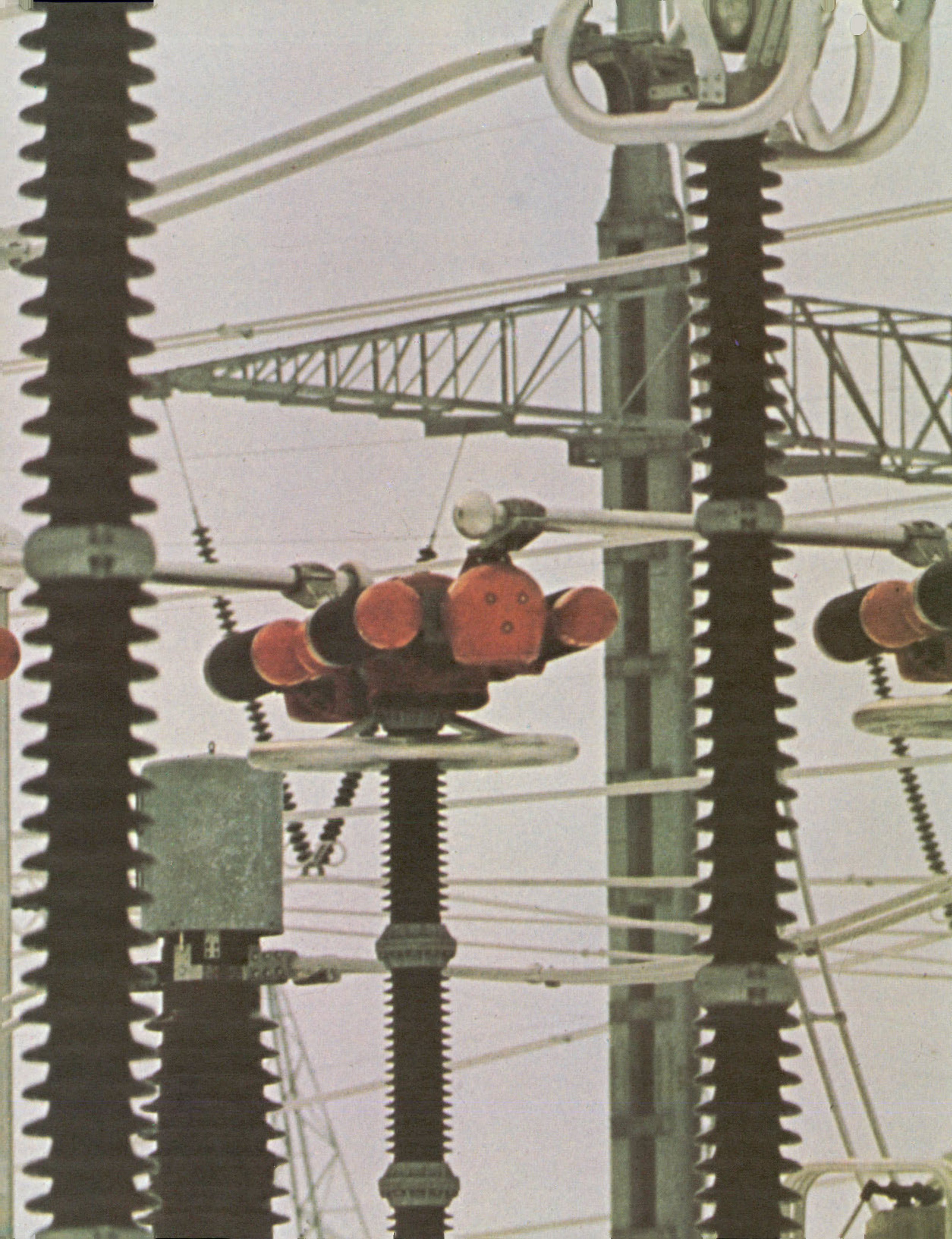
Assistant
Deputy
Minister



ENERGY DEVELOPMENT SECTOR

June 28, 1973, saw the culmination of many months of hard work by the Energy Development Sector when the Minister tabled Volumes I and II of Phase I of "An Energy Policy for Canada" in the House of Commons.

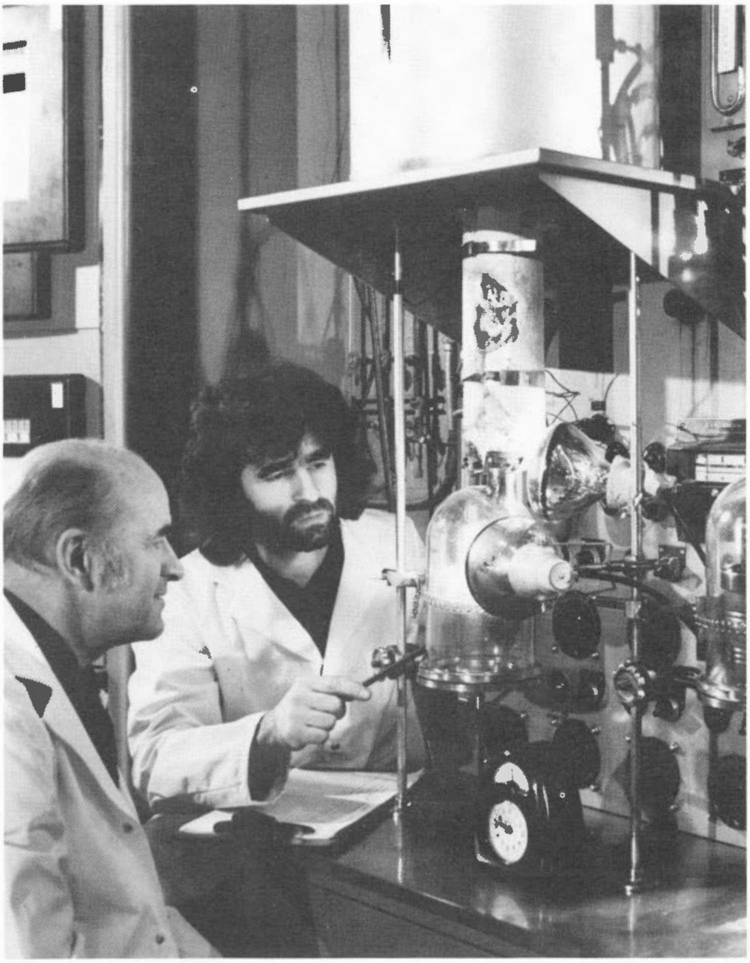
The report covered all aspects of the energy situation in Canada and laid out various options that could be carried out in the future. The analysis forms the framework for future policy development. It is also being used as a vehicle to obtain views of the public at large as well as industry, provincial governments and special interest groups. Extensive consultations had been planned at that time so that, as the Minister said in the foreword to Volume I, "... following those consultations the Government of Canada will then reach the second phase of the approach to the energy problems of deciding how, and with what instruments, our existing policies should be altered."

Widespread distribution of the report had been planned, and to enlarge this distribution Public Relations and Information Services produced a booklet called "Energy and Our Way Of Life" based on the analysis, for use in schools. Teachers and students received 210,000 copies through a Canadian high-school magazine and a further 600,000 were requested by teachers for use in school classrooms.

The workload of the Energy Sector did not, however, ease with the publication of the energy analysis. Lights burned in sector offices into the early hours of the morning in the fall of 1973 as a result of events in the Middle East.

The dramatic *rise in the cost of oil* from OPEC (Organization of Petroleum Exporting Countries), the cutback of production in the Middle East, and the embargo of oil shipments to the United States did have an effect on Canada. It seemed in the fall that there could be serious shortages of home heating fuel in eastern Canada during the winter. However, steps taken by the oil companies and the federal government, plus the help of a mild winter, eased the situation.

The price of Canadian oil had also been rising during 1973 and, to ease the financial burden on Canadian consumers, the government on September 4, 1973, requested the oil companies to impose a voluntary freeze on price increases. While this was in effect the oil companies were permitted to pass on two international price increases, effective November 1 and December 1, for oil used in the region east of the Ottawa Valley line, which depends on imported oil. West of that line the price remained at September levels well into 1974.



Mines Branch fuel experts determine the "pitch" content of a sample of oil produced from Athabasca oil and bitumen. The "pitch" is the non-saleable portion of the refined bitumen.

So that Canadian oil would not be sold in the United States at less than the world price, a tax was placed on all exports of crude oil from Canada. Also, extension of pipeline facilities from Sarnia to the Montreal area was planned to provide additional security against international disruption of supply. Hearings were to be conducted before the National Energy Board to determine feasibility of the plan before final approval. This would be part of a longer-term plan for a coast-to-coast oil-pipeline system as announced on January 16, 1974.

At the time when it was expected that there might be severe shortages of oil during the winter the government decided a control might be needed on the allocation of petroleum supplies. This would ensure equitable distribution of all petroleum products to wholesalers. The Energy Sector, in conjunction with other departments, recommended the formation of an Energy Supplies Allocation Board. A bill to establish this board was introduced in the House of Commons on December 3, 1973, and received Royal Assent on January 14, 1974. The board, under a Parliamentary declaration of a national emergency caused by energy shortages, has powers for the mandatory allocation of energy supplies and to implement rationing if necessary.

On December 6, 1973, the Prime Minister placed a proposal before the House of Commons to set the basis for a new national oil policy. This is designed to create a national market for Canadian oil; a pricing mechanism that will provide incentives for the development of oil resources; increased returns and revenues that result from higher prices used in a manner conducive to security and self-sufficiency; the establishment of a national petroleum company, principally to expedite exploration and development; the early completion of a pipeline to the Montreal area, and intensification of research on oil-sands technology. It was also decided at that time, in consultation with the provincial premiers, to continue the freeze on oil prices until March 31, 1974.

At the First Ministers' Conference on Energy in January, 1974, the ministers reached a decision that the increase in oil prices resulting from higher oil taxation overseas that was effective January 1, 1974, should be "cushioned" by federal payments. To accomplish this, $240 million was allocated from the department's supplementary estimates for payments to oil importers in the first quarter of 1974. This enabled the importers to restrain price increases in an amount of about $4 per barrel. Such increases would have been passed on to the consumers in eastern Canada, had the oil-import-compensation program not been put into effect. The Energy Sector developed procedures for the administration of the oil-import-compensation program in early 1974 and administered the program during the year.

In March, 1973, crude-oil export controls had been instituted because market demand for Canadian oil in the United States was such as to threaten adequacy of supply within Canada. Similarly, export controls on oil products were started in June, 1973.

In the autumn of 1973 the Energy Development Sector was involved in the analysis of the potential effect of the Arab oil embargo on supplies of crude oil and petroleum products in Canada. The sector participated in an interdepartmental committee which examined options to improve the supply situation and recommended courses of action to the Cabinet.

The sector has continued to serve as the secretariat for the Task Force on Northern Oil Development. During the year preparations on an interdepartmental basis were made for the examination of an application for construction of a natural-gas pipeline along the Mackenzie River valley by Canadian Arctic Gas Pipeline Limited. This application was subsequently filed on March 22, 1974.

Studies also proceeded on the production and transportation of natural gas from the Arctic Islands via a route along the west or east side of Hudson Bay.

The department is continuing with an oil-and-gas resource inventory, and during the year further work was done by the sector, in co-operation with the Geological Survey of Canada and other government agencies, to define potential resources of oil and gas in Canada.

In accordance with the Prime Minister's statement on December 6, 1973, $40 million is to be made available for research and development of the oil sands in co-operation with the Alberta government.

In early 1974 *the uranium industry* experienced a dramatic shift from a buyer's to a seller's market. The price for uranium rose, and this, combined with the increased demand from users in Canada and overseas, will trigger an increase in exploration in Canada. As a consequence uranium producers are now coming into their own after being in a slump for many years.

The Minister and senior officials of the department on a visit to the plant of Great Canadian Oil Sands Ltd.

In early 1973 the sector participated in a study to define the government's position on proposals that a uranium-enrichment plant be built in Canada. The Minister released a statement on August 1, 1973, in which he stated that an enrichment plant could not be considered an essential national project in Canada requiring government ownership or subsidization. However, the Minister also indicated that the government was prepared to assist private industry in acquiring the necessary technology from foreign governments if a project was shown to be in the national interest.

At the First Ministers' Conference on Energy in January, 1974, the Minister announced guidelines for discussions with provincial governments and industry on suitable mechanisms to ensure that the domestic nuclear industry will have a long-term uranium supply.

The Minister also announced that the remainder of the government stockpiles of uranium oxide will be held for the domestic market. There have been recent sales to overseas electrical utilities from these stockpiles, including 1,000 tons to Japan and 4,600 tons to Spain.

Nuclear power in Canada during the reporting period also took an upward trend, comparable to the sales picture in the uranium industry. This was spurred on by the decision of Ontario Hydro to have much of its new electrical generation based on the CANDU reactor; the success of the four-unit Pickering nuclear station; the completion of a sale of a reactor to Argentina; receipt of a letter of intent from Korea for the purchase of a CANDU reactor; and the decision of the federal government to build a heavy-water plant at Gentilly.

The department continues its appraisals of *coal supply* for use in eastern Canadian steel mills and by Ontario Hydro, especially as the situation changed from a buyer's to a seller's market, with an unprecedented increase in price, in early 1974.

The sector has participated with the Ministry of Transport in studies on the transportation of western coal to eastern markets. Representatives have also been engaged in a railway study with special emphasis on terminal facilities at Thunder Bay and in some assessments of a coal-in-oil pipeline from Alberta to Ontario.

The department continues to co-sponsor the annual Conference on Coal which, in 1973, was held in Victoria, B.C. Interest remains high in this conference and it is expected to increase with the future possibilities for western Canadian coal in the domestic and overseas markets.

As a follow-up to work that was carried out for the report "An Energy Policy for Canada—Phase I", an analysis of *the petroleum industry's profits* has been completed. It included appraisals of the effect on industry of various proposed rent-collection schemes.

The sector is also looking at methods of financing of energy projects, especially in the United States, where new and novel approaches are being taken. Possible ways of financing Canadian projects, such as the Alberta oil sands and major pipelines, were related to these methods.

Progress has been made during the year in refining available data on the *undeveloped hydroelectric potential* of various regions in Canada. A more accurate estimate of the resources capable of development is necessary to establish better estimates of the quantities of fossil and nuclear fuels that will be needed to provide the additional electrical-energy requirements.

While a 1968 study concluded that tidal developments in the Bay of Fundy would not be economically competitive, there have been in the interim some substantial increases in the costs of alternative sources of energy. A federal-provincial tidal-power review committee is recommending further studies in specific areas.

The electrical section has participated, in close co-operation with the uranium and nuclear section, in assessing the economics of nuclear generation, especially in areas outside the provinces of Ontario and Quebec. The section has also participated in assessment of the capital investments which nuclear developments will require during the next two decades.

Studies were carried out on the advantages of improved regional interconnections from which individual utilities or regions might benefit economically and through which supply could be made more secure. A policy was subsequently approved and announced at the First Ministers' Conference on Energy in January, 1974. This encourages regional interconnections through federal grants for interconnection studies and loans for up to 50 per cent of the construction cost in approved cases.

Specific application of this policy is being discussed with the Province of Prince Edward Island in connection with an underwater cable link to the mainland and with the Province of Newfoundland and Labrador in connection with the proposed development of the Gull Island hydroelectric site on the Lower Churchill River.

The Nelson River Transmission Agreement between Canada and Manitoba, under which Atomic Energy of Canada has built a high-voltage direct-current transmission line, has reached the point where the equipment associated with the initial phase of the development has been declared to be in service. Negotiations are proceeding on a basis for extending the provisions of this agreement to cover subsequent additions to the development.

Discussions took place during the year with the Canadian Electrical Association on a co-operative research program which would involve all of the Canadian electric utilities. The federal government has offered financial participation in the initial stage of the program. Negotiations are continuing to develop this into a permanent program which will complement the R&D support provided by the Department of Industry, Trade and Commerce.

Members of the section continued to take part in activities of the Canada-USSR Electric Power Working Group. These included a seminar in Leningrad on construction methods in cold climates and mechanical aspects of electrical transmission lines. The seminar was followed by a technical tour in Siberia. The Soviet members of the group visited Canada in September, 1973.

Several members of the section participated in a mission that travelled to China in order to look for opportunities of marketing Canadian electrical equipment.

The issuance of *Canada Oil and Gas Permits* was suspended on March 21, 1972, pending review of land regulations, and no permits were therefore issued during the fiscal year 1973–74. Some 285 permits comprising 7.5 million hectares (18.6 million acres) were returned to the Crown during the year, including 131 deep-water permits covering 3.3 million hectares (8.2 million acres) on the continental slope off Labrador and 39 permits comprising 1.2 million hectares (2.9 million acres) on the Labrador Shelf. On March 31, 1974, the government administered 4,949 permits covering 132 million hectares (326 million acres), 85 per cent of which was sea bottom off the East Coast, the region of greatest exploration activity.

Revenues from "offshore lands" during the fiscal year amounted to about $709,600, an increase of 52 per cent over 1972–73.

During the fiscal year, exploration for oil and gas proceeded at a moderate pace off the East Coast and in Hudson Bay; there were no exploratory activities off the West Coast pending a review of federal-government environmental policies in that region.

During the year, work was completed in conjunction with the Department of Indian and Northern Affairs on a draft of new Drilling Regulations and a start was made on new Production Regulations. Both sets of regulations will be promulgated under the Oil and Gas Production and Conservation Act.

Fifty-one separate geophysical programs involving 74,000 km (46,000 line miles) of seismic surveys were undertaken during the year off the East Coast and in Hudson Bay, using 15 vessels and costing an estimated $15 million.

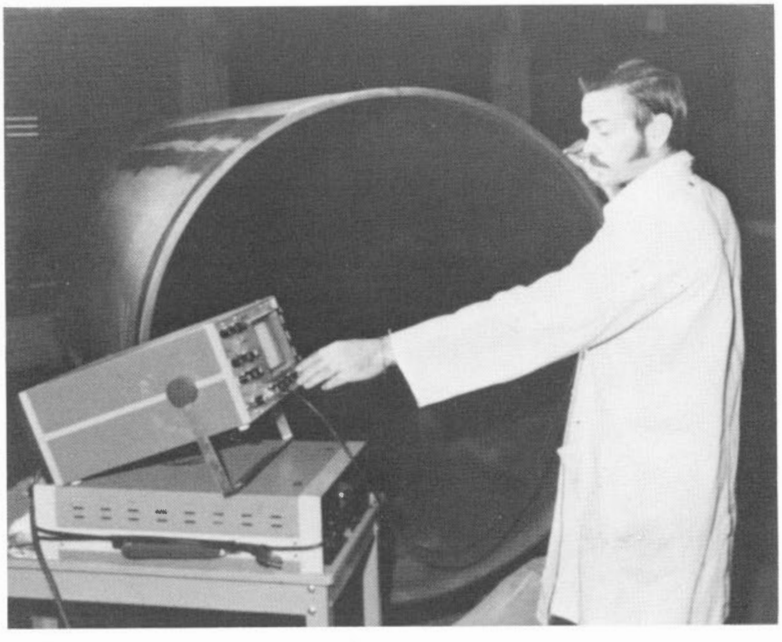
Off the East Coast, 27 wells were drilled at a cost of about $65 million, including 8 wells on the Scotian Shelf, 15 on the Grand Banks, 2 in the Gulf of St. Lawrence and 2 on the Labrador Shelf. This brought the total number of East Coast offshore wells to 85. As many as 6 drilling units were active, including 4 semi-submersibles.

Exploratory drilling resulted in two possible discoveries and one non-commercial show of hydrocarbons. On the Labrador Shelf, there were favorable indications of hydrocarbons in a well 40 miles off the Labrador Coast north of Hamilton Inlet. Due to the lateness of the season this well, drilled by the advanced-design dynamically-positioned drilling vessel Pelican, could not be tested, and so the full significance of the find will not be known until the summer of 1974.

Revenues for the year from federal leases in the provinces amounted to about $440,000, largely from production royalties, and constituting an increase of 10 per cent over 1972–73.

During the year the United Nations Seabed Committee, to which the Resource Management and Conservation branch has continuously provided representation, held its last meeting in Geneva, Switzerland, concluding a series of sessions that have taken place over the last six years and have dealt with a wide-ranging spectrum of matters pertaining to international law in the oceans. The work of this committee having been completed, negotiations proceeded to the Third Law-of-the-Sea Conference to be held in Caracas, Venezuela, during the summer of 1974. First procedural meetings for this conference were held in New York in December of 1973. Of primary importance to Canada and the department in the forthcoming sessions will be the definition of the outer limit of national jurisdiction over seabed mineral resources, and the nature of the international regime and administrative agency to be set up to govern the seabed beyond this limit.

During the year negotiations with Denmark resulted in an agreement regarding the delineation of offshore boundaries of jurisdiction over seabed resources in the Davis Strait–Baffin Bay region. There were no negotiations with the United States regarding the settlement of conflicting claims to shelf boundaries off the east and west coasts, or with France with respect to the continental shelf surrounding the Islands of St. Pierre and Miquelon.



Mines Branch expert tests sample of pipe for pipeline.

MINERAL DEVELOPMENT SECTOR

The Mineral Development Sector is charged with developing federal policies for mineral resources. The emphasis is on resource use and the contribution of minerals to the Canadian economy. Policy advice is based on systematic intelligence and analysis.

The high level of economic activity in industrialized countries intensified demand for all minerals in 1973. High world prices reflected the level of demand. For many commodities price seems to be approaching cyclical peaks, even allowing for inflationary conditions and currency problems.

Canada is simultaneously a consuming nation and a producing nation; an industrialized country and a developing country. Consumers seek security of supply and access to resources on favorable terms. Producing countries want better returns from mining, either in the form of financial returns or the extra benefits from further processing of resources.

Political and economic events are rapidly transmitted to other centres these days as communication is almost instantaneous. No part of the Canadian mineral industry, no region, no level of government and few communities are isolated from the swirl of world forces that affect Canada's mineral-export staples (copper, nickel, zinc, lead, iron ore, molybdenum, potash, gypsum, and the precious metals). To these may be added smelter products such as aluminum.

As a nation, Canada produces an exceptionally wide range of minerals. Two-thirds of all minerals produced are exported, and mineral exports comprise nearly 30 per cent of all exports. Consequently, minerals are more important to this nation and its economy than is the case for any other industrialized country. Yet Canada is by no means self-sufficient. We import several strategic materials such as bauxite, diamonds, chromium, manganese, and tin.

The two main controls affecting international economic co-operation are the *General Agreement on Tariffs and Trade* (GATT) and the International Monetary Fund. Negotiations on the former are to take place in 1974. The Mineral Development Sector is engaged in economic studies of the effects of mineral tariffs within the context of the overall Canadian government response. The results of the forthcoming Tokyo round of negotiations will be exceptionally important. The level of mining activity, the use of mineral resources, the further processing of resources and consequently the health and vitality of communities are affected by tariff and non-tariff barriers.

Terrain scientist, member of Geological Survey of Canada, inspects test cut along Mackenzie Highway. The loose, easily eroded soil makes construction extremely difficult.

Temporary bridge (top) and giant culvert (bottom) ready to be installed on portion of Mackenzie Highway, which will become an important artery for the development of the natural resources of Canada's North. Several of EMR's sectors—Mineral Development, Energy Development—are involved in policy development for the management of northern resources along with the conservation of the environment.

Most people recognize that mineral commodities were unequally distributed by nature across the nation; that some communities, regions and provinces are more dependent than others on particular commodities. The location and grade of a particular deposit cannot be changed. In EMR, the Science and Technology Sector works closely with the Mineral Development Sector in situations where it is possible to change the economic circumstances that lead to development: In this regard the sector manages *mineral-development programs*, normally funded by the Department of Regional Economic Expansion, in association with a number of provinces. For example, as a result of the federal-provincial Western Economic Opportunities Conference, the need for expansion and diversification of western iron and steel production was recognized. Steps have been taken to realize this objective. Similarly, the viability of an East Coast steel complex is being examined. In the far north, the sector was assessing the economic feasibility of the proposed lead-zinc mine at Strathcona Sound, the first industrial project of its type in the area.

The ability of the mineral resource base to sustain the economy in future years is vital in any consideration of Canada's future. Initial work in EMR suggests that known and potentially available mineral resources are adequate to meet domestic needs, and allow for continuation of exports. But what do minerals really mean to Canadians? What supplies are required, what employment is generated by the industry and in ancillary activities? What revenues accrue directly and indirectly? Through economic research using "input-out" analysis and econometric models the sector is making progress in this area of concern. In time, there will be better answers to such questions than are now available.

Price levels for commodities and supply-demand imbalances are usually controlled by long-lasting market forces. In other countries, as in Canada, returns from mineral resources can be significantly affected by short-term problems. Too high a price, and the cost of finished goods must rise; too low, and future supplies are threatened owing to the lag between exploration, discovery, investment in development and production. Short-term factors are often resolved by the industries concerned. But to an increasing degree institutional mechanisms are being developed to cope with problems not covered by GATT or in bilateral arrangements between nations or the normal business dealings of companies.

The sector participated in 1973 in the United Nations Conference on Resources that recognized the interdependence of resource producers and consumers. Canada has long been a member of the International Tin Council and is also a member of the International Lead-Zinc Study Group. Both groups have significant capacities to forecast in the short and medium term, an important factor in resolving problems and maintaining a reasonable stability for these commodities. Both include producers and consumers, leading to a balance of rights and obligations in accord with Canadian commodity trade policy. Canada's interest in resources prompted it to accept observer status in the Iron-Ore-Producers Group, and attendance at meetings of the Copper-Producers Group, Mercury-Producers Group, etc.

The Departments of External Affairs and Industry, Trade and Commerce have important responsibilities in international affairs. The sector's role is to provide assessments of emerging commodity problems from a resource-management viewpoint, and to work on the technical committees.

During 1973–74, Canada received mining and trade missions from Poland, Spain, South Korea, and the People's Republic of China, and hosted more than a half-dozen meetings with officials of other countries. A fruitful interchange was begun with Poland, as Canadian and Polish government officials and mining experts exchanged visits. As a result, the groundwork has been laid for exchanges of mining expertise and expanded trade between the two countries.

On mineral-resource-management problems, views are exchanged between countries at the ministerial and official levels, through missions, conferences, and contact with agencies. The special involvement of corporations domiciled in the U.S., Japan, and the EEC in Canadian mineral resources provide a continuing basis for dialogue on markets, investment, price and supply.

Involvement in these types of activities requires the sector to maintain a strong analytical staff. A wide-ranging intelligence of mineral affairs both domestic and foreign permits a rapid response by the sector to questions of the day, and provides the basis for involvement in longer-term problems of mineral-resource management and policy affecting mineral resources.

Periodic reviews are made of the state of the mineral industry in Canada to help other parts and levels of government, industry, and the public get the information they need. A digest is published annually in the form of the "Canadian Minerals Yearbook." A special publication of topical interest for 1973 is entitled "Mining and Environmental Law."

The Mineral Development Sector is leading a review of national mineral policy in the federal government. In 1973, the first steps were taken to find the common elements, the ties that bind together different interests within the federal government, the provinces and the mineral industry. The ten provincial mines ministers and the federal government announced a set of objectives that will form the basis for a national mineral policy.

Late in 1973, it was agreed to establish a Canadian Ministerial Conference on Mineral Policy. Its purpose is to provide a governmental forum for consultation on issues that are national in scope. The conference is not viewed as a joint decision-making body, but an important new avenue of intergovernmental communication. Ministers agreed that in 1974 the conference would focus on uranium policy; the respective roles of governments in the control, management and disposal of minerals; and the further development of a national mineral policy. In the meantime, different views, sincere views and above all concerned views are being expressed as to the issues that should constitute a strategy for Canada in today's world, in harmony with Canada's resource endowment, and the needs of regions.

The Centre for Resources Studies at Kingston, Ontario, was established on October 1, 1973. It is under the jurisdiction of Queen's University and sponsored by the university, the Department of Energy, Mines and Resources and the Canadian Mining Association. The purpose of the Centre is to carry out high-quality, independent research on those important questions which face the nation in mineral-resource development and mineral-resource policy.

EMR formalized a long-standing agreement with the Canadian International Development Agency to continue acting as CIDA's technical advisor in planning and implementing mineral-related foreign-aid projects. In CIDA-sponsored projects abroad, Canadians are hired by the agency to act as advisors and supervisors of local tradesmen, technicians and managers. In India, for example, a group of Sudbury miners have almost completely changed the work habits of the 5,000 Indian miners at the Khetri copper mine. In what is turning out to be an impressive success story, the Sudbury miners have helped to boost production 400 per cent by demonstrating improved drilling, loading, and tunnelling techniques, and by suggesting a bonus system that spurred the miners to double their efforts.

In 1973–74, EMR aided CIDA in planning instruction for miners in India and mine projects at various locations in Burma, Tanzania and Malaysia, and helped to recruit Canadian professional personnel to supervise these projects. Some 35 training programs in Canada were organized in mining technology with UN or CIDA fellowships. In the past, nine out of ten UN sponsored trainees in the geological sciences, mining and metallurgy were sent to the United States. Today, most UN trainees are being sent to Canada for practical experience.

Members of the Geological Survey of Canada inspect core of subsoil obtained in Northwest Territories. Study of soil content and permafrost penetration help scientists determine the capacity of the soil to support engineering and other projects.

Users of aerial photography can now study microfilm showing complete aerial coverage of Canada and microfiche index cards through viewers like these at the National Air Photo Library. The system facilitates ordering of aerial photography and reduces storage space.

SCIENCE AND TECHNOLOGY SECTOR

Surveys and Mapping

The growing importance of exploration and development of fossil fuel resources in the Arctic and northern Canada requires adequate surveys and topographic maps. During the fiscal year 1973–74, the Surveys and Mapping Branch began to step up its program in the north to serve these needs, and activities over the next several years will emphasize work in these frontier areas.

The major products of the Surveys and Mapping Branch are accurate topographic maps, aerial photographs and data from a national network of survey control points, precisely established and maintained by government geodesists. These are basic tools for the development of Canada's resources and have always been essential for many industrial, scientific, educational, legal, engineering and tourist-industry purposes.

A principal highlight for the branch during 1973–74 was the appointment of Raymond E. Moore as director in July, 1973. He replaced Dr. S.G. Gamble who was appointed Assistant Deputy Minister (Administration) for the Department of Energy, Mines and Resources.

Total budget for the Surveys and Mapping Branch during 1973–74 was $17,506,000. Of that, $5,458,000 was spent on control and legal surveys; $7,997,000 on mapping services; and $2,271,000 on distribution of technical information, with $1,760,000 being recovered through the sale of maps and air photographs. A sum of $70,000 was allocated for feasibility studies and contract management of external-aid project for the Canadian International Development Agency (CIDA), and the balance of the budget went for administration.

During 1973–74, about 3,000,000 maps were sold through the Canada Map Office, and almost 16,000 requests were received by the National Air Photo Library for air photographs.

A major responsibility of the Surveys and Mapping Branch is to get information to professional clients as quickly and as efficiently as possible. Important steps toward this end were taken in 1973 when the branch developed a new data-base system aimed at quick response to requests for new mapping, particularly in the far north. Available topographic maps for this region are mostly reconnaissance types at the scale of 1:250,000. This map scale is adequate, unless some form of resource development occurs. Not knowing where the demand for the more detailed 1:50,000 map scale may occur, the branch has stored in the data-base system co-ordinate data generated from aerotriangulation, which may be drawn upon for rapid map compilation, as the need arises.

Young geologist on traverse checks her bearings before continuing. It is no longer rare to find women in geological field parties.

Such a system allows a selective choice of information for production of a topographic or line map, or a photomap, depending on the user's needs. It also cuts the time needed to process requests from four years to one year for a color map, three to four months for a monochrome map and even less time for an emergency printout. The branch spent $500,000 to begin the program which, during 1973–74, processed into the bank enough information for 800 maps. The data bank will be completed by 1979. An index is available for the content of the bank, and is regularly updated.

There will also be more use of *monochrome maps*, as opposed to the full-color topographic-series maps, so topographic map information can reach the public faster. During 1973, this new emphasis doubled production of topographic maps over 1972. Of the 1,223 maps produced in 1973, 549 were monochromes.

The National Air Photo Library has finished *microfilming the complete aerial coverage of Canada* for easy reference as another service to the public. Cassettes of microfilm containing up to 2,000 images are available. Index maps showing relative ground positions of the photographs have been placed on microfiche, with up to eight index maps per fiche. Major users can buy these cassettes and cards for their own use, or they may view them in the library to order the prints they want. The system reduces the amount of space needed for archive storage and provides a quick reference for ordering prints.

During 1973, microfilming of legal-survey data was also undertaken. The data were obtained from surveys of federal lands, including Indian lands, done on request from other federal departments, and they are available to the public.

The method of establishing horizontal control by measuring, from points on the ground, the Doppler frequency shift of satellites is being used extensively in *geodetic surveying*, particularly in Arctic and offshore areas. Geodetic surveying establishes horizontal control (latitude and longitude) and vertical control (the exact height above sea level) of selected points across Canada to extend and densify the national network of survey control points. This network is essential to accurate mapping by both government and private mappers. The Doppler assessment was done by the University of New Brunswick which, with the help of the Surveys and Mapping Branch, established 21 Doppler stations from the Atlantic to Manitoba. The Doppler method is based on the principle that electromagnetic waves coming from a moving object appear to undergo a frequency shift in relation to a stationary observer. The position of a Doppler ground station can be calculated by recording this fequency shift, because the position of the satellite is known in terms of latitude and longitude at all times.

The success of the Doppler method means an end to the aerodist in the branch's geodetic surveys. This method was employed for the last time in 1973 to establish horizontal control in northern Ontario and northern and central Manitoba, completing coverage of this area suitable for mapping at a scale of 1:50,000. The aerodist is an airborne-assisted electronic distance-measuring device that measures the amount of time it takes for a radar beam to bounce from an airplane to two ground stations and back again as the aircraft passes midway between the stations. From this, the distance from airplane to station is calculated and then the distance between the two stations. The branch has used the aerodist method for the past 10 years, and it has greatly reduced the cost and time of surveying Canada's wilderness areas.

In its geodetic work, the branch established 1,600 new bench marks across Canada for vertical control during 1973–74. One of the most important projects, the levelling along the Mackenzie River valley begun in 1972, continued the following year. The branch also went ahead with its work in horizontal control in British Columbia, using, for the first time, a first-order traverse to establish primary control in a large area of the province north of Prince Rupert between the Alaska Highway and the Alaska boundary. In a first-order traverse, surveyors measure the distance between two points by using electronic distance-measuring devices and angular measurements. This is a departure from the traditional method of calculating distances by triangulation, and, because it reduces both the time and money required to survey, it will probably be used more in the future. In all Canada, horizontal-control work established a total of 99 first-order and 320 second-order horizontal stations during 1973–74.

The International Boundary Commission began the task of replacing stone cairns of the Alaska–Yukon triangulation with more permanent marks during 1973. This was necessary because these stations are being used more and more as surveying reference points by those doing surveys for resource development in the area.

A readjustment of the national network of horizontal control will begin during 1974–75 in Canada following an understanding in 1973 with the United States and Mexico to develop a more uniform survey control network for the whole of North America. Over the past few years, geodesists have found that there are definite distortions in the network. This is because distances measured by the new high-accuracy electronic distance-measuring devices do not conform with data from older surveys in which distances were calculated by triangulation. Thus, resurveying in the regions where triangulation was used followed by computer readjustment of the data to conform with other regions surveyed is essential for an accurate, uniform national and international network of survey control points. The program in Canada will probably take 10 years to complete.

During 1973–74, the Surveys and Mapping Branch published several new products and developed new formats for some maps to make them more acceptable to the public. The fourth edition of *The National Atlas of Canada* was one of the most important new publications. The Atlas, a collection of 334 multicolored maps, 400 graphs and explanatory texts on 266 pages, was completed in the looseleaf form in both English and French in 1973. A contract was also signed early in 1974 with a private publisher for the production and distribution of a bound edition in the fall of 1974. The publication provides an authoritative graphic summary of Canada's physical setting, human geography, resources and economy during the past decade and is a major national reference work.

In the production of *aeronautical charts*, a new publication, RNAV Ottawa–Montreal, was published for the new STOL service between those two cities. A new format for the VFR (Visual Flight Rules) terminal area chart was developed, and a new northern supplement and IFR (Instrument Flight Rules) handbook were published.

Other map products new in 1973 included a map of the Yukon Territory at a scale of 1:1,000,000 and a resource atlas of Newfoundland produced, on request from that province, to coincide with Newfoundland's 25th anniversary as a province of Canada.

On the whole, 3,600 maps were produced—an increase of 25 per cent over last year. Copies printed amounted to 10,000,000. Of these, 1,223 were of the topographic series, 110 of which were produced by the Winter Works Program in Vancouver, now in its third year. Automated cartography, the production of maps with the aid of computers, made up 10 per cent of the branch's production of topographic maps and general maps of Canada. Such automation will gain more impetus in the future as part of a general increase in map production to keep up with Canadian development.

A program for the computer adjustment of blocks of aerial photographs was developed by branch engineers during 1973 and has been accepted as standard procedure by private map producers. The adjustment reduces the need of a great number of horizontal control points throughout the whole block by using measurements of selected points along the perimeter only. The system also reduces the cost of map production.

A special light-weight tower was developed and tested in 1973 by the International Boundary Commission to be used in precise angular measurements by survey teams in the field. The easily transported tower weighs less than 360 kg (800 pounds), comes in five-metre sections that rise to a height of 20 metres and is designed to do the work of much heavier towers based on a design that is 50 years old. The new tower is constructed to carry a theodolite and certain electronic distance-measuring devices. It is placed inside another light-weight tower, developed during the past year by a private manufacturer, which supports the surveyor so that his movements do not disturb the instrument.

Geological Survey of Canada

The Geological Survey of Canada entered the 1970's with a considerably expanded mandate. This derived in large measure from the new emphasis on the protection of the natural environment and the preservation of ecological patterns, on the one hand, and on the need for national self-sufficiency in mineral resources, especially energy resources, on the other.

This led the Survey to expand very greatly its investigation of terrains, from an engineering and conservation point of view, the probing of the ocean bottom, near shores and on the continental shelves, and its inventory and prognosis of existing and probable mineral resources.

Along with this work, the Geological Survey continued to map the bedrock geology of Canada and to study the processes that have led to the formation of the Canadian landmass and whose understanding is essential in the search for valuable deposits.

The total budget of the Geological Survey in the fiscal year 1973–74 was $19,830,000, of which about $600,000 was contributed by other federal departments (mainly for joint research projects in the Arctic). Of this, field work consumed $4.5 million, and the long-term federal-provincial aeromagnetic surveys, which are let out to contract, $1,130,000. Most of the remainder of the budget went to salaries and equipment.

The appointment of a new director, Dr. Digby McLaren, the former head of the Survey's Institute of Sedimentary and Petroleum Geology in Calgary, occurred during the year. (The former director, Dr. Yves Fortier, became Senior Advisor, Earth Sciences, to the Assistant Deputy Minister, Science and Technology.)

The following projects may exemplify the work of the Geological Survey during 1973–74, as it would be impracticable to give here a description of each of the 493 projects undertaken that year—many of them of equal importance.

Of particular interest both to geological science and to the prospecting industry was a continuation of the *Bear-Slave Geochemical Operation,* started in 1972. This survey, based chiefly on the sampling of lake sediments, covered an area of about 93,000 square kilometres (36,000 square miles) north of Great Slave Lake. The follow-up in 1973 covered an area of 3,800 square kilometres (1,500 square miles), and laboratory and office assessments continue.

Field party of Geological Survey of Canada surveys beach morphology near Tuktoyaktuk, N.W.T., on the shore of the Arctic. *(Inset)* Discussing the day's findings of a geochemical survey near Great Bear Lake.

Loading drums with rock samples collected on geochemical survey at Wopmay Lake, N.W.T.

Geochemical surveys, a relatively recent development in geology, are based on the fact that all metals contained in the earth's crust tend to "migrate." This means that the chemical compounds containing the metals are dissolved by groundwater and are carried along with it, often over considerable distances, after which they may become lodged in rocks and sediments. Thus a mineral deposit will become surrounded by a "halo" of weaker concentrations. Being very large, the halo is naturally much easier to spot than the deposit itself, especially as the halo may appear at ground level, while the deposit originating it may be buried at considerable depth. However, metal concentrations in the solutions are usually extremely weak, being measured in parts per million, and highly sensitive laboratory methods are required to establish them.

Geochemical surveys have become a valuable tool in geology, as they may give indications of metal potential in certain areas. However, they are not equally useful or reliable in all types of terrain. Areas with dense deciduous forest cover, for example, are poor geochemical areas, as the vegetation processes tend to obscure or distort the readings. On the other hand, the sparse coniferous vegetation of Canada's subarctic regions, such as the area north of Great Slave Lake, was believed to be excellent "hunting ground" for the geochemist—which was borne out by the Bear-Slave operation. A number of interesting anomalies—unusually high contents—were noted, and hypotheses were put forward to explain them. It was found that the general picture indicated by the geochemical survey did not conform readily to the data produced earlier by reconnaissance bedrock mapping; geologists believe that a re-evaluation of earlier, standard surveys may be required. If such a second look should show the anomalies to be associated with siliceous volcanic rocks, the mineral potential would be regarded as high.

The two-year operation was carried out with a small staff, thanks to the high mobility made possible by small aircraft and helicopters. A field laboratory was set up for rapid sample analysis. Parts of the area under investigation were also overflown to provide color air photographs to aid in the geological interpretation.

It was the largest area in Canada ever to be subjected to a geochemical survey of this type. The preliminary report on the operation concludes that the region "is eminently suitable for applied geochemistry; indeed, in places it may be close to ideal."

Chemical analyses also played an important part in another highly interesting and unusual project of the Geological Survey—a sampling of hot springs in British Columbia to assess their *geothermal potential*. The recent crisis in the petroleum market and the general apprehension that traditional energy sources may become strained or depleted has naturally directed attention to untapped sources. The so-called hot springs which are found in regions of recent or current volcanic activity are such a potential source. In Canada, hot springs occur mostly in the geologically young and active mountains of British Columbia.

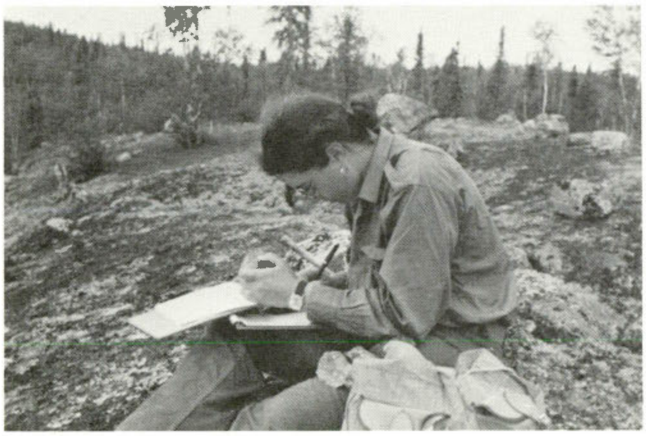
Until now, precise data on British Columbia's hot springs have been scarce, and the preliminary report on the survey states that "the geothermal potential of western Canada is impossible to assess on the basis of existing data. Several Quaternary volcanoes (i.e., those no older than about one million years) in British Columbia have produced lavas of an age and type commonly associated with hydrothermal fields elsewhere, but no active fumaroles or boiling springs are known in Canada." Of course, warm water issuing from the ground may indicate boiling water at depth; but this will not be verified without detailed investigation.

The chemical composition of the water provides evidence of the conditions at depth—water with a high content of silica usually indicates a recent or hot volcanic environment, whereas a high content of carbonates indicates an older, cooler environment.

Therefore the sampling program carried out during the 1973 field season embraced chemical analyses as well as other techniques on approximately 50 thermal springs in British Columbia. Some sampling was also carried out during the winter.

There appeared to be no temperature difference in hot springs between summer and winter. One hot spring, located about 160 kilometres (100 miles) north of Vancouver had a temperature of up to 60°C (140°F), and the drill pipe extending into the spring was so hot that the drillers could barely handle it. Even the rocks some distance from hot springs still show high temperatures.

Top: Members of a geological "fly camp" load their gear on an "Otter" for return to base camp. *Bottom*: Geologist uses small sledge hammer to obtain rock samples for geochemical survey.



Top left: Brief pause during helicopter-supported field survey: The geologist makes entries in his note book, while the chopper pilot refuels. *Bottom left*: Making notes during geological traverse. *Right*: Terrain scientists collect sample of beach material on the shore of the Arctic.

The way in which geothermal energy may be converted to practical use in Canada is not yet certain. A problem is also presented by the lack of legislation covering access to and use of thermal springs. Mining legislation has not so far concerned itself with these natural phenomena, and this question will have to be dealt with before development can begin.

The legacy of recent geological activity is also the subject of another type of investigation carried out by the Geological Survey in 1973–74—that of the *landslide-prone areas* of the Ottawa valley.

The so-called Champlain Sea—a large invasion of the sea into the St. Lawrence River valley and adjacent regions about 10,000 years ago—left behind large amounts of sea-bottom sediments, mostly clay. In many parts of the area these sediments have since been washed away, but where they remain they often represent a considerable hazard, as they have the capacity to store up large amounts of water, which may cause them to turn into sliding mud with little warning. The disastrous landslide at St. Jean Vianney in 1971 and the lesser slides at Templeton and Chelsea in 1973 (in Quebec) and the 1971 slide at Casselman (Ontario) all started in these Champlain clays. Geologists hope that they will be able to classify soils in the area affected by the degree of landslide danger, so that builders and homeowners will be left in no doubt as to the risks they may be taking.

What makes such work even more important is that certain other areas of Canada also have soils dating from the same period and having the same characteristics. This applies, for example, to thousands of square kilometres around the southwestern part of Hudson Bay. The only reason why landslide damage has not been reported from that area is that settlement is so sparse there. If enough information can be obtained before the advent of development—e.g., pipelines or other transportation routes—construction may be planned in such a way that slide dangers will be averted.

The ocean and seabed off Canada's east coast may well become a large new source of mineral wealth, in addition to the wealth in fishes and other sea food. In order to understand the peculiar marine environment and the forces that continue to shape it, the Atlantic Geoscience Centre of the Geological Survey has been carrying out a broad range of investigations in marine geology.

One such study, in the summer of 1973, concerned past and present *processes affecting the nearshore environment* in the Strait of Canso and Chedabucto Bay, Nova Scotia. Not only has that area seen important industrial development in recent years, due in large part to the construction of the causeway linking Cape Breton Island to the mainland, it has also been the scene of a disastrous oil spill from the tanker "Arrow" in 1970, which fouled many of the beaches.

Geologists set up a temporary laboratory in a Port Hawkesbury school gymnasium and had a small vessel at their disposal for surveys and sampling. Participating in the program were 31 scientific and technical staff representing five research agencies from government and a university. Activities included comprehensive bottom sampling, water sampling for suspended solids and dissolved constituents, a shallow seismic survey and coastal mapping.

The scientists found that the construction of the causeway had divided Canso Strait into two distinct oceanographic environments with pronounced differences in the salt content and temperature stratification. The quality of the bottom sediments and the water has been affected by industrial wastes from the industrial park at Point Tupper. Living foraminifers—tiny unicellular animals that populate the oceans in vast numbers—were completely absent, and the water was highly turbid and contained traces of metals. Much of the coastal environment of Chedabucto Bay was still affected by the residue of the oils from the "Arrow" disaster.

The study sheds new light on the effect of industrial activities on marine ecology.

Projects that do not take place in the field but that are at least of equal importance are the *evaluations of Canada's fuels and minerals* that are being carried out by the Geological Survey's Institute of Sedimentary and Petroleum Geology in Calgary and by head office staff in Ottawa. By using all available data on geological settings, in Canada and abroad, that are known to be favorable for the occurrence of certain types of fuels or ores, along with data from oil and mining companies, economic geologists engage in "plays" that may yield better assessments of our energy and resource prospects, thus helping to plan appropriate regulatory measures.

In order to provide the broadest possible base for such evaluations, the federal government is negotiating with provincial governments—which carry out their own geological studies—for a joint evaluation program covering all non-renewable resources as well as terrain types.

Mines Branch

The Mines Branch is a large laboratory and pilot-plant complex conducting research to develop new and better methods of extracting minerals and fuels from the earth's crust and processing them into useful products. Today's twin demand for new sources of energy and minerals and a clean, attractive environment are reflected in the research and development work of the Mines Branch. As most of Canada's high grade and readily accessible mineral deposits are already being mined, research emphasis at the Mines Branch is placed on developing recovery techniques for ores and minerals that present problems because of low grade, impurities, or complexities of mineral composition. The total budget of the Mines Branch in the fiscal year 1973–74 was $14,116,000.

Dr. Donald Coates, formerly the head of the branch's Mining Research Centre, was appointed director of the Mines Branch, succeeding Dr. John Convey, who was recently appointed Senior Adviser on Mining and Metallurgy.

Machine feeding excavated tar sands onto conveyer belt, at Athabasca Tar Sands. EMR is advising the government on development and financing of these and other energy sources.

In 1973–74 the "energy crisis" struck Canada, underlining the importance of extending existing energy reserves as well as developing new sources of energy. Fuels research at the Mines Branch includes a comprehensive evaluation of the quality of Canada's fossil fuels and the development of refining methods for the low-grade petroleum of the *Athabasca oil sands*. The enormous potential of the sands cannot be tapped until efficient, economical techniques can be developed for separating the oil from the sand, and upgrading the oil for commercial use. Some of Canada's low-grade crude oils contain unwanted sulphur and traces of nickel and vanadium. Mines Branch fuel experts have developed a "hydrocracking" process which eliminates much of the nickel and vanadium, reduces sulphur content, and increases the fuel yield by about 20 per cent. In this process, the production of waste coke is virtually eliminated, and the liquid product has a wide range of fuel uses. The process is now ready for testing on an industrial scale.

As energy needs grow and the cost of oil and gas continues to rise, coal will be used increasingly as a source for thermal electricity, especially in the coal-rich western provinces. During the year, the Mines Branch continued work on a federal-provincial project to determine the amount of *lignite coal* in the Ravenscrag Formation in Saskatchewan that can be used for thermal power production for the next 20 years. About 1,500 samples have been analyzed annually for the past two years, and the assessments and recommendations are expected by the end of 1974. Discussions are going ahead with the provinces concerning similar projects.

In addition to developing the technology for opening up new sources of fuel for the future, the Mines Branch is also seeking the most efficient methods of using existing energy resources. Combustion experts performed a series of winter *driving tests* on an assortment of automobiles under highway and stop-and-go city driving conditions to measure fuel economy and pollution emissions. It was found that many strategies could be followed to improve gasoline mileage and reduce significantly pollution emissions from current designs of engines. Several fuel-economy devices attached to the engines were tried out, and some increased gasoline mileage considerably.

Mines Branch experts have developed new methods for safely increasing the gradients of open-pit mines such as this one, thereby reducing the overall size of the pit and making excavation more economical.

After many years of research the Mines Branch has also developed a "blue-flame" *oil-furnace burner* that reduces fuel consumption by about 10 per cent during a typical winter and is virtually nonpolluting. The burner is now ready to go to the industrial prototype stage and may one day become a commodity item.

Transporting *liquid fuels through pipelines* is another area of Mines Branch expertise. In the future, much of Canada's oil and gas will come from faraway frontier areas, and reliable, durable pipelines will be a necessity. Accordingly, metals research at the Mines Branch is now focusing on ensuring the structural soundness of pipelines for use in the Arctic. A major pipeline project has been launched to study the behavior and use of metals and alloys in the harsh Arctic environment. Branch metallurgists are testing pipeline metals for strength, weldability, corrosion, cracking, brittleness, and ductility in order to select the best materials for the job. During 1974 the branch will produce a monograph on metals and alloys for use in the Arctic, and a report on the structural suitability of the proposed pipes for the Mackenzie Valley pipeline.

Mining research is aimed at maximizing ore production from both open-pit and underground mines with minimum cost and environmental disturbance. The second year of a five-year $4-million project to optimize the design of the rock slopes of open-pit mines was completed on schedule. The goal of the project is to reduce the excavation of waste rock from open-pit mines by more than ten per cent a year—a reduction of some 35 million tons that could save the mining industry up to $50 million annually. In 1973 the total budget for the project was $650,000, of which $450,000 was contracted out. At the completion of the project, an engineering manual on pit-wall design for the use of operating engineers will be produced.

Mine safety is also a major concern of the Mines Branch. Bigger machines and deeper mines have produced an underground working environment demanding more attention to pollution by dust, radiation, noise and diesel exhaust fumes. At branch laboratories in Ottawa and Elliot Lake, scientists are testing the sources, effects and methods of controlling harmful components of mine air. In co-operation with a private research foundation, the branch has modified a dust sampler which gives a more accurate reading of dust levels in metal mines. These instruments are now being tested in several mines.

Particulate emissions from diesel engines used in underground mining are also being studied to determine the effectiveness of water scrubbers and afterburners to remove harmful carbon particulates. Test results to date will provide new guidelines for mine-ventilation design. Branch scientists are also developing monitoring systems for an early warning-detection system to prevent explosions.

Over the years the Mines Branch has developed a sound reputation for its close working relationship with industry. An example of this effective relationship was illustrated in 1973 with the completion of a project to develop a process for the *production of spodumene,* a lithium-bearing mineral used in the manufacture of heat-resistant glass. Branch scientists developed a difficult and complex flotation process for the spodumene, and industry applied this laboratory work to pilot-plant scale. The branch has obtained Canadian and American patents for the process, which is now ready for commercial application.

The Mines Branch is also working closely with industry on the development of a unique *electric smelting furnace* for iron ore. After a decade of research in branch laboratories, a contract for $303,314 has been awarded to a major Canadian steel company to further develop the process under industrial conditions. This novel smelting process lowers energy needs, alleviates pollution problems, increases output and allows the use of coal as a source of carbon instead of the more expensive coke that is required for blast-furnace smelting. In this process, the off-gases from the electric furnace are used within the overall smelting process, reducing energy needs by about 30 per cent.

Industrial interest in the "shaft-electric furnace" has become keen in the last few years due largely to the increasing scarcity and cost of scrap steel as furnace feed, increasing energy costs, and a growing awareness of industrial-pollution problems. Since the shaft-electric furnace can be operated economically in smaller units than is possible with blast furnaces, such a unit could find use in small or medium-size steel plants located in areas where the population is too small to support large integrated steel works.

Other significant research related to steelmaking is aimed at finding a substitute for expensive and increasingly scarce imported *coking coals*—an essential ingredient in the smelting of iron ore. Western Canadian coal could provide a major supply of low-volatile coking coal, but there are problems in transporting western coal economically to major steel producers in the east. One solution is to transport coal in an oil slurry through a pipeline. In this way, both thermal coal for use in electric generating stations and coking coal could be transported over long distances. Branch researchers are studying methods for separating coking coal from such coal-oil slurries without deterioration of the coking characteristics. So far, laboratory tests have shown that separation is technically feasible.

In the field of *mineral sciences*, a whole range of physical, chemical, crystallographic, and magnetic studies determine mineral characteristics important to the extraction and processing of mineral ores. A promising new project was started during the year to assess the potential of sophisticated image-analysis equipment for a whole range of mineralogical research. Using this "image analyzer" it is possible to determine quickly and efficiently the proportion of each mineral in an ore sample, and the size distribution of these minerals. This information determines the minerals which must be concentrated in order to recover specific elements, and the size to which the ore must be ground to liberate the mineral. The image analyzer makes routine tasks that are long and complicated with traditional methods.

Branch scientists have used the image analyzer successfully to analyze many ores, including a *fine-grained zinc ore* of a type that occurs in New Brunswick but that is not found in any currently producing mine in Canada. It does, however, occur at the Santa Lucia zinc deposit in Cuba, and Mines Branch expertise was enlisted by the Canadian International Development Agency (CIDA) to help with finding a suitable method for processing the ore. Studies have shown that the fine-grained ore of New Brunswick and Cuba requires very fine grinding to achieve optimum mineral separation. The Mines Branch also assessed a silver deposit in Morocco at the request of CIDA and found the ore of sufficient potential to support a small mining operation.

More than 30 per cent of the total Mines Branch research budget is assigned to various projects related to environmental improvement, some of which have already been mentioned. One of the goals of the branch is to develop new methods of processing and recovering mineral resources that will reduce environmental problems. In 1973–74, research continued on *hydrometallurgical methods* of processing sulphide ores that avoid the sulphur-dioxide pollution caused by conventional smelting processes.

The initial phase of hydrometallurgical treatment is leaching. The ore is treated with a liquid that dissolves the valuable metal components. Once in solution, the metal products can be separated and ultimately recovered by such processes as solvent extraction, ion exchange, and electrolysis. The sulphur produced as a by-product is nonpolluting and has commercial potential. Branch metallurgists have developed hydrometallurgical processes, some simple and some more complex, for the treatment of nickel-copper-iron sulphide concentrates that can recover nickel (along with associated cobalt) and copper to produce either crude or refined metals. Such processes, in addition to being nonpolluting, would prove especially useful when the size of an ore deposit is too small to justify the costs of building a conventional smelting complex. A plant using hydrometallurgical processing could be built at the mine site.

In another area of environmental research, studies are continuing on *converting mineral wastes* into useful products. In 1973–74 processes were developed for: the manufacture of mineral-wood insulation from asbestos tailings, production of dry-pressed brick from iron-mine tailings and production of calcium-silicate building bricks from the residues of magnesium metal production. Branch scientists are also studying methods for recycling cans from garbage to reclaim tin and steel components. Successful results of this new project could lead to far wider applications of scrap-metal re-use.

Not all mineral wastes, however, can be converted into useful products. In fact, most mining and metallurgical wastes end up in tailing ponds and waste dumps, with potential for harm to the environment. To minimize the environmental effects of these wastes, branch researchers are studying a variety of methods for *removing harmful substances* from water, effluents and tailing ponds before they enter drainage systems. Tests were conducted on the problem of water contamination caused by the weathering (exposure to atmospheric factors such as wind, rain, sun) of sulphide-containing tailings from processing mills. Tests were also carried out on the tendency of certain clays to absorb polluting traces of metal from mine-waste waters. During the year research continued on the revegetation of mine wastes. Not only does revegetation prevent erosion by wind and water and reduce the polluting effects of airborne dust and seepage water, but it is more pleasing to the eye than exposed waste dumps. Field-plot and growth-chamber studies were done on acidic mine tailings in the Elliot Lake area to determine the most suitable plants and fertilizers for soil, weather, surface, and sun and wind conditions.

A geophysicist with the Earth Physics Branch measures the declination and dip of the earth's magnetic field near the north magnetic pole off Bathurst Island in the Canadian Arctic. Data from the study were used to calculate the new position of the wandering pole.

Earth Physics Branch

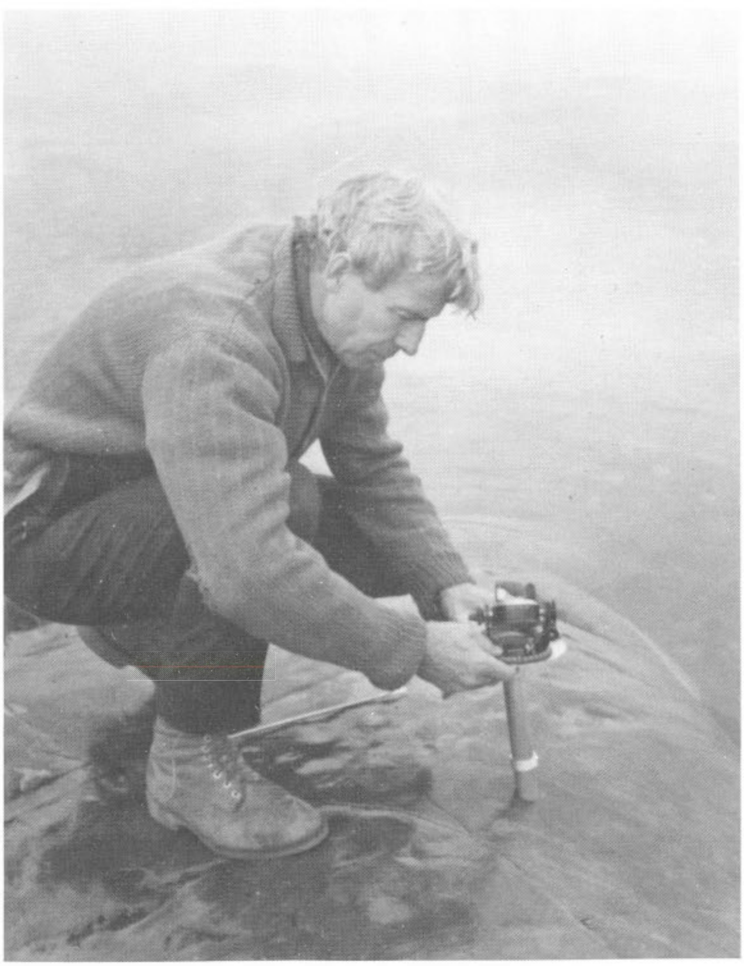
The Earth Physics Branch, during 1973–74, diverted most of its efforts from the regular, continuing programs to urgently required geophysical studies and research projects concerning exploration and resource development in the Canadian North and West.

Generally speaking, the branch studies the seismic, gravitational, geothermal, geodynamic and geomagnetic properties of the Canadian landmass and their relationship to similar data from across the world. These basic geoscience services provide key information for resource development, energy transportation, navigation, telecommunications and national defence and contribute to knowledge of the geological evolution of Canada and geological hazards such as earthquakes. As part of its routine work the branch also maintains a network of seismic, geomagnetic and earth-motion observatories across Canada and produces maps of the gravity and geomagnetic fields.

During 1973–74, the branch operated on a budget of $4,892,000, of which $1,318,000 went to the Gravity Division; $1,369,000 to the Division of Geomagnetism; $1,572,000 to the Seismology Division and $633,000 to administration.

A principal highlight for the year was the appointment of Dr. K. Whitham as director in December, 1973. He replaced Dr. John H. Hodgson who accepted an UNESCO position in the Philippines.

During 1973, the Seismology Division completed a seismic-hazard study for the northern Yukon and the Mackenzie Valley. The study is in three parts. One part, published as "Seismic Risk in the Northern Yukon and Adjacent Areas," is an historical account of seismic occurrences there. The second part, soon to be published, outlines the microseismic events (those too small to be routinely recorded by the division's seismic network) registered during a special six-week experiment in 1972. The third part is a theoretical calculation of what would happen to the ground near a pipeline if an earthquake of a certain size occurred in the area. In the future, similar studies will be done for Arctic areas that show potential for resource development, particularly if that development includes pipelines.



Earth physicist checks the position of a rock core to be used in paleomagnetic survey.

Improvements made at the seismic-array station in Yellowknife, N.W.T., now allow seismic events to be computer-processed there as they happen, thus eliminating the delay caused previously by having the magnetic tapes processed in Ottawa. The station was established in 1962 to do research on discrimination between earthquakes and nuclear explosions. At the station, seismometers are arranged in an array and any ground motion they detect is transmitted to the new computer which monitors, digitizes and analyzes all incoming signals and immediately detects any seismic events. A telephone connection between computers in Ottawa and the Yellowknife equipment scheduled to be established in the near future will make the processed information available in Ottawa within 24 hours.

Early in 1974, the *geothermal unit* of the Seismology Division began to assess the possibilities of geothermal power as a feasible energy source in Canada by shallow drilling in the Lillooet Valley area of southern British Columbia. This region has potential as a source of geothermal power because of the hot springs there and also because it is close to the urban area around Vancouver. This work, conducted with the co-operation of the Geological Survey of Canada, is only part of the unit's program which actually centres on permafrost and heat-flow studies.

Results from a feasibility experiment carried out during the summer of 1973 in the Quesnel area of British Columbia with the *Vibrosis deep-reflection technique* of studying the structure of the earth's crust are encouraging and indicate that the technique is useful for future branch work. The oil industry has used this device regularly to study potential oil-bearing structures to a depth of three to five kilometres, but its use by the branch to 30 or 40 kilometres (20-25 miles) is quite new. This is the first time the division has used the device and the first time it has been tested in an area already geophysically surveyed so that results can be compared with those already established. The technique, which relies upon the reflection of vibrations sent into the crust from the surface, is valuable because the equipment is easily transported by truck. It is also "cleaner" than present techniques, many of which use explosives, and enables seismologists to obtain a more detailed picture of crustal structure.

A team of four geophysicists from the Division of Geomagnetism calculated the present position of the *earth's north magnetic pole* as just north-west of Bathurst Island at 77.1°N, 101.8°W following a two-month trip to the Arctic during the summer of 1973. This is the first time since 1962 that the position of this perpetual wanderer has been established by ground observation. The magnetic pole is now moving about 11.5 miles north and 1.2 miles west per year. This wandering is evidence of secular or slow change in the orientation of the earth's magnetic field. Assigning the magnetic pole a provisional location every five to ten years is essential for the production of magnetic maps and for establishing a pattern of variations in compass readings for the Arctic. Such knowledge is necessary for navigation in the area. Data for the calculation came from four temporary stations set up on sea ice and two permanent magnetic stations at Resolute Bay and Isachsen. The team also established 21 temporary stations in the northeast Arctic to study other aspects of secular change in the earth's magnetic fields.

An important study, based mostly on *paleomagnetic data*, showing the relationship between oil occurrences and climate, nutrients and tectonics (particularly plate tectonics which have governed continental drift through geological ages) was published early in 1974. The paper argues, in brief, that plate tectonics govern the preservation and pooling of oil as well as the formation of oil deposits, which results from a combination of climate, nutrients and water that is suitable to the growth of oil-forming plankton. Paleomagnetic data, drawn from the study of magnetism in ancient rock, are important to the theory of plate tectonics because magnetic particles in many rocks align themselves with the orientation of the earth's magnetic field at the time the rock is formed so that any shift in continental location since that time is indicated if the magnetic alignment of a rock is different from an alignment expected for a rock of that geologic age.

Calculations for the *first geoidal map of Canada* were completed by the Gravity Division during 1973 using the new world gravity standards adopted by the International Union of Geodesy and Geophysics in Moscow in 1971. The map shows the shape of the geoid under Canada which corresponds approximately to sea level and takes into account the curved surface of the earth. It will help geodesists and cartographers to correlate survey measurements made on Canada's land surface and measurements of the geoid as a basis for accurate map preparation. A geoidal map is especially useful in Canada where mapmakers deal with a large landmass and varied topography. The calculations for the geoidal map are accurate to $\pm$ 5 metres as far as measuring the total surface of the earth goes and $\pm$ 1 metre for local measurements. This accuracy is adequate for current needs, but a better knowledge of the geoid will be necessary in the near future to meet the needs of geodesists and geophysicists using improved electronic distance-measuring instruments and satellite Doppler receivers which establish survey measurements by measuring, from points on the ground, the Doppler frequency shift of satellites above (see Surveys and Mapping).

A new edition of the *Bouguer anomaly map* of Canada was published by the Gravity Division in 1973 compiled from some 350,000 gravity observations made on land and sea. Major contributors of information were the Gravity Division and the Atlantic Geoscience Centre. Other important contributions were made by provincial agencies, universities and petroleum and mineral-exploration companies. The new map, which shows gravity variations for most of Canada, is based on the International Gravity Standardization Net (1972) and the Geodetic Reference System (1967) and, in future, information from all gravity stations in Canada will be given in terms of the new international absolute gravity system. Another innovation in producing the new map was the use of automated methods to organize data, convert them into the new system and smooth and contour it.

The Gravity Division acquired two satellite Doppler receivers to help in the *study of polar motion* which has been carried out to date with Photographic Zenith Tubes (PZT's) at Shirleys Bay near Ottawa, Ont., and at Priddis near Calgary, Alta. Like the PZT's, which are an astronomic technique for photographing stars as they cross the zenith, the receivers are keyed to an international program for determining the position of the pole of rotation of the earth. As part of a world-wide network, they observe, every day, at least five satellites that have been put in orbit by the United States to allow receivers to accurately assess their positions in latitude and longitude by measuring the satellite's Doppler frequency shift. The receivers, operated alongside the two PZT's, measure irregularities in the position of the rotational pole to within one metre over a few days. The study is important because irregularities in polar position may indicate changes in mass distribution within the earth arising from major earthquakes. Other practical applications of the study include greater accuracy in geodetic observations, aligning radio telescopes and monitoring deep-space probes.

Geologist and earth physicist on coring project.

Canada Centre for Remote Sensing

The Canada Centre for Remote Sensing was established in 1971 as a branch of EMR. According to official documents, its purpose is "to collect, process, disseminate and develop applications for data applicable to resource management and environmental control of Canadian land and ocean masses, which are obtainable from specialized remote sensors in airborne and space vehicles."

In order to carry out its function, CCRS can call upon a fleet of four aircraft based at the Ottawa airport and equipped with various sensor combinations. It also operates a satellite-receiving station at Prince Albert, Sask., which records imagery from the Earth Resources Technology Satellite, launched by NASA in 1972, ground data-handling facilities in Ottawa and Prince Albert, and an applications laboratory in Ottawa equipped with instrumentation for image processing and analysis.

The annual budget of CCRS is approximately $6 million. Of this, the Airborne Division spent about $2 million and the Data Processing Division (which also operates the Prince Albert Satellite Station and all of the computer installations in Ottawa) spent about $3 million; the Applications Divisions spent about $800,000. The remainder went for administrative and similar expenditures.

Broken down in another way, $2 million of the total budget went for capital expenditures, and $4 million for operating expenditures. Remote sensing is a highly automated technology, and purchase and replacement of computers and other complex equipment absorbs a considerable proportion of the budget.

Now that some two years have passed since the introduction of large-scale and integrated airborne and satellite remote sensing in Canada, the time has arrived for reviewing some of the results and assessing to what extent early promises and expectations have been fulfilled.

Not surprisingly, benefits have been greatest and most obvious in areas peculiar to Canadian geography and settlement patterns. Thus the Arctic, whose vast extent and poor accessibility still raise formidable obstacles to exploration and transportation, is an especially fruitful field for remote sensing. In the summer of 1973, for example, an attempt was made by Donald Fisher & Associates, Prince Albert, to transmit ERTS imagery to ships operating in the ice-infested waters of the Arctic Archipelago. The transmission of the imagery, which showed ice conditions in the Arctic waters, was experimental, and it will be put on a more solid basis in 1974. However, a geophysical-exploration ship managed to avoid costly delays and to save thousands of dollars by being advised of ways of circumventing the ice. If, as is expected, satellite imagery will provide ice coverage that is at least as good as if not better than the visual observations thus far made from aircraft patrols, the patrols may be reduced, at great savings to the taxpayer. It has been estimated that annual savings of $4 to $8 millions can be achieved with present technology in the ice reconnaissance field.

Part of an image obtained by the Earth Resources Technology Satellite (ERTS) over Byam Martin Channel in the Arctic. Such imagery is useful in determining the position and movements of sea ice.

The remote sensing of crops also appears headed for a big future. The "Spring Wheat Project," carried out parallel in Canada and the United States, is aimed at identifying wheat acreage in certain selected areas of the western provinces, from satellite imagery. The project is based on the principle, basic to much of remote sensing, that different types of vegetation have different "spectral signatures," expressed as the relative amounts of solar radiation at a number of wavelengths reflected from an element of the earth's surface. For example, the number of such elements on one satellite image is about 16 million. To analyze such imagery with human observers is obviously impracticable; but a correctly programmed computer can accomplish the work in short order. A team of researchers, drawn from various government agencies, including CCRS and the Department of Agriculture, is now working on ways and means of transforming the data into computer-processable form.

The "Spring Wheat Project," like nearly all other remote-sensing projects, is dependent on three levels of observations: ground observers, who carry out "ground truthing" or spot checks to verify spectral signatures; airborne imagery, often obtained with photographic cameras; and satellite imagery, obtained with a multispectral scanner, a device operating somewhat like a color television camera.

The airborne arm of the Canada Centre for Remote Sensing flew about 300 projects during 1973–74, with imagery obtained over nearly 80,000 line-kilometres (50,000 line-miles). The projects had been requested by numerous user agencies—federal, provincial, university, and private.

Airborne imagery was provided at nominal or no cost to most users during the year, but in order to place this service on a more realistic, self-sustaining basis, charges were set at $5.50 per line-mile in 1974–75 and at $11.00 per line-mile in 1975–76. There will also be additional incidental charges.

New sensors under development for use in aircraft are: a pulsed laser fluorosensor for detection of oil slicks on water; a stabilized camera mount for hydrographic mapping using photogrammetric techniques; a lidar system for airborne hydrographic sounding; and a microwave holographic radar for measuring ice thickness.

It is the policy of CCRS to turn as many remote-sensing operations as possible over to private industry. A major step in that direction will be the letting of a contract for the operation and maintenance of the aircraft now used for airborne missions and presently operated by the Canadian Forces Airborne Sensing Unit. A request for a proposal for such a service has been transmitted to Canadian companies possessing expertise in the field of air surveys, and officials hope that a viable airborne remote-sensing company will result, which may gradually acquire aircraft of its own and enter into independent deals with users.

Another, similar plan calls for the transfer of all the production of black-and-white satellite imagery from EMR's Ottawa laboratories to those of Donald Fisher & Associates at Prince Albert, with CCRS retaining only certain policy controls.

After experimentation with several fairly complex systems for identifying and ordering ERTS imagery, the so-called "ERTSFICHE" has been developed by EMR experts, and it has greatly simplified cataloguing, indexing and dissemination of ERTS data. It consists of microfilm reproduction of imagery, grouped by days and orbit tracks, enabling users to see exactly what each image contains, along with extent of cloud cover, before they order it.

Polar Continental Shelf Project

Polar Continental Shelf Project (PCSP) is the name given to an annually repeated effort on the part of EMR to provide electronic position-finding, air transportation and supplies to Canadian and foreign scientists and surveyors exploring the northern Arctic, where the severe climatic and geographical conditions make it almost impossible for smaller field parties to operate on their own.

The total budget of the PCSP in 1973–74 was $3.1 million, nearly all of which was spent on field activities, the overhead being extremely low. Base camps were kept at Resolute on Cornwallis Island and at Tuktoyaktuk near the Mackenzie River delta. Major field work was carried on from mid-February to mid-October 1973, taking advantage of the warmer weather and long daylight.

The biggest field projects, in terms of men and money, were hydrographic surveys in Amundsen Gulf and in Norwegian Bay; the former ran parallel with a gravity survey. Hydrography was carried out by staff of the Department of the Environment, and the helicopter, fixed-wing, and transportation support provided by PCSP amounted to over $400,000.

Such geophysical measurements and soundings of the sea bottom are an essential basis for further exploration—the search for offshore oil, safety of marine navigation, understanding the geology and the long-term processes that have shaped, and continue to shape, the geography of the Canadian Arctic.

Altogether, the PCSP supported 65 field projects in 1973. Most of the major ones were undertaken by EMR and the Department of the Environment, and consisted of various types of surveys. Among the non-Canadian agencies taking part were several from the United States, one from Switzerland and one from Germany. The Swiss team made climatological observations during the winter of 1973–74, and the Germans excavated archeological sites on Banks Island, discovering interesting and remarkable stone and bone tools and ornaments.

Other investigators studied the animals, birds and fishes of the Arctic, geological and geophysical features of the islands, glaciers, sea-ice behavior, and the effect of exploration and construction on the Arctic environment.

Top: Members of a Polar Continental Shelf Project field party prepare high explosives for a seismic test. *Bottom*: Lowering a diver through a hole in the Arctic sea ice, as part of an oceanographic study.

A colored flare marks the wind direction on a makeshift landing field in the Arctic.

Explosives Division

The Explosives Division is responsible for the administration of the Canada Explosives Act and related activities in the explosives field. One of the main responsibilities of the division is control over all factories that produce commercial blasting explosives, military explosives, blasting accessories, sporting ammunition, fireworks and other pyrotechnics. In addition to ensuring the quality and safety of these explosive products, the Explosives Division also oversees their road transportation, storage, sale and importation. Control is exercised by a licensing system supported by inspections by members of the division. All licenses and permits are issued from the Ottawa office.

The number of factories licensed to manufacture explosives increased from 60 to 66 by March 31, 1974. They produced about 215,000,000 kilograms of commercial blasting explosives compared with 170,000,000 kilograms in 1972–73. Production of fireworks, ammunition and blasting accessories also increased but not to the same degree as commercial blasting explosives.

Since an amendment to the Canada Explosives Act in 1972 restricting the sale of high-hazard recreational fireworks to qualified individuals, the Explosives Division has provided courses to qualify candidates as "Fireworks Supervisors." By the end of March, 1974, about 2,500 persons had attended courses at centres across Canada.

A Bill to further amend the Explosives Act to provide more effective control over the sale, purchase, possession and security of explosives was recommended in 1973 by the division and accepted by Cabinet Committee in February, 1974.

RESEARCH AGREEMENTS

The underlying purpose of the department's Research Agreements is to fund extramural research and development projects that are directly related to the department's mission. Canadian research organizations that are not directly managed by the federal government and that undertake research in the natural, physical and social sciences and engineering are eligible to apply on behalf of individual investigators in their employ.

The intention is to bring many kinds of expertise to bear on the problems of national policy, to apply a multidisciplinary competence to the development of advice to the government and information for the community at large. The branches of EMR, with their disciplinary orientation, are responsible for assessing the proposals which relate to their own objectives and activities, and for monitoring the investigations throughout the life of the agreement.

Research Agreements are made for the following fiscal year, and those made for 1974–75 totalled $861,528. They were concluded with 38 Canadian institutions, and represented a slight increase over the preceding fiscal year.

Members of university faculties will again receive the largest proportion of the funds—$769,428, divided among 106 principal research individuals. Other awards are made to members of provincial research councils and specific research institutions.

Typical research projects include:

- the effect of blasting on oil-sand slopes;
- geotechnical properties of the Athabasca oil sands;
- in-situ recovery of oil from the Athabasca oil sands;
- improvement of energy utilization in the transportation and urban use sectors in Canada;
- development of general-purpose computer simulation programs for petroleum reservoirs;
- combined pyrolysis-gasification of coal and wood-waste;
- life expectancy of Canada's oil and gas resources;
- a computer system for storage, retrieval, and analysis of mineral-deposits data;
- regional metallogenic analyses of Nova Scotia and Newfoundland;
- exploration case-history studies of Canadian ore deposits;
- radio-frequency interferometry as applied to ice and permafrost sounding;
- sediment movement in the Minas Basin, Bay of Fundy;
- urban cartography;
- developments in automated cartography;
- local earthquake studies in the Canadian Cordillera.