DEPARTMENT OF
ENERGY, MINES AND RESOURCES
OTTAWA, CANADA

annual report 1968-69

Hon. J. J. Greene, Minister

CANADA

Department of
ENERGY, MINES AND RESOURCES

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98292—1

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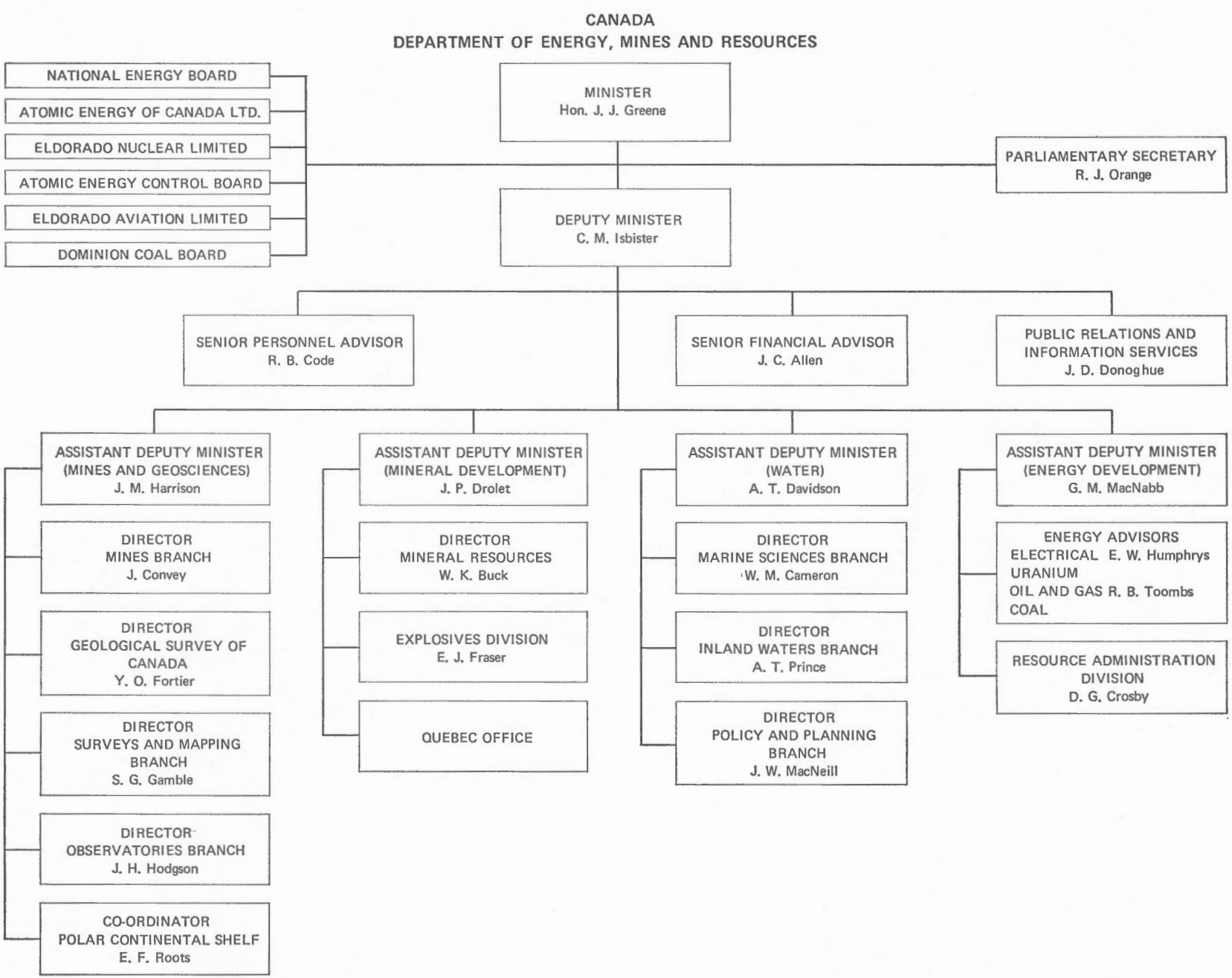
CONTENTS

98292—1½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INTRODUCTION

The Department of Energy, Mines and Resources is the federal government's principal agency for the discovery, investigation, development and conservation of the nation's mineral, water and energy resources. It carries out geological, hydrographic, oceanographic, geophysical, hydrologic, geodetic and topographical surveys, engages in mineral and metallurgical research, both technological and economic; assesses and helps to plan the distribution of water and energy resources; and carries out a number of policy-making and administrative tasks affecting Canada's resources and the industries associated with them.

The Department is housed mainly in Ottawa, with several research establishments in other parts of Canada, chiefly in British Columbia, Alberta, Ontario, and Nova Scotia.

This report covers the fiscal year April 1968 to March 1969.

The largest group within the Department, in terms of personnel, is the Mines and Geosciences Group, consisting of the Surveys and Mapping Branch, the Geological Survey of Canada, the Mines Branch, the Observatories Branch, and the Polar Continental Shelf Project. Both the range of activities and the information disseminated by these technical and scientific organizations reached new levels during the year under review. The Surveys and Mapping Branch's Geodetic Survey put 31 parties into the field to extend or increase the density of the existing national survey framework for mapping and charting, municipal control and engineering projects. The last of the field control required for the 1:250,000 mapping of Canada was established on islands in northern Hudson Bay by parties working from icebreakers. These islands had previously resisted all attempts at surveys, owing to pack ice or fog. The Topographic Survey forwarded for reproduction a record number of 657 National Topographic Series maps. This high number of clearances was reached through a high rate of production. Compilation for the islands in Hudson Strait noted above completed mapping at the 1:250,000 scale, and in future that series—a monumental achievement in the mapping of Canada—will only have to be revised from time to time. The Air Photo Library filled a record number of 7,324 requisitions, covering 844,568 prints from air-survey negatives.

The Geological Survey of Canada sent about 100 full-season parties into the field in all parts of Canada. Two large helicopter-supported projects, one in northeastern Baffin Island and the other in northwestern District of Mackenzie, resulted in the completion of reconnaissance studies of an area measuring 153,000 square miles. The Mines Branch continued a large number of experimental projects designed to assist the Canadian mineral industry in achieving more effective or economical operations. A complete system for the electrochemical determination of soluble oxygen in molten steel, for use in steel plants, was devised and made ready for industrial trials. The resurgence of industrial production in Japan has led to a tremendous demand for coking coal in that country. To ensure that western Canadian coal producers will reap the full benefits of this expanding market, the Fuels Research Centre has improved and modernized its facilities for evaluating coking coal, along with its equipment for the experimental processing of coal. Over half the ore mined in Canada comes from open pits, and considerable research at the Mines Branch is devoted to the theoretical design of the best pit slopes and other engineering factors. Further progress was made in the development of an advanced metallurgical furnace, combining gas, oil, and electricity as heat sources.

During the year the Observatories Branch made plans for redesigning its Mirror Transit Circle, an instrument intended to measure star positions and the rotation of the earth. Meanwhile, the Branch inaugurated its Photographic Zenith Tube Observatory at Calgary on May 18, 1968, with scientific representation from the United States and Britain. The Meteorite Observation and Recovery Project (MORP) established its headquarters at the University of Saskatchewan. The Dominion Radio Astrophysical Observatory at Penticton teamed up with an observatory in Saskatchewan and one in Australia to conduct a long-baseline-interferometer experiment to determine the angular diameters of quasars. The Dominion Astrophysical Observatory at Victoria observed its 50th anniversary, in honour of which the American Astronomical Society held its 127th meeting in that city.

Although the federal government has halted expenditures on the proposed 156-inch optical telescope on Mount Kobau in British Columbia, it has agreed to turn over existing equipment to a consortium of western Canadian universities, which hope to bring the project to fruition. Collaboration is being extended by the Observatories Branch. In the field of geophysics, the Branch moved its geomagnetic observations to a new laboratory on the eastern outskirts of Ottawa, where environmental conditions are expected to be excellent for a long time to come.

The Mineral Resources Branch, mainstay of the Mineral Development Group, carried out a series of fundamental regional studies designed to serve as guides to economic redevelopment in the Atlantic region and elsewhere. It provided advice to the government on numerous matters concerning Canada's mineral industry, and continued the publication of its studies on the production and trade of Canadian minerals. The Roads to Resources program, administered by the Branch, was nearing completion, with the remaining $350,000 (out of a federal share of $75,000,000) committed for completion in 1969-70.

In the Water Group, the Marine Sciences Branch expanded its survey fleet with the commissioning of CSS *Limnos*, a vessel designed for research on the Great Lakes. Design, specifications and contract drawings were completed for a second such ship. At the Bedford Institute in Dartmouth, N.S., considerable construction went on during the year, including the extension of the jetty, the expansion of the laboratory wing, and the addition of two more floors to the office wing. The Hydrographic Service distributed a record number of charts—309,200. A highlight in oceanography was the cruise "Hudson Geotraverse," which followed a one-degree-wide strip from Cape Breton Island to the Mid-Atlantic Ridge; it was expected to yield fundamental data on the formation of deep ocean basins. The Policy and Planning Branch and the Inland Waters Branch continued to expand their role among bodies planning and administering resources in Canada, as evidenced by their participation in, or contributions to, such agencies as the Interdepartmental Committee on Water, Canadian Council of Resource Ministers, Interdepartmental Committee on Resources, Joint Program Committee of the Canada-British Columbia Agreement for Studies and Flood Control in the Lower Fraser Valley, Canada-Ontario Committee on the Canada Water Conservation Assistance Act Programs, Northern Ontario Water Resources Study, Steering Committee for the International Field Year on the Great Lakes, International Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, International Columbia River Treaty Permanent Engineering Board, Groundwater Observation Well Network, Canadian National Committee of the International Hydrologic Decade, Saskatchewan-Nelson Basin Board, boards of control for the Great Lakes, and numerous others.

The Energy Development Group participated in planning and discussions looking toward the expansion of Canada's energy network, notably in the field of electric power. It advised other departments of the federal government on oil and gas policy and prepared to take over the remaining responsibilities of the Dominion Coal Board, which is to be dissolved with the phasing-out of subventions. The Canadian coal industry was being encouraged to establish an industrial organization to act on its behalf in maintaining effective liaison with the federal government. The Resource Administration Division noted expenditures of over $18 million by the oil industry in Canada on oil and gas permits for offshore exploration during 1968, an increase of about 38 per cent over the previous year. The past fiscal year also saw the establishment by the federal government of "mineral-resource administration lines" in Canada's offshore areas, dividing federal and provincial jurisdiction in that field.

MINES AND GEOSCIENCES GROUP

Surveys and Mapping Branch

The past fiscal year has seen the re-arrangement of the operating units of the Surveys and Mapping Branch into the major groupings of Field Survey, Aerial Survey and Map Production. In organizing all units of the Branch into groups, each with a common general purpose, it was obvious that those concerned with field surveys should be in one group, those concerned with air photography and photogrammetry in a second, and those concerned with the production of maps in the third. This re-assembling was accomplished without extinguishing the names of units such as Topographical Survey and Geodetic Survey that had served Canada continually for the past 60 years.

The Field Survey now embraces Legal Surveys, the Geodetic Survey, and the International Boundary Commission; the Air Survey embraces the Topographic Survey and the National Air Photo Library; and Map Production embraces Cartography, Air Charts, Geography, Toponymy, and actual Map Production.

FIELD SURVEY DIRECTORATE

Geodetic Survey

Thirty-one field parties established horizontal and vertical control to extend or increase the density of the existing national survey framework for mapping and charting, municipal control and major engineering projects. In addition the Survey continued and expanded its activities on investigational projects.

The extension and strengthening of first-order horizontal control was carried out in the Northwest Territories and six provinces. In the Northwest Territories and Alberta a team cooperated with the Topographical Survey on the aerodist control project. In British Columbia a network was extended north up Kootenay Lake to Revelstoke, thence west to connect with existing surveys near Salmon Arm, closing a large loop; from Revelstoke a new network was extended east to Golden and a spur net run from Golden north to Mica Dam. In Alberta, scale control was established in the existing network between Suffield and Calgary. New networks were established in Ontario from Chatham to Windsor and from Chatham to Sarnia. In northern Quebec, triangulation was extended south from Great Whale River to Fort George and thence southeast to connect with existing triangulation at the north end of Mistassini Lake, closing a large triangulation loop. In the Quebec City area a long-term program for increasing the density of and extending first-order surveys was started. This program will cover the economically important areas of southern Quebec, and is being carried out in cooperation with the Quebec Department of Lands and Forests. A dense first-order network was established in Prince Edward Island to provide the framework for a plane-coordinate survey system which will cover the entire province. A re-survey of the Magdalen Islands was carried out to replace destroyed stations and to connect Hydrographic Service control stations.

First-order levelling was carried out in seven provinces. The Trans-Canada level line was extended eastward from Kamloops, B.C., through Alberta and Saskatchewan to the Manitoba border. In the course of this operation, vertical control networks were established in Banff, Lethbridge, Red Deer and Medicine Hat in Alberta. Re-levelling was carried out in the vicinity of Bennett Dam in northern British Columbia to check crustal movements. Levelling of high precision, using the metric system, was carried out between Kingston, Ontario, and Beauharnois, Quebec with five connections made to United States Lake Survey bench marks on the south side of the St. Lawrence River. This work is a part of the program for the re-evaluation of the International Great Lakes Datum, 1955. Elsewhere in Ontario, water crossings were made to connect Wolfe and Howe Islands, near Kingston, to the national framework, and the area levelling in the southwest quadrant of the National Capital area was completed. In Quebec a new line was completed from Fugereville to Guérin and forty water gauges were tied in along the St. Lawrence River to check bench mark stability. In New Brunswick, lines were run from Woodstock to Saint John on both sides of the Saint John River, from

Hartland to Saint John and from Sussex to Riverside. Many water gauges were connected in the course of this work.

Five astronomic parties worked in seven provinces. One Laplace point and twenty deflection stations were established in the Kootenay-Revelstoke area of British Columbia. Two Laplace points and one deflection station were established in Alberta, one Laplace point in Ontario. In Quebec two Laplace points and one deflection station were established and in the Maritimes three Laplace points and six deflection stations were established.

The aerodist program was continued and an extensive area was controlled in northern Alberta and extending into the Northwest Territories to Yellowknife and Fort Simpson. A large part of the area is under intensive oil exploration, and this survey provided the control for 1:50,000 mapping as well as the necessary geodetic framework surveys to aid in development. An area of 150,000 square miles was controlled. At the close of the aerodist operation an experimental project was undertaken in priority areas during September to supply additional framework control of lesser precision, to assist in locating sites where oil exploration is active. This operation used the *Autotape,* a new electronic airborne survey method to extend control points into very difficult terrain.

Another long-term project, the tellurometer traversing in the western Cordillera to provide control for 1:50,000 mapping and in support of the Observatories Branch gravity survey, was continued. A Topographical Survey party extended control through an area of 10,000 square miles in southern British Columbia while a party from the Mapping and Charting Establishment controlled an area of 26,000 square miles.

Assistance to provincial and municipal authorities in establishing coordinate systems of control surveys continued to be a major effort. Work was carried out in British Columbia at Vancouver-Burnaby and in Nova Scotia in the Port Hawkesbury area of the Strait of Canso, Antigonish and Amherst. In Ontario, two parties worked at extending coordinate systems in Chatham, Windsor, the Niagara Falls area, St. Catharines, and along Highway 401 and Highway 3. A third party was engaged in municipal levelling in Barrie, Woodstock, Kitchener, Waterloo and Guelph.

Three parties were engaged in establishing field surveys to control 1:25,000 mapping at Halifax, Chatham, Ontario, and Calgary.

Two parties supplied field surveys for 1:50,000 mapping near Fredericton and Woodstock in New Brunswick and near Nipawin, Saskatchewan.

The last of the field control required for 1:250,000 mapping was established on islands in Northern Hudson Bay by a party working off the icebreakers CGS *Labrador* and *N. B. McLean.* These islands had previously, because of pack ice or fog, resisted all attempts at mapping surveys.

One party completed a winter levelling project during February and March 1969, covering about 285 miles between Winisk Lake and Sakwaso Lake in northern Ontario. This work was needed to provide more accurate vertical information for water-resources research in that area.

Legal Surveys

The main work of the Division, as usual, was its legal surveys in Indian reserves, national parks and territorial lands. Once again the largest project was on the Caughnawaga Reserve where approximately half of the large Indian village and 800 acres of farm land were resurveyed and subdivided.

The Division had 16 survey parties in the field and, in addition, arranged contracts with 43 private survey firms to complete as many as possible of the projects required for federal government departments. They worked on projects in 122 Indian reserves and in six national parks. Technical instructions were issued for some 200 surveys on Crown Canada Lands for provincial and private interests.

In the Territories, the largest projects were residential and industrial subdivisions at Frobisher Bay and Baker Lake, but smaller miscellaneous surveys were made at 12 other settlements in the Northwest Territories as well as in the Whitehorse area of the Yukon. The control network at Carcross was completed.

Two commissions for interprovincial and territorial boundaries were active in this period. The resurvey of the southerly 240 miles of the Manitoba-Saskatchewan boundary was continued and approximately 51 miles of trial line was completed. Preparation for the maintenance survey of the British Columbia-Yukon Territory-Northwest Territories boundary was begun.

Survey documents entered in the Canada Lands Surveys Records numbered 1,633 plans and 211 field books, some 1,000 of the former being plans previously stored in the Mining Recorder's office at Dawson.

About 55,000 document extracts and astronomical field tables were despatched and information on 443 airline distances was supplied for official purposes.

The Board of Examiners for Dominion Land Surveyors met eight times. Of the thirty candidates who sat for part of the 1969 annual examinations, three completed the preliminaries, three the intermediates, and three the finals to qualify for the D.L.S. commission. One candidate was granted his certificate as a Dominion Topographical Surveyor.

International Boundary Commission

During the 1968-69 fiscal year, the Boundary Commissioner for Canada and the Commissioner for the United States made joint inspections at various points along the line and inspected the work of field parties on several sections of the boundary.

Three Canadian field parties carried out work on the Quebec-Maine, the Ontario-Minnesota, and the British Columbia-Washington boundaries.

The task of controlling growth along the 20-foot boundary vista was greatly relieved by the introduction of power spraying equipment mounted on a tracked motor vehicle. This newly developed equipment was used to complete herbicide treatment on 108 miles of Quebec-Maine boundary. An additional 15 miles of heavy growth were recleared along the height-of-land boundary.

On the Ontario-Minnesota boundary, resurveys were commenced on Lake of the Woods and through Rainy River, to re-establish reference monuments which were lost or moved through erosion or construction operations, and to improve the overall accuracy of the original boundary surveys in that area.

The program of maintaining the 400 miles of mountainous vista along the 49th-parallel boundary by aerial applications of herbicides was continued during the field season. Chemicals were applied by helicopter to 60 miles of 20-foot vista through forest sections of international boundary from the Fraser Valley to the Okanagan Valley.

Altogether Canadian parties recleared 15 miles of boundary vista, treated 168 miles with chemicals, inspected 432 monuments (of which 40 were repaired and 17 reconstructed in new locations) and determined new geographic positions for 47 monuments and other markers.

AIR SURVEY DIRECTORATE

Topographic Survey

During the past year, the Topographic Survey Division forwarded for reproduction a record number of 657 National Topographic Series maps. This high number of clearances was reached because of a continuing high rate of production, together with a concerted effort to reduce the number of maps in post-compilation phases and an acceleration of the revision of out-of-date maps.

Eighty per cent of our production of maps was at the 1:50,000 scale. The square mileage depicted on maps cleared for reproduction in this series increased by over 100 per cent, although the number of maps (533) increased by less than 20 per cent. This was due to the change of format of the popular 1:50,000 scale map from 15 x 15 minutes to 15 x 30 minutes.

Compilation for several islands in Hudson Strait completed the new mapping at the 1:250,000 scale, and the task in this series is now one of revision. Nineteen sheets at this scale were passed forward for reproduction. New and revision mapping in the 1:25,000 series of maps increased to a total of 105 maps, an increase of about 400 per cent over the best previous year.

Under agreement, this Department reproduces the 1:50,000 maps compiled by the British Columbia Department of Lands, Forests and Water Resources. The Topographical Survey reviewed 25 British Columbia maps in this series prior to clearance from reproduction. The Mapping and Charting Establishment, Department of National Defence, also assisted in production of National Topographic Series mapping by the compilation of eight maps at 1:50,000 for training purposes.

Photomaps produced as map substitutes are meeting wide acceptance. During the past year, 75 photomaps at 1:50,000 were produced and an additional 75 at larger scales.

In the field of research and development, the development of a set of computer programs for the three-dimensional adjustment of large photogrammetric blocks was finished during the past year. This system was used for the first time for the production of maps in November 1968, and had completely replaced the old system by the end of the year. The new system eliminates a large number of manual operations and considerably speeds up the adjustment phase of the aerotriangulation. Another computer program to level

stereoscopic models analytically with the use of lake surfaces or equivalent vertical information was completed. This program was developed specifically for photogrammetric processing of aerodist photography.

National Air Photo Library

During the period under review, 7,324 requisitions for photographic work, the highest annual total in the Library's history, were prepared for processing. These requisitions covered 844,568 prints from federal government air survey negatives (contact prints, enlargements, diapositive mapping plates, lantern slides, transparencies, etc.). This represents an increase of more than 10 per cent over the previous year in the number of requisitions raised and prints provided. The Library also processed 174,917 black-and-white photographs, 958 colour photographs and 166 mosaics (MG series) in connection with maintaining a file copy of each set of photographs produced by or for the federal government in the mapping of Canada. This brought the total of the Library collection to over 3,325,400 black-and-white prints, 13,492 colour prints, 24,000 uncontrolled (RE) mosaics and 982 semi-controlled (MG) mosaics. Many new services and products are being provided, largely in response to requests for colour, "false colour" (infrared) and the products of remote-sensing systems. This has placed an additional strain on production facilities that is not fully revealed by production figures.

In September the National Air Photo Library officially opened to the public its Western Branch (Calgary) Air Photo Library. This Library is located in the building of the Institute of Sedimentary and Petroleum Geology in Calgary. Since its opening to the end of the period under review, this branch office has raised 164 requisitions requesting 31,173 prints of federal government negatives held in Ottawa, and has received from Ottawa approximately 500,000 prints for local inspection by clients.

MAP PRODUCTION DIRECTORATE

Cartography

The Division carries out the finished drawing of all topographical maps and special maps produced by the Branch. Maps received from the Air Survey Directorate for reproduction numbered 657. Derived map compilations produced by the Division totalled 169; these included 43 air-chart bases, 8 topographical maps, 118 regional and special-purpose maps. Drafting production for the year totalled 479 completed jobs; these included 49 at 1:25,000, 278 at 1:50,000, 8 at 1:125,000, 27 at 1:250,000, 10 I.M.W. sheets, 29 air-chart bases and 78 miscellaneous drawings. The new *Atlas and Gazetteer of Canada* was forwarded to the Queen's Printer for reproduction in French and English.

At the end of the fiscal year the status of the 1:50,000 series stood at 28 per cent published, with 3,663 sheets now in print of the potential 13,150. The status of the 1:250,000 series stood at 99 per cent published, or 909 of a potential 918.

The conversion of the 8-mile series to 1:500,000 is now 96 per cent complete, with 210 in the new format of the total 219.

Map Reproduction

The map printing during the past year included 821 topographical maps, 276 air charts, 16 wall maps and special sheets, 762 maps and charts for other branches of the Department and 217 maps and charts for other departments—a total of 2,092 maps and charts printed.

Aeronautical Charts

Forty-seven different series of charts and flight-information publications were maintained, with 116 new charts added to the series. Twenty-two new radar-surveillance charts were produced. The first issue of a *Canadian Flight Planning and Procedures Manual* was published; it is to be revised every 105 days.

Geography

Twenty-five per cent of the *National Atlas of Canada* was processed beyond the editorial and translation stages during the year. The cartographers are preparing these sheets for publication in French and English. The Division produced three special sheets during the year. The Urban Analysis Series, a joint project between the Emergency Measures Organization and the Surveys and Mapping Branch, was cancelled in 1968. The Division continued to examine methods of computer analysis and display of special information and computer graphics suitable for thematic mapping. Cooperation with the Department of National Health and Welfare resulted in the production by the latter of an experimental *Atlas of Hospital Utilization in Canada.*

Toponymy

During the fiscal year 1968-69 the Division investigated approximately 20,000 names and approved 3,500 new names. The geographic nomenclature for 387 maps was verified and approximately 120 inquiries involving significant research in the Division's records were answered. A new edition of the *Gazetteer of Manitoba* was issued in 1968. The revision of the *Gazetteer of Saskatchewan* was forwarded for reproduction early in 1969, and work on the first edition of the *Gazetteer of Quebec* brought it to the final stages.

Comprehensive study of the toponymy of New Brunswick started in 1967 and was almost completed. The Map Library dealt with 1,467 inquiries, loaned 972 maps, atlases and gazetteers to departmental agencies and others concerned with map production and cartographic research. It acquired 5,303 new maps and 105 gazetteers and atlases during the year.

The 1968 annual meeting of the Canadian Permanent Committee on Geographic Names was held in Edmonton.

BRANCH FUNCTIONS

Map Distribution

The number of maps and air charts distributed to civilian clients during the year rose to 2,162,000, marking the first time in the history of the Surveys and Mapping Branch or its predecessors that distribution has exceeded two million. Map distribution to the Canadian Armed Forces remained relatively steady at 1,500,000.

A statistical study of civilian map use in Canada was made during the past year. The following tables illustrate some of the interesting results of this study.

Map Use by Province

	Per cent
British Columbia	13
Alberta	17
Saskatchewan	5
Manitoba	6
Ontario	17
Quebec	23
New Brunswick	6
Nova Scotia	4
Prince Edward Island	1
Newfoundland	3
Yukon	3
N.W.T.	2
	100

These figures do not include maps used by other federal agencies.

Map Use by Occupation or Industry

	Percentage of Orders	*Percentage of Maps*
Federal Government	7	23
Provincial Governments	6	19
Industry and Commerce	5	3
Schools	9	5
Universities	6	7
Outdoor Sports	12	3
Engineering and Scientific	11	7
Air Navigation	20	16
Tourist Industry	4	2
Retail Sales	10	13
Use Unknown	10	2
	100	100

Map Use by Scale

Series		*Percentage of Distribution*	*No. of Sheets Published*
1:25,000		1	538
1:50,000		50	3,663
1:125,000		2	149
1:250,000		23	909
1:500,000	Base Map	2	226
	Air Chart	9	226
1:1,000,000	Base Map	1	68
	Air Chart	2	68
Other Maps		10	1,253
		100	7,100

Interdepartmental Committee on Air Surveys

The Interdepartmental Committee on Air Surveys carried out air photography in all provinces and territories to meet requirements from 14 federal departments and agencies. The increase in the use of colour photography by the technical community continues. "False colour" (colour film exposed through infrared filters which produce unnatural colours such as red for healthy vegetation, yellow for dead vegetation etc.) is also being used to a greater extent, especially by agriculturists.

Technical Aid Section

The Surveys and Mapping Branch continued to provide technical advice and engineering support to the Canadian International Development Agency (formerly External Aid Office) in topographical mapping projects in Tanzania, Nigeria, Trinidad and Tobago, Guyana

98292—2½

and Jamaica. It also provided practical training in surveying and mapping techniques to students from developing countries attending Canadian technological institutes and universities. One such course, a 12-week seminar, was attended by students from Africa and from Commonwealth countries of the Caribbean.

The annual meeting of the federal and provincial survey directors was held in Edmonton, Alberta. The meeting decided on a review, being carried out by G. S. Andrews (formerly Surveyor General of British Columbia), of the administration of surveying and mapping in Canada.

Geological Survey of Canada

The Geological Survey is responsible for providing geological information, concepts and techniques to assist in the evaluation of the nation's potential mineral resources, in the search for mineral deposits, and in the planning by industries and federal and provincial agencies concerned with renewable and nonrenewable resources of northern and regional development, land use and engineering projects. The Survey investigates, describes, and explains the geology of Canada, including continental shelves, provides a national and regional geological framework including correlation of geological knowledge between regions or provinces through total or partial survey related to the capability of the province concerned, and provides a research-and-study competence in various specialized disciplines. Through this latter function the Survey maintains standards appropriate to the systematic investigation of the geology of Canada, investigates problems such as the properties, identification, classification and origin of minerals, ores, fossils, structures, and landforms, and provides a national cadre of specialists available as a source of expertise to various federal and provincial government agencies, to industry, and to the general public. The Survey also examines theories, develops and tests new instruments and methods, and performs pilot projects and surveys as aids to geological research and the search for mineral deposits. The results of the studies carried out by the Geological Survey are disseminated to users through extensive independent publication, through scientific, professional and trade journals and conferences, official communications, and participation in national and international scientific conferences. The Survey maintains libraries and collections of books, oil-well cores and samples, mineralogical and paleontological specimens for reference by its own staff, by other government agencies and by industry and provides geological information to the general public, tourists, hobbyists and educators.

During the report period the Branch had 505 active projects of which 213 had a field component. There were 223 project leaders including four postdoctoral fellows, eight university professors and 20 seasonal employees.

In 1968-69, there were 67 graduate assistants employed in the field and 23 in the office; 108 student assistants were attached to field parties and 42 were assigned to office duties.

During the 1968 field season about 100 full-season field parties conducted studies in all parts of Canada. Two large helicopter-supported projects, one in northeastern Baffin Island, the other in northwestern District of Mackenzie, resulted in the completion of reconnaissance studies of an area of 153,000 square miles. The activities of the smaller parties ranged from studies of the Pacific Continental Margin to the development of geochemical techniques applicable to mineral exploration, from studies of landforms in the Arctic to hammer-seismic surveys to aid in the mapping of surficial deposits, and from detailed studies of Precambrian rocks to stratigraphic studies of Paleozoic and Mesozoic rocks necessary to solve problems affecting petroleum exploration.

To stimulate and support research in the geological sciences at Canadian universities, 112 grants totalling $220,000 were made to 24 universities; in addition five special grants totalling $43,000 were made to five universities for research in the development of computer-processable files of geological data.

The scientific results of the Survey's research are published in a variety of forms designed to fit user need and the nature of the material. During the report period, 6 memoirs, 10 bulletins, 2 economic geology reports, 2 miscellaneous reports, 67 papers and 18 geological maps (excluding those used to illustrate the preceding reports) were issued under Survey auspices. In addition, staff members published 138 technical

papers in a wide range of outside journals. These varied from one-page notes on subjects of current interest to a 584-page textbook. Sixty-eight scientific papers were presented at major technical meetings held in Canada and abroad, 49 talks were given to graduate seminars and smaller technical groups and staff members participated in the presentation of six university courses.

About 367,000 items were distributed, mainly from the Ottawa office but about 10 per cent through the Survey's Institute of Sedimentary and Petroleum Geology in Calgary and a lesser amount through the Branch's Vancouver office. The library had a circulation of about 39,500 items during the report period. The staff handled 8,370 inquiries, of which 1,650 required information searches, an increase of nearly 40 per cent in this particular aspect of the library's work.

In addition to the headquarters in Ottawa the Survey maintains an office in Vancouver, and the Institute of Sedimentary and Petroleum Geology in Calgary. A resident geologist was stationed at Whitehorse throughout the year and another at Yellowknife until early February 1969.

CRUSTAL GEOLOGY

The prime objective of this division is to study and interpret the folded, metamorphosed and igneous rocks that form the earth's crust beneath Canada in order to provide the basic geological data required to forecast, discover and evaluate Canada's mineral resources and to provide scientific knowledge on the origin and historical evolution of the crust.

Nineteen field parties carried out studies in the Canadian Shield, four in the Appalachian region, 13 in the Cordilleran and Pacific Margins area, four in the field of petrology and one in the field of Eastern Canadian paleontology and three in coal research. In addition numerous office and laboratory studies, many based on earlier field studies, were carried out.

The major project carried out in the Canadian Shield, "Operation Bylot", resulted in the mapping at the scale of 1:250,000 of 53,000 square miles of northeastern Baffin Island, part of which contains the large potential iron-ore deposits of Baffinland Iron Mines at Mary River. Studies of specific Precambrian geological problems included those made of the Hurwitz and Hornby Bay groups, a study of volcanic rocks in the Seal Lake area, Labrador, which is part of a continuing study of volcanic rocks in the Precambrian Shield, and mapping of several 1:250,000 map-sheets in Manitoba, District of Keewatin, and Newfoundland.

In the Cordilleran region, detailed studies of the important Anvil base-metal deposit were completed and a study of the northern coastline of Vancouver Island was commenced. As most of the Survey's personnel connected with Cordilleran geology are in Vancouver, the office there is frequently visited by mining people, and during the period covered by this report there were 11,440 callers.

Members of the Appalachian, Eastern Lowlands and Atlantic Margins section study the composition, stratigraphy and structure of post-Precambrian rocks in these areas (including Hudson Bay Lowlands) to evaluate potential mineral and petroleum resources. Field investigations were carried out in Botwood and the Straits of Belle Isle, Newfoundland, in Antigonish area, Nova Scotia and at Tuadook Lake map-area, New Brunswick. The latter area is of interest because it lies in a belt that contains the Bathurst mining camps.

Members of the Petrology Section continued studies of specific rock types designed to provide a means of elucidating petrologic problems of economic or regional significance. They also carry out research on extraterrestrial materials and maintain the National Mineral Collection. The section operates the Petrology Laboratory which provides special petrographic services for staff members and identifies rock specimens for the public.

The Geochronology Section develops facilities for isotope geology, and coordinates the Survey's age determinations and stable-isotope investigations. During the report period new laboratory facilities became fully operational and additional potassium-argon extraction lines have been assembled, thus providing the opportunity for experimental studies with terrestrial and oceanic basalts less than one million years old. Such data may be important in answering the question "have the continents drifted apart?"

The Coal Research Section is responsible for microscopic investigations of Canada's coals and associated clastic sediments in the fields of coal petrology and palynology, thus providing information valuable for coal geology, coal mining and coal utilization. In the period under review, studies of coal rank, environmental and facies studies of coal, research on coking coals, and investigations on the uranium possibilities in lignite were carried out as were studies of fossil pollen and other spores designed to support other geological studies.

Paleontological studies in eastern Canada are carried on under the auspices of this division, and during the report period members of the Eastern Paleontology Section prepared 50 reports on 449 lots of fossils. Those identifications are used primarily by other staff members to solve problems of correlation. The section was visited by geologists from universities, oil companies and other countries who examined collections and consulted with staff members. In Canada and other countries more than 20 experts on particular groups of fossils are studying Geological Survey material collected from eastern Canada for the Branch.

EXPLORATION GEOPHYSICS

This division conducts and administers geophysical surveys in Canada and over the adjacent continental shelves as an aid in geological mapping. Members of the staff also devise and test-run instruments for geophysical mapping, prospecting and other geophysical investigations and develop new methods on interpretation of geophysical data in terms of geological parameters with special emphasis on quantitative methods.

Extensive projects in aerogeophysics, begun in 1967-68, became operational during the report period and should show evidence of important production next year. The Skyvan and Queen Air projects mentioned in last year's report are proving most successful. Sufficient development data were obtained during the year so that technical recommendations could be made to the Mines Ministers Conference in September 1969, regarding airborne EM surveys.

The Federal-Provincial Aeromagnetic Survey Program continued, but as the work is now reaching into the climatically difficult far-northern areas, a new basis for contracting has been devised. New contracts will be for six years, they will be done by a consortium of companies and the government will take a greater share of the weather risk.

During the year 579 aeromagnetic maps were published; the total available now exceeds 5,000.

About 13,000 line-miles of high-resolution aeromagnetic survey data were obtained from low-level traverses made in cooperation with the National Aeronautical Establishment across the Atlantic Ocean between Gander, Newfoundland, Shannon, Ireland, and southern Greenland. This information is useful in determining ocean-floor spreading in the North Atlantic Ocean.

Studies directed towards the development and assessment of techniques for the remote measurement and delineation of rocks and minerals, properties and structures from airborne and borehole data were continued. Such techniques are likely to become increasingly important in the next decade.

Paleomagnetic studies, long considered to be rather esoteric, are beginning to indicate practical value; the work done in collaboration with International Nickel Company of Canada is a case in point.

GEOCHEMISTRY, MINERALOGY AND ECONOMIC GEOLOGY

Those aspects of geology that contribute most directly to our knowledge of the occurrence of economically important elements and minerals are the responsibility of this Division, whose staff also provides data and concepts that will contribute to the search for mineral deposits and develops methods that may be used in prospecting.

The major research projects conducted in 1968-69 were (1) the coordinated study of the geology of mineral deposits by a group of economic geologists, each of whom is responsible for research into the geology of economic elements; (2) the development and testing of geochemical prospecting methods; (3) mineralogical studies of ore- and rock-forming minerals; and (4) the long-term implementation of a geochemical census of economic elements in the crustal rocks of Canada.

Studies continued of the geochemical factors which control the concentration of nickel in basic and ultrabasic rocks, and a metallogenic map showing the various types of nickel deposits, their distribution and general geological environment, was submitted for publication. A fourteen-month study of Michipicoten iron-formations by a research associate from Japan was completed, resulting in new criteria for recognizing primary and metamorphic features in siderite-sulphide stratiform deposits. Studies of Canadian copper deposits, lithophile metal (Li, Be, Sn, W, Mo) deposits, titanium, vanadium and rare-earth deposits and lead-zinc deposits were continued and several progress reports were published. A major report on Huronian rocks and uraniferous conglomerates was prepared and publication was expected in May 1969.

Projects in geochemistry described in last year's report were continued. More than 100 visitors from industry consulted with members of the Geochemistry

Section. Many of these were particularly interested in the Survey's studies on radon as a method for uranium exploration and in the methods being developed for computer interpretation of geochemical data. Biogeochemical techniques were tested successfully in the Cobalt, Ontario district, and other studies in this field were continued.

Chemical and instrumental analyses were continued to provide compositional data on geological material. A total of 119,002 analyses were made on 25,400 samples in the laboratories of the Geochemical Section and 57,760 analyses were performed in the laboratories of the Analytical Chemistry Section.

Mineralogical studies made by the division include the physical and chemical properties of minerals and the geological significance of mineral associations and textures, use of X-ray diffraction, X-ray emission and absorption, and electron-beam techniques. The Survey's mineralogists compile and publish data on Canadian minerals, examine mineral and rock specimens as a public service, prepare collections of minerals and rocks for sale and maintain the Systematic Reference Series of the National Mineral Collection. In 1968-69, 8,628 sets of rocks and minerals were sold.

Work in geomathematics and data processing continued. An interesting aspect of this work is the development of mathematical methods for predicting the areal distribution of gold occurrences in greenstone belts and their relationships to the geological environment.

INSTITUTE OF SEDIMENTARY AND PETROLEUM GEOLOGY

This Division of the Survey is in Calgary and is responsible, through field and laboratory research, for describing the geology of the western and northern sedimentary basins from the international boundary to and including the Arctic Islands and between the Canadian Shield and the Rocky Mountain Trench. The Institute also has custody of samples and other data resulting from exploration in all provinces of western Canada and is also the repository of drilling cores and other data which are submitted in conformity to regulations. The scientific work is carried out by six research sections. During the report period the Institute comprised 40 scientific and professional staff, 22 technical staff and 18 administrative support staff. Liaison is maintained with members of the petroleum industry, universities, provincial departments and professional societies. During the year more than 2,000 persons used the core and sample examination facilities. The number of samples now exceeds eight million, and there are 8,000 boxes of core.

Field work was carried out by parties of the Arctic Islands Section in southeastern Ellesmere and eastern Devon islands and in the Foxe Basin area. The Structural Geology Section is responsible for the geometric analysis of formations that may contain fossil fuels or saline substances and for basic research into the mechanics of deformation. In support of these objectives five staff members undertook field investigations. The Paleozoic and Mesozoic Stratigraphic Sections are responsible for basic research towards establishing a stratigraphic and historical framework for the strata of these periods. "Operation Norman", a two-year, aircraft-support reconnaissance project in northern District of Mackenzie, involved members of both sections and resulted in the mapping of 100,000 square miles. The western Paleontology Section carries out studies designed to date the sedimentary rocks of western and northern Canada and to provide descriptions of fauna and flora vital to stratigraphic correlation. A total of 2,420 lots of fossils were examined and 98 reports were prepared. In addition, 17 reports on 676 lots were prepared by university paleontologists for use by the Survey. Mention was made in the 1967-68 Annual Report of discussions held between industry and the Petroleum Geology Section. As a result, four projects were initiated this year: (1) studies on the environment of oil and gas in western Canada; (2) a collaborative project with the Coal Research Section (Ottawa) to study the metamorphic changes in coals as an indication of hydrocarbon types; (3) a geochemical study in cooperation with Panarctic Oil to investigate trace amounts of hydrocarbons; and (4) a joint program with Geoservices North America Limited to test their surface-prospecting method.

QUATERNARY RESEARCH AND GEOMORPHOLOGY

This Division provides geological and geomorphic knowledge about unconsolidated deposits and landscape features and assists in applying this knowledge to the Canadian economy. This mission has a most important economic aspect involving the application of geological and geomorphic knowledge in mineral exploration, agriculture, forestry, water supply, pollution and waste disposal, construction and foundation engineer-

ing, and in urban, rural and recreation planning. At the end of the fiscal year the staff comprised 34 professionals, 16 technicians and four administrative employees. Twenty-six of the professional staff engaged in field work in 1968. Seven staff members are in Calgary and one at the Canada Centre for Inland Waters at Burlington.

The Regional and Stratigraphic Projects Section describes and explains the Quaternary geology and geomorphology of Canada. Field work was carried out in eight provinces and the Northwest Territories. Reconnaissance studies in southeastern Ellesmere Island and northeastern Baffin Island were completed, and several staff members continued a variety of studies on Banks Island. Studies of the glacial geology of southwestern New Brunswick continued. At the request of the provincial government the feasibility of prospecting for sand, gravel and silica sand near Moncton was studied.

The Sedimentology and Geomorphic Processes Section investigates processes of landscape change involving slope movement and erosion, frost action, weathering, and sediment movement and accumulation. During the report period studies were carried out on a variety of topics including varved sediments, eskers in Keewatin District, raised beaches in the southern Lake Huron region, and the delta lakes of Mackenzie Delta.

The Paleoecology and Geochronology Unit provides radiocarbon dates and analyses of fossil materials (mainly pollen). Such studies are valuable in investigating changes in environment and plant and animal distribution during the Quaternary. During the year, 186 radiocarbon age determinations were made; 14 were on archeological material submitted by the National Museums of Canada.

Studies by the Engineering and Indicator Geology Unit are of direct practical value. During the year the Survey provided advice to the Inland Waters Branch on proposed power sites and river-diversion projects on the Albany River, Ontario, and to the St. Lawrence Seaway Authority during construction of the new Welland Canal.

Mines Branch

The Mines Branch is a complex of laboratories and pilot plants designed to assist the Canadian mineral industry in the more efficient extraction and elaboration of mineral wealth of all types, and to improve and broaden the uses of metals and minerals. During the twelve months under review the Branch continued a number of promising research projects and started several new ones.

The work is carried on in six Divisions—Physical Metallurgy, Fuels Research Centre, Mining Research Centre, Mineral Sciences, Extraction Metallurgy, and Mineral Processing.

Physical metallurgy is concerned with the composition and behaviour of pure and alloyed metals as well as the smelting of iron and steel. Much of the work falls into the category of "troubleshooting" for government departments and private industry. Fundamental research into the melting and solidification of metals and the physics of liquid metals also forms part of the Division's work. Research on fuels concerns especially the treatment of Canadian coals to render them more acceptable to the metallurgical industry at home and abroad, the chemical structure of hydrocarbons, and the beneficiation of Canadian heavy crude oils. The Fuels Research Centre also seeks to improve the safety of mining equipment in explosive atmospheres and to reduce air pollution from combustion.

Mining Research Centre specialists concentrate on such problems as rock breakage, ground and dust control, managerial operations control, and the distribution of technical information to the mining industry. In the Mineral Sciences Division the emphasis is on the composition and properties of useful minerals. The complicated sulphides occupy much attention, as do multioxide systems of such elements as niobium, tantalum, and aluminum. Research is also being conducted on the fabrication of piezoelectric and magnetic ceramics, surface phenomena on minerals, and crystal structure. In the Extraction Metallurgy Division, bacterial leaching of uranium ore, an experimental shaft-and-electric-arc furnace, prevention of embrittlement during electroplating, and the thermodynamics of metallurgical reactions are the main fields of interest. Research in mineral processing covers practical aid in the processing of newly discovered ores, the evaluation of commercial ceramics, the improvement of industrial minerals such

as shales and concrete, and the flotability of non-metallic minerals.

Details of these and other investigations will be found in the following.

PHYSICAL METALLURGY DIVISION

The Physical Metallurgy Division undertakes a wide variety of work concerned with research, development, processing and fabrication, and application of metals and their alloys. This work is undertaken in support of the Canadian mining and metallurgical industry and also in response to requests received from other government departments.

The research and development of the Division have been organized under five headings: casting and solidification, forming and fabrication, engineering properties and service evaluation, alloy metallurgy, and research-and-development techniques and equipment. There are a number of active projects in each of these areas. Some typical examples of these projects are presented.

In the field of casting and solidification, work is being carried out to evaluate the influence of various deoxidation methods on certain critical properties of structural steels. A project is under way on the development of grain refinement for cast bronzes. Fibre-reinforced composite materials produced by directional solidification are being evaluated in another research project.

Forming-and-fabrication projects include research on the problem of low ductility in welds of 18% Ni 250 maraging steel. This research has established optimum welding and heat-treating conditions to prevent brittleness in such welds. Another forming-and-fabrication project is a study of the relationship between sintering behaviour and powder-particle characteristics of Canadian nickel powder. Research on the hot and cold rolling of wrought nickel is another example of work in this area. This project was undertaken to develop design data for the proposed new rolling mills for the production of strip for nickel coinage at the Royal Canadian Mint.

A great deal of the work in engineering properties and service evaluation has been concerned with mechanisms of failure by fracture, fatigue and hydrogen embrittlement. One project is concerned with the fracture mechanisms of ultra-high-strength steel. Another project has indicated that atmospheric environment can play a critical role in the fatigue behaviour of high-strength aluminum alloys. This emphasizes the need for a better understanding of the role of the surface oxide on this and other commercial aluminum alloys. Research has been undertaken to determine the degree of hydrogen embrittlement that might result from the fabrication of heavy-structural-steel sections by welding followed by pickling and galvanizing. This work was undertaken to help evaluate the maintenance cost of galvanizing heavy section-welded steel structures, such as bridges, etc.

In the field of alloy metallurgy, research is continuing on the development of high-strength cast steels of improved toughness. Several research projects concern the relationship between the alloy metallurgy of a wide range of alloys and their mechanical properties and corrosion resistance. These projects cover steels, aluminum, magnesium, copper, titanium, uranium, zirconium and zinc alloys.

A considerable amount of work has been expended on the development of new research techniques and associated equipment. Work on the electrochemical determination of soluble oxygen in molten steel is continuing in association with a commercial organization. A complete system for use in steel plants for the electrochemical determination of soluble oxygen in molten steel has been designed and made ready for industrial trials.

In addition to the above research and development the Division has responded to requests for research assistance from government departments, companies and universities. This Division handles several hundred such requests each year. A few typical examples are outlined.

Among the more intensive investigations was the study of pipeline failures. During the course of this year at least seven pipeline failures were investigated on behalf of the National Energy Board. In all cases metallurgical reasons for these failures were identified, thereby permitting the necessary corrective measures to be taken.

An evaluation of three different welding processes used to seal clad atomic-energy fuel-rod elements was undertaken for Atomic Energy of Canada Ltd. This investigation indicated that only one of these proposed methods was suitable.

Two investigations were undertaken on behalf of the pulp and paper industry. The brittle failure of abrasion-resistant white-cast-iron wear blades in ground-wood refiners was investigated. Recommenda-

tions were made that would improve the service life of this item. The second item was a component of a quality-control installation used in the production of ground wood pulp. A critical component of this installation was failing with very short life. The causes for failure were identified and recommendations for the correction of this difficulty were made. These recommendations have subsequently been successfully adopted.

The Department of Transport requested advice on the repair of bottom plates on ships of riveted construction that were built during the period 1900-1930. Based on our examination of samples it was recommended that repairs should also be made by riveting. Precautions were also given concerning the susceptibility of this kind of steel to low-temperature brittle fracture. A Quebec shipyard was advised about methods of welding vertical steel plates.

The Royal Canadian Mint requested an investigation to determine any differences in physical properties and microstructure of 1968 twenty-five-cent coins made from nickel from two different sources. It was demonstrated that there were significant differences in certain physical properties of these coins that would make possible the identification of source material.

Technical assistance was given to many Canadian universities, usually by preparing for them small quantities of special alloys for post-graduate research.

As usual the Division has been heavily involved in the certification of industrial radiographers across Canada. During this period 12 persons completed practical tests in Ottawa. A total of 30 senior and 82 junior applicants were certified. The certification of radiographers in the category of aircraft structures has been established. The practical tests are conducted at the Canadian Forces Base in Trenton, Ontario, under the guidance of this Department. The Department of Transport has ruled that radiographic inspection of civil aircraft must be supervised by certified personnel. It is expected that this ruling will result in an increase in the number of applicants seeking certification.

During the past year, three outside organizations have made use of the research facilities of this Division. The Steel Castings Institute of Canada has a permanent staff of two at the Division to conduct research on its behalf. The Canadian Zinc and Lead Research Committee maintains one research worker here. The Department of National Defence has been supplying one man intermittently to carry out corrosion research.

FUELS RESEARCH CENTRE

World conditions are continuing to exert a profound influence on Canada's mineral-fuel economy. This fact is strongly reflected in the activities of the Fuels Research Centre, which has as one of its prime objectives the development of processes for the conversion of Canada's mineral fuel resources into products that will meet the diverse needs of modern industry both at home and abroad.

The resurgence of Japan from postwar privation and chaos to its present position as the second-largest industrial power in the free world, in terms of gross national product, has been associated with a rapid expansion of the Japanese steel industry and a greatly increased demand for coking coal. Part of this demand is being met by the establishment of fifteen-year contracts for western Canadian coking coal. The value represented by the contracts signed to date amounts to $1.5 billion, and this market appears to be growing steadily.

To ensure the expansion of the Japanese market (and the development of new markets in the central part of North America) the Fuels Research Centre has improved and modernized its facilities for evaluating coking coal. This is essential to satisfy the growing demand for assessment of the quality of reconnaissance samples of coal from western Canada. The Centre has also improved its processing capability on the pilot scale to remove the mineral matter from coking coal. This has been allied with the development of new methods of drying fine coal. These new techniques show promise of reducing costs, as well as the atmospheric pollution associated with thermal driers. These efforts to bring to fruition technical innovations as quickly as possible are essential to meet the requirements of the Japanese market.

In anticipation of the problems arising from the transportation and storage of fine coking coal, research was initiated to develop new and more sensitive analytical techniques to detect and measure the weathering of coal. This investigation was successfully concluded during the year with the development of a new chromatographic technique for the detection of weathering and an interesting new method for the measurement of the total organically combined oxygen in coal.

The construction of the new buildings for the Fuels Research Centre on the western outskirts of Ottawa was largely complete at the end of December, when the relocation of the equipment and laboratories

began. One of the larger items to be constructed is the modern 18-inch oven, which will carbonize an 800-pound charge of coal. This facility is being built with the aid of funds from the Canadian Carbonization Research Association, which is an industrial group composed of Canada's major steel producers, coal companies and a coal-tar-processing company. This reflects the close association between the Metallurgical Fuel Engineering Group and the metallurgical industry to find new techniques for matching Canada's coal resources to the special requirements of this industry.

Good progress has been made by the Western Regional Laboratory of the Fuels Research Centre in Edmonton on the application of compound water cyclones to the upgrading of Cape Breton coals. This work was conducted with the encouragement of the Cape Breton Development Corporation and the support of the Dominion Coal Board. At the year-end, these studies had been extended to the problem of reducing the pyrite content and mineral matter of fine coal.

The Hydrocarbons Group of the Fuels Research Centre is concerned with the evaluation of Canadian petroleum resources (including engineering studies of transportation and comparisons of Canadian fossil fuels); gaining a better understanding of the fundamental chemical structure of these raw materials; and, finally, developing improved processes to beneficiate Canada's heavy crude oils to supply the needs of the future.

The number of Canadian crude oils evaluated during the year was reduced due to staff shortages and the need to accelerate pilot-plant work, as it was known that the relocation of this equipment to the Corkstown Road site would inactivate these programs for a considerable period.

The emphasis in applied petroleum research has continued to be on the development of processes and equipment for the conversion of valuable products. Part of this program involved an appraisal of the combined liquid-and-vapour-phase hydrogenation process. The pilot plant, using a circulating suspended catalyst, was operated for 700 hours. Many of the mechanical difficulties were overcome to achieve smooth operation. The results have not been fully assessed, but the indications are that when residual oil is used as the feed-stock, the throughput is low and the product quality exceeds specifications.

The group also evaluated thermal hydrogenation of whole crude from the Athabasca tar sands to yield a refinery feed-stock. It was demonstrated that hydrogenation at moderate pressure, without catalyst, offers considerable promise as a practical initial treatment. This simple, partial refining step allows the residuum to be reduced to levels that are in balance with the energy requirements of operating a hot-water-separating plant and the demands of mining.

Research in catalysis, associated with petroleum refining, has led to the development of an inexpensive process for making high-surface-area alumina for catalyst supports. This alumina is capable of being formed into pellets of high mechanical strength with relatively low pelleting pressures. These pellets have a greater capacity for bringing about reaction, due to their low density and the relatively greater accessibility of the internal surface.

The Fuels Research Centre is concerned with research that will improve the safety of mining in Canada. In this connection, an important contribution was made by the Canadian Explosive Atmospheres Laboratory through the certification service and by conducting research on the explosive properties of gaseous mixtures, particularly as they influence the design of electrical equipment used in mines. Investigations were made of the strains that develop on the walls of explosion-proof electrical equipment when subjected to various internal gas/air explosions. The ability of an enclosure to resist structural damage from internal gaseous explosion depends not only on the magnitude of the stress, but also on the natural vibration-frequency period of the enclosure. This information will help Canadian industry to design more effective equipment, and will also provide a basis for examining imported mining machinery.

Air pollution from combustion sources is a matter of increasing public concern. Research to alleviate some of this pollution is being conducted at the Canadian Combustion Research Laboratory. The development of a new and more accurate plume-rise equation to predict the manner in which stack gases are dispersed from tall chimneys has been completed, and preparations are in progress for field studies to secure more detailed information on the settling of particulates, as well as the variations in concentrations of sulphur dioxide with distance from the stack. Research is also in progress on domestic-size blue-flame burners in an attempt to reduce smoke and pollution from unburned hydrocarbons. As the formation of noxious atmospheric pollutants is influenced by the aerodynam-

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ic conditions existing in the furnace, a tunnel furnace is now under construction to study the aerodynamics of flames. This furnace, when completed, will provide a flexible facility enabling this laboratory to complement the work of the International Flame Research Foundation at Ijmuiden, Holland.

MINING RESEARCH CENTRE

The Mining Research Centre carries out research in three laboratories: Canadian Explosives Research Laboratory, Rock Mechanics Laboratory, and Elliot Lake Laboratory. In addition, many of the individual projects are done in mines throughout the country with the joint support of the companies and the Centre.

The Centre operates on the project system, individual projects being integrated with the work of individual companies and universities throughout the country. Wherever possible, the prospect of an attractive payoff is used in the selection of projects. Those projects on which the potential benefit-cost ratio is particularly high receive maximum concentration of the budgetary resources.

The *breaking of rock* both at the mining face and subsequently in reducing the large blocks of ore to a fine size suitable for processing is a major part of mining. The objective of rock-breakage research is to explore the mechanics of breakage using forms of energy other than explosives with a view to radically new mining methods. This is a pioneering activity undertaken at the request of the Mining Association of Canada as a result of a survey showing that their members believe rock breakage is one of the most important areas in which research should be able to effect savings. Beside helping to improve efficiencies in current systems through the discovery of novel methods of drilling, blasting, crushing and grinding, it was also envisaged that conventional operations may be telescoped into some combined procedure quite unlike current practices. The work is being done primarily in the Elliot Lake Laboratory.

Blasting research is also being pursued to increase safety and to reduce the cost of drilling and blasting in industry, which accounts for the expenditure of approximately $100,000 per year in Canada. By the application of analytical techniques it should be possible to produce significant savings within a reasonable period of time. The resources of the Canadian Explosives Research Laboratory, the Rock Mechanics Laboratory and the Elliot Lake Laboratory, together with those of some private companies, are all being used for this work.

How to ensure stability of the rock around a mining excavation—that is, *ground control*—is an important aspect of mining. Solutions of the problem are being sought through analytical methods, which have been used in the design of building structures for over a hundred years. Before such methods can be successfully applied, however, considerable research is necessary, both because of the great variety and complexity of mining openings in Canada and because adoption of the large safety factors common in structural design might seriously impair effective extraction. The work is done mainly through the Elliot Lake Laboratory.

Besides the basic projects that are being pursued with the resources of the Mines Branch alone, cooperative projects with mining companies from Newfoundland to British Columbia constitute a major part of the ground-control research. Control of the weak and friable roof rocks in both the eastern and western coal fields is being studied with various companies. Work is being done in the Saskatchewan potash mines and Ontario salt mines. In the former case, little experience exists in the world for mining such materials at the depths of these deposits. Studies also are being conducted to establish appropriate designs and operating sequences for mining multiple, parallel seams in one of the uranium mines. Stress and deformation measurements have been made in hard-rock mines subjected to rockbursts. Much information has been gathered from underground measurements in base-metal mines in both Quebec and Ontario on the stability of pillars. Design procedures have been evolved for support with rock bolts; work is proceeding to achieve the same objective for support supplied by filling with waste mill tailings. Canada has one of the largest underground mining industries in the world, and such studies are extremely important to the Canadian economy.

As over 50 per cent of the ore produced in Canada comes from open pits, a substantial part of the research budget of the Centre is applied to open-pit mining. To produce 100,000 tons of ore from these mines, typically 150,000 tons of waste rock must also be excavated from the slopes required for these pits, which can be as deep as 1,000 feet. The economic feasibility of any potential open pit is, therefore, largely dependent on the slope to which the walls must be cut. Scientifically determined *optimum pit slopes* would be worth much to industry. Individual mines however, do

not have adequate incentive to engage in the comprehensive program required for such a technological advance, and government enterprise is required.

Computer simulation of open-pit slopes is being used to examine the basic factors influencing the stability of slopes in rock. Under study are stress distributions in typical slopes subjected to varying tectonic stresses together with deformation patterns and their correlation with known modes of failure. In addition, optimization of excavations is being sought by changing slope angles as the mine gets deeper.

Research is being conducted towards improving the *environmental conditions* in mining. Whereas the physiological effects are the concern of other research groups and ventilation design is done by mine staffs, the physics of measuring environmental conditions requires the more detailed study that is being undertaken in this program. At the present time, the projects concern primarily standard methods for measuring dust and radiation hazards and are being conducted in close cooperation with the Mine Accident Prevention Associations of Ontario and Quebec as well as with individual companies experiencing critical problems. Although conditions in Canadian mines are generally good, improvements must be made constantly in the working environment (e.g., air-conditioning, humidity control, noise suppression, and good lighting) to ensure continuous interest on the part of technical personnel and labour in working in the mines. The work is being done primarily in the Elliot Lake Laboratory.

Work has been started on *systems analyses* of various mining operations. Advances that are made by physical research on the various phases of operations (drilling and blasting, ground control, transportation, etc.) are being examined to determine their influences on mine economics. Computer programs are to be developed for use by company staffs on mining properties.

With the high degree of complexity of current technology, we find that no organizations exist in the country with the personnel and facilities capable of assisting those with problems in many specialized areas. Consequently, calibration, testing and advisory services are provided when required by companies and agencies in the mineral and associated industries. This is consistent with the Mines Branch policy of orienting its research to fill gaps in technology of particular concern to the country. At present, most of the work is being performed at the Canadian Explosives Research Laboratory.

The general function of *communication* is being expanded by the development of an Information Centre involving both the Mines Branch Library and the Elliot Lake Laboratory whereby, through information officers and telex links, it is planned to provide industry and the universities with assistance in finding and obtaining the latest research information on any subject. At present, integration with private research is achieved either through joint projects or through liaison on subjects of mutual concern. The companies cooperating with the Mines Branch in research produce approximately 75 per cent of the Canadian mining output. Besides the conventional method of publishing significant results in journals, interim reports are written. Some of these are distributed exclusively through the Mining Association of Canada to interested companies, while others are used as research notes that are exchanged with laboratories both in Canada and abroad.

In 1963, the Canadian Advisory Committee on Rock Mechanics was formed to stimulate greater interest in this base science for mining and to coordinate research. The membership has consisted primarily of representatives of industry and of the universities, with Mines Branch personnel essentially providing the secretariat (the chairman and the secretary).

One of the principal ways in which the Mines Branch, with advice from the committee, has been able to stimulate research is through its grants in aid which, starting with $10,000 in 1962, have grown to a total of $310,000 for mining research in general with the majority of these funds being used for research in rock mechanics. The committee also periodically examines and appraises the research of the Centre in rock mechanics.

MINERAL SCIENCES

The Mineral Sciences Division is a multi-disciplinary "Materials Research" type of organization concerned with research of use in the whole field of minerals technology. The Division divides its activities into three main fields: (a) mission-oriented research into the properties and behaviour of minerals and related materials, (b) studies of the characteristics of mineral assemblages and the distribution of the values that bear on the exploitation of ore deposits, and (c) inorganic chemistry (phase-equilibrium studies of oxide systems, structural chemistry) and analytical research with a special interest in the development of internationally accepted standards of analyses.

Sulphide Research

The properties of sulphides and related minerals are being investigated in considerable depth to suggest new and improved methods of beneficiating and using this important category of ore minerals. Insight into the forces that bind atoms together to form stable mineral structures has been gained through infrared spectroscopy of a number of sulphides, including pyrite (FeS_2), marcasite (FeS_2), cattierite (CoS_2), vaesite (NiS_2), cobaltite (CoAsS), arsenopyrite (FeAsS), gudmundite (FeSbS) and loellingite ($FeAs_2$). Physical-chemical factors that affect the structural stabilities and compositions of the skutterudite minerals (Co, Ni, Fe)As_3 have been deduced from a critical analysis of their compositions, solid-solution limits, magnetic properties and specific gravities. Investigation of complex intergrowths of silver-antimony-mercury minerals by microscopy, electron-probe microanalysis and phase-equilibrium studies have, for the first time, provided an adequate characterization of, and explanations for, ore assemblages in the Cobalt mining camp. Some progress was made toward characterizing a new copper-iron sulphide mineral in terms of its stability relations and crystal structure. Improvements were made in level of precision. Single crystals of a number of sulphides required for experimental work in the sulphide research have been grown successfully by vapour-transport and Czochralski methods. To ascertain the surface properties of sulphides a kinetic study was initiated of surface-solution equilibria of lead sulphide in aqueous media. These and other research projects on sulphide minerals have substantially extended the knowledge about their fundamental properties and behaviour.

Mineral-Surface Studies

Research continued of the mineral-solution interface. A phenomenon known as the double layer occurs at the surface of minerals in contact with ionic solutions, with electrochemical properties that can be measured. This has been done for a number of oxides—hematite, silica and others—and the work has now been extended to sulphide minerals. These measurements have proved more difficult because of greatly increased surface reactivity. Using the data obtained, together with theoretical relationships, it has been possible to derive thermodynamic parameters useful in predicting the characteristics of adsorption—important to most mineral-treatment processes, including flotation. Other studies related to surface phenomena undertaken during the year, were electrophoretic measurements of mineral-leaching bacteria in direct-current fields; oleic-acid adsorption on hematite; and preliminary work on surface properties that are of interest in electrostatic separation.

Ferrites

An expanding program on the chemistry and technology of magnetic ceramic materials based on ferrite compositions is under way. The work has hitherto been restricted to studies of "hard" or permanent-magnet ferrites, which are widely used in computers and magnetic tapes. Studies of the effects of such variables as stoichiometry, particle size and shape, calcination and sintering times and temperatures on the magnetic properties of the ferrite ceramics have been conducted, and a study was made of the kinetic mechanism of their formation. As a consequence of the knowledge and capabilities that have been established at the Mines Branch in this work a number of Canadian companies have been directly assisted and advised.

Mineralogical Studies of Canadian Ores

Studies of ore-mineral assemblages that are characteristic of Canada's economically important deposits have been undertaken to provide basic mineralogical data of value in the exploitation and beneficiation of the ores. Other aspects of the depositional history have been gleaned from a detailed study of the textures of the other ore minerals. A lengthy study of the Cobalt-Gowganda area is nearly completed, on the basis of which mineralogical and chemical zoning has been delineated in the ore deposits, textural and compositional relationships of the constituent minerals have been clarified and described, a number of minerals in the deposits have been fully characterized, and a large body of new knowledge on the silver mineralization has been accumulated.

Non-destructive Assaying of Metal Values in Ore Estimation and Grade Control

In recognition of the need to obtain large volumes of data for use in ore estimation and grade control, studies were undertaken to evaluate the technique of using portable X-ray fluorescence equipment. Field and laboratory work indicated some range of applicability, but the limitation of X-ray fluorescence to only the surface of minerals proved to be an obstacle in some cases. As a result, feasibility studies of using neutron

activation, which has substantial penetration into the material being analyzed, were carried out and the results showed promise. The greatest attention was focussed on copper. Accurate and rapid analyses can be made, but the technique of applying such a method in the field for assaying drill cores and samples must still be developed.

The Analysis of Ores and Minerals. A wide range of analytical techniques, conventional chemical, spectroscopic and instrumental, continues to be employed in the solution of problems of composition arising in researches throughout the Mines Branch, as well as from industry and other government organizations. For instance, significant advances were made in the limits at which gold can be determined in its ores. By combining neutron-activation analysis with the fire-assay method, greater sensitivity was achieved, and custom assays of samples for platinum-group metals were performed for a number of private companies or individuals. This service was instituted in 1967 because of difficulties encountered in obtaining consistent results by outside laboratories in the determination of these elements.

Instrumental Analyses

The following instrumental types of techniques have been used in connection with problems under investigation in the Division: spectrochemical analysis in the visual, infrared and X-ray spectral regions, both qualitatively and quantitatively; atomic absorption spectroscopy, which has replaced conventional chemical analysis in the determination of many metallic elements, with a consequent saving of time and improvement of accuracy; differential thermal and thermogravimetric analyses, which serve a very useful purpose in following the course of complex mineralogical and metallurgical reactions; neutron-activation analysis, which affords a very useful direct method of estimating oxygen in metals; and phase-equilibrium studies, which give information concerning the temperature and compositional stability of the compounds occurring in multi-component oxide and other systems.

Crystal-Structure Analysis. A very comprehensive and sophisticated system has been assembled and set in operation for the detailed study of atom positions in crystals of interest to the Division. This facility, incorporating among other items a four-circle goniometer and a computer for data collection and equipment control, is unique in Canada and has been used for the study of a number of compounds.

EXTRACTION METALLURGY

In the Extraction Metallurgy Division, applied research continued on hydrometallurgical and pyrometallurgical processes, on electroplating technology and on causes and prevention of metal corrosion. The work was broadly based to meet the immediate and future needs of Canadian industry, and new developments were communicated to the industry through publication in technical journals, and through cooperative industry—Mines Branch organizations such as the Canadian Mineral Processors and the Canadian Uranium Producers Metallurgical Committee, and by field trips, informal contacts, and direct reports.

Hydrometallurgy

Bacterial action on iron sulphides under favourable conditions can produce oxidizing acidic solutions which have considerable economic potential in the leaching of certain ore minerals. A long-term research program has been directed toward developing a plant process embodying bacterial action on iron-sulphide-bearing uranium ores. Moderate acidity, agitation and slurry density have been found necessary for a viable bacterial environment, and in a pilot plant designed to test results of the research program, these conditions were attained by use of thickeners as bacterial leach reactors. While extraction efficiency is as yet slightly lower than in conventional leaching, the pilot-plant study has shown that under favourable conditions an economic process could be developed, since heat and reagent costs are considerably reduced.

In conventional leaching of uranium from Elliot Lake ores, there is some extraction of rare earths, thorium and yttrium. While only the yttrium is currently of economic interest, the rare earths and thorium have a market value if available in a relatively pure state. An investigation using solvent extraction was therefore undertaken to develop methods of producing separate rare earths.

A systematic re-evaluation of uranium-leaching variables has been carried out over the past several years by mathematical models derived from statistically-designed experiments. The models delineate the significant leach variables and their optimum ranges, and can be used to predict the effects of changes in these variables. The work was related to process developments in the operating uranium-leach plants and showed that process temperatures, which have gradual-

ly been increased over the past decade, are approaching the limits of optimum economy.

Pyrometallurgy

A combination shaft furnace - electric furnace has been under development for some time at the Mines Branch to provide a more efficient electric smelting unit that can be built to suit the requirements of a broad range of Canadian metallurgical operations. The unit utilizes energy sources of electricity, gas and oil, each in its most efficient and effective way, to obtain maximum productivity from the electric furnace.

As it is now developed, substantial economies in electrical energy are achieved by pretreating incoming feed with hot reducing gases from the electric furnace and from gas burners, in the shaft furnace. The experimental program of the past year was directed largely toward determining the operational benefits of the improved unit, and for this purpose smelting programs were carried out producing pig iron from iron-oxide pellets, and steel from SL-RN pre-reduced pellets. In the smelting of iron oxide it was found that 25 per cent of the reduction of the feed had been achieved in the shaft furnace by the hot reducing gases. More sophisticated data-gathering equipment was installed and data-processing facilities have since been improved by installation of a terminal linked to a National Research Council computer, to enable operating data to be analyzed rapidly enough to guide the control of furnace conditions.

Corrosion and Its Prevention

Research on the causes and prevention of metal corrosion in industrial environments was carried on throughout the year, both in the laboratory and in the field. Corrosion of reactive metal surfaces by sulphurous acid deposited from atmospheres contaminated by sulphur-dioxide-bearing combustion gases can be severe in industrial areas, and research was continued toward prevention of such attack. Reagents such as sodium oxalate and hexamine were earlier found to inhibit sulphurous acid corrosion of mild steel and zinc, and in the past year studies on aluminum showed that borax was partially effective for the protection of this metal.

In the long-term program on the improvement of industrial electroplating, a new plating-bath composition for electroplating chromium on high-strength steel was developed. The chromium coating applied to the high-strength steel is non-porous and thus provides greatly improved protection. It was found, too, that mild steel could be given a non-porous chromium coating from the new plating bath, so that the new development could have wide industrial application.

In the field a survey of the effects and possible causes of corrosion in the mining industry was undertaken, and conditions underground and on surface were studied. The results of the survey are being used to formulate research to combat the corrosion difficulties of the mining industry.

Basic Research

The basic research of the Division was largely concerned with the kinetics and thermodynamics of metallurgical reactions of importance to the mining industry. Typical of the work carried out is the long-term research on the kinetics of leaching chalcopyrite ore. This study is directed to developing the underlying principles and controlling factors governing the extraction of metals such as uranium and copper from ores, and is of importance in treating low-grade ores.

The sulphur in many Canadian metal-sulphide ores can be turned into a valuable by-product if it can be recovered economically and sulphur-dioxide release to the atmosphere avoided. A possible route to achieve these aims is the chlorination process, which produces elemental sulphur and metal chloride, and a long-term program has been under way to define underlying principles and basic data necessary for process development.

MINERAL PROCESSING

The Mineral Processing Division carried out basic and applied research in aid of the mining, ceramics and construction-materials industries and continued to supply expert advice to industry and other government departments.

Research to improve basic processes for concentration of metal ores in the mining industry included studies of grinding-process control, development of new types of filter media, investigation of the electrochemical properties of surfaces of minerals in aqueous solution, systematic evaluation of the variables of hydrocyclone classification, and flotation of iron, copper and molybdenum ores.

Applied research was conducted to assist the mining and metallurgy industries in development of new mines, improvement in existing plants, and better utili-

zation of resources. Treatment processes were developed for new mine projects including copper-nickel, lead-zinc, copper, silver, gold and iron ores. Industrial assistance projects included reclamation of chromite foundry sand, use of plant tailings as mine backfill, recovery of silver from old tailings deposits, and participation in the preparation of international analytical standards for platinum.

A pilot plant was operated to further develop an economical process for the treatment of a complex base-metal ore from New Brunswick.

Research in the industrial-minerals field was directed towards new and improved processes for the conversion of Canadian industrial minerals to useful products. The separation of non-metallic minerals, high-temperature preparation of ceramic products, and the improved utilization of mineral products were some important areas of research and investigation. Technical information was provided on processing methods, and on specifications of a wide variety of minerals and products. Evaluations were carried out on numerous samples of industrial minerals which were submitted by industry, the public, and other government agencies.

Long-term projects continued in the non-metallic mill dealing with the floatability of industrial minerals, removal of reagent coatings from mineral particles, the development of mineral-processing equipment and the recovery of weakly magnetic minerals. Investigations on the beneficiation of industrial-mineral ores included fluorite-barite from Nova Scotia, quartz sand from Ontario, spodumene from Manitoba, barite from Ontario, scheelite from the Northwest Territories, ultrabasic rock from Ontario, and marl from Saskatchewan.

Experiments on the thermal properties of ceramic products, rocks and minerals indicate that a method has been developed by which the thermal conductivity of rocks composed of several minerals can be calculated. Assistance was given to a Canadian company by providing it with technical procedures developed at the Mines Branch on the manufacture of piezoelectric ceramics. Laboratory investigations were initiated to determine how Canadian-manufactured aluminas could be used in the manufacture of electronic ceramics, and how a combination of Canadian alumina and kyanite could be used for the manufacture of special ceramics. Research and development continued on Canadian clays and on clay products, particularly from Ontario, the Atlantic Provinces and the Prairies.

An extensive research-and-development project has resulted in an accelerated strength-testing method for early prediction of the 28-day and 91-day compressive strength of concrete. Field test data received from several companies indicated the value of the method, and several organizations are planning to use it. The CSA Committee on Concrete Materials and Methods of Concrete Construction decided to include the method as information in its Standard A-23. The work on the ring-test for determining the tensile strength of cement, mortar, gypsum plaster and concrete created widespread interest both nationally and internationally. Of all the methods available, the ring test appears to be the only practical one for determining the tensile strength of concrete that incorporates aggregates up to 3 inches maximum size. Investigations continued on the assessment of lightweight aggregate and concrete, and on the evaluation of building and ornamental stone. Of particular interest was the finding that gem-quality lapis lazuli from Baffin Island was suitable for the establishment of a small industry for the Eskimos in that area.

Initial studies of the autoclave calcination of a slurry of by-product synthetic gypsum from phosphoric-acid plants indicated that a quick-set, hemi-hydrate plaster could be produced by this technique. The static system for determining the length-diameter relationship of chrysotile asbestos fibre is being investigated further by the Quebec Asbestos Mining Association. The procedure for orienting chrysotile asbestos fibres was allowed by the U.S. Patent Office. The technique for determining surface area, based on a modified gas chromatograph was turned over to Canadian Patents and Development Limited for further study.

Almost all studies carried out in the Division require prior mineralogical evaluation. Investigations of the relationship between the mineralogy and ceramic properties of clays and shales and between the mineralogy and physical properties of aggregates and building stones are carried out continuously.

TECHNICAL SERVICES

The Technical Services Division provides engineering and technical support services to the six Mines Branch divisions engaged in fundamental and applied research. The Division provides consulting and design-engineering capability in the mechanical, electrical, industrial-instrumentation and control technologies.

The engineering group is backed up by skilled technicians and trades craftsmen who support research

98292—4

personnel by developing, manufacturing and installing many classes of equipment for laboratory and pilot-plant applications. These craftsmen, who represent most of the building-construction and industrial trades, have developed a capability to work with a wide range of standard and exotic materials, metals and alloys and to fabricate devices from the same. Because of this diversity the Technical Services Division has successfully completed broad and complex projects as well as highly specialized ones.

Altogether the Division completed 2,703 work orders during 1968-69. Preponderant among these was work done for the Physical Metallurgy Division.

Further work on machineability and fatigue was carried out. Metal-cutting research was undertaken by a major Canadian steel company.

The Division collaborated with the non-ferrous section of Physical Metallurgy Division to provide a metrology service for its research on the ageing properties of various magnesium alloys. The metrology facilities of the Division are able to provide a direct service to the research scientist, as very precise length measurements can be made under environmentally controlled conditions. A long-term ageing project of this nature requires that the rate of change of temperature in the metrology room be held to a minimum. It is expected that improved environmental-control equipment will be purchased and installed this year.

Continuing development was carried out on the ion-bombardment equipment for the Physical Metallurgy Division. As a direct result of this work it was recognized that the use of hollow hemispherical collectors provided an excellent method of teaching the three-dimensional geometry associated with crystallographic problems. A device was developed in conjunction with the research group involved which makes possible the direct production and viewing of stereographic and gnomonic projections of any chosen crystal orientation. A patent has been applied for through Canadian Patents and Development Limited.

A three-year program of updating the Physical Metallurgy Division's sixteen heat-treating furnaces was completed.

LIBRARY

The Mines Branch Library consists of the main library with a staff of three professional librarians, four clerks and a typist; there is a branch library in the Physical Metallurgy Division with a library clerk in charge, an active collection at the Mining Research Laboratories, Elliot Lake, with a clerk in charge, and a collection at the Western Regional Laboratory in Edmonton with a technician in charge. Further library services will be needed as the various divisions move out to the Corkstown Road site during the next few years. Since the main library will probably be the last to move, another branch library will be established there to serve the various divisions in the interim.

Subscriptions to more than 831 journals, and purchases of monographs, textbooks, abstracting and indexing services, are supplemented by publications acquired through exchange agreements with scientific and technical societies in all parts of the world.

The library's serials are publicized by means of the National Science Library's Union List of Scientific Serials in Canadian Libraries, and its books in the Union Catalogue of the National Library. In addition, our holdings are now announced in the Comprehensive List of Periodicals for Chemistry and Chemical Engineering published by Chemical Abstracts Service, Columbus, Ohio.

The shortage of trained professional staff continues, though not as severely as before.

Circulation during 1968-69 reached 53,711 items, an increase of 7.5 per cent over the previous fiscal year. The number of books and journals in the library stands at 77,000 and that of documents at 10,800.

Observatories Branch

The Observatories Branch is involved in two major disciplines—astronomy and geophysics. Astronomy is studied in major observatories at Ottawa, Penticton and Victoria, and at a number of field stations. The proposed 156-inch Queen Elizabeth II telescope, which was to have been placed on Mount Kobau in south-central British Columbia, was cancelled during the year by government decision, but site-testing is continuing and the site will be maintained for the installation of smaller telescopes.

There are three geophysics divisions: Seismology, which operates 29 seismograph stations plus an array for the detection and identification of nuclear explosions, and sends out field parties in all parts of Canada; Geomagnetism, which studies the present and past geomagnetic fields through 11 permanent observatories and a major laboratory, and which conducts field surveys in all parts of Canada; and Gravity, which is involved in field work in all parts of Canada.

Stimulated by exciting advances in the space age, public interest in astronomy has shown a marked increase. Over 10,000 visitors were registered at the Ottawa Observatory during the past year, about half at the regular Saturday evening program, the remainder in the 125 specially arranged group tours. A further 100 requests for tours had to be refused. The Victoria Observatory is even more popular with the public, receiving about 37,000 visitors throughout the year, most of them during the daytime when they view the 72-inch telescope and a small museum; some of them on Saturday nights when they are permitted to see through the telescope. The Radio Astrophysical Observatory at Penticton discourages visitors since the ignition system of cars interferes with the operation of the telescope, but regular visiting hours are established on Sunday afternoons during the summer. No record is kept of the numbers who attend.

The large volume of written requests received from individuals and school groups for information on astronomical questions is being met by a series of printed leaflets prepared by the Dominion Observatory, Ottawa. This service is slowly being extended to cover geophysical topics as well.

ASTRONOMY DIVISION—OTTAWA

The Time Service, comprising the time laboratory and the CHU transmitters, has been modified according to a long-range plan to provide a Canadian standard of time and frequency acceptable to both the scientific and layman user. The second of the proposed new transmitters was acquired and the second of three vertical antennas was erected to radiate the signals more efficiently. The transmitter site was turned over by the Department of Transport to the Department of Energy, Mines and Resources. The purchase of the second of three required caesium atomic standards, and the replacement of outdated equipment with modern solid-state circuitry, has made the Time Laboratory a centre where time may be resolved to the tenth of a microsecond. Correct time is distributed to a variety of users: The Bell Telephone Company, the R.C.M.P., the C.B.C, and various government laboratories have direct lines to the time lab; Observatory time is required to mark the official closing of tenders on government contracts; the radio time signal is recorded continuously by the Montreal Police Department on the tape recording of official dispatches.

The Mirror Transit Circle, a transit telescope employing features of modern technology such as photography and remote servo control, has been under development at the Dominion Observatory since 1954. It was intended to replace the Meridian Circle, which had outlived its usefulness in the determination of fundamental star positions. When it was brought into operation in 1968 it showed an unsuspected sensitivity to thermal effects. By the end of the year it became increasingly apparent that in its present form it was not a practical telescope. The additional research to make it functional will require specialized engineering and additional funds, both of which will have to await a more favourable economic climate. Meanwhile, data are still being accumulated so that a scientific report on the instrument may be submitted to the astronomical community.

On May 18, 1968, the Photographic Zenith Tube Observatory at Calgary was inaugurated with scientific representation from the U.S. Naval Observatory and the Royal Greenwich Observatory. The installation is successful; many plates have been secured and the measurement of them is proceding. The Ottawa PZT site was operated on 194 nights for a total of 3,436 transits, all of which have been measured and the results forwarded to the international coordinators for time and polar motion.

The Meteorite Observation and Recovery Project (MORP) established its headquarters at the University of Saskatchewan in Saskatoon in 1968. Three of the proposed 12 camera stations were constructed during the year and testing of the instruments in the first station was well advanced by the spring of 1969. Much of the instrumentation for the remaining stations has been ordered.

The Meanook-Newbrook observatories continued their active program of meteor spectroscopy. The analysis of these spectra is conducted in Ottawa, and three papers on meteor astronomy were published or submitted for publication during the year.

A peninsula on the Ottawa River at Shirley's Bay has been selected as the most suitable Canadian site for

98292—4½

a small solar observatory as the result of a site survey commenced in 1966, during which 100,000 fine-scale images of the sun were recorded. A contract for mechanical construction of the spar telescope was awarded to Canadian Westinghouse Ltd., Hamilton, Ontario. Installation of optics and electrical control systems will be performed in the solar laboratory at the Observatory. Plans for the development of the site, including the observatory building and the road, have been prepared for implementation during 1969-70.

DOMINION RADIO ASTROPHYSICAL OBSERVATORY

This Observatory studies stars and interstellar space through their radio emissions. It operates three major telescopes for the purpose—a conventional 84-foot "dish" tuned to 1,420 MHz, and two arrays operating at 22 MHz and 10 MHz respectively. It is in process of constructing a "super-synthesis" telescope, which will consist of two "dishes" mounted on railway lines in such a way that the distance between them can be varied; tenders have been called for the construction of the movable towers and the design of much of the equipment is well advanced.

The main research projects of the Observatory have been concerned with the low-frequency spectra of radio sources, the distribution of nearby galactic neutral hydrogen, the structure of ionized hydrogen regions, quasar angular diameters and pulsar intensity fluctuations.

Survey observations with the 22-MHz array have been completed for the whole sky visible from Penticton. Observations of 200 radio sources have been analyzed for spectral flux densities. These are being compared with similar 10-MHz measurements in a detailed study of spectra. A study of the low-frequency absorption due to ionized-hydrogen regions as observed at 22-MHz and 38-MHz yielded new measures of the kinetic electron temperatures in these regions. An analysis is being made of the association of radio sources having steep low-frequency spectra with clusters of galaxies.

Long-baseline-interferometer experiments were conducted between this Observatory and Prince Albert (Saskatchewan) and at Parkes (Australia) to determine the angular diameters of quasars. A long-baseline experiment utilizing the 22-MHz array and the 46-M paraboloid at the Algonquin Radio Observatory detected the bursting radiation from the planet Jupiter and indicates a source diameter less than 2 per cent of the diameter of the planet. A new hydrogen maser has been acquired for the long-baseline interferometer which permits more accurate time keeping.

Observations with the large 10-MHz array have continued through the winter nights of 1968-69. Reduction of the observations will yield a map of a large region of the northern sky. In addition to studies of individual galactic sources, the maps will be useful in determining the amount of diffuse ionized hydrogen in the galactic disc.

Data obtained from the neutral hydrogen line profiles observed at intermediate galactic latitudes with the 25.6 paraboloid and the 100-channel spectrometer were analyzed to study the distribution of random motions of gas in the solar vicinity.

Considerable effort has been devoted to the study of pulsars. Although our paraboloid is small compared with others which have been used for these weak sources, several investigations are in progress, including a study of intensity variation.

Reduction of data from the 1,420-MHz continuum survey has continued, and maps have been prepared of large regions of the sky.

Experiments on radio pulses from cosmic-ray air showers are continuing in collaboration with the University of Calgary. A new 22-MHz array, pointing magnetic north-south, is being built.

The Observatory has undertaken a feasibility and design study in cooperation with the University of Alberta for a large low-frequency array to be ready for operation by the next sunspot minimum. The instrument, which will operate at a frequency of about 13 MHz, will extend our current work at 10 and 22 MHz to much fainter sources. A site has tentatively been located in the valley of the Clearwater River in the Alberta foothills.

DOMINION ASTROPHYSICAL OBSERVATORY

This year marked the fiftieth anniversary of the opening of the Dominion Astrophysical Observatory as the major Canadian observatory for researches on the structure of the galaxy and physical studies of the stars and planets. To celebrate this occasion, the 127th meeting of the American Astronomical Society was held at Victoria and a special issue of the *Journal of the Royal Astronomical Society of Canada* was prepared with articles giving reminiscences of early days at the Observatory and describing present and past

research. A display showing photographs taken during construction of the Observatory was set up in the exhibit room for the 37,000 visitors.

New instrumentation for the telescopes continued to increase their efficiency and to make these telescopes comparable to any except the very largest in the world. New 6-inch secondary mirrors for the 48-inch telescope with special high-reflectance coatings replacing 16.5-inch mirrors involved a new concept which will probably be important in the design of future telescopes. In order to achieve maximum efficiency three sets of three small mirrors were made and installed in special turret mountings which could be rotated to reflect the wave-length region required; the change-over also involved a special prism-lens system to change the focal ratio of the telescope. The new system was installed in March, and excellent results are being obtained. Designs have also been completed to improve the 72-inch telescope at the focal plane, with new slits for the spectrograph and new viewing eye pieces to facilitate the observation of the faint stars that can now be studied, and to improve the field for objects shown to the visitors.

Important results that have been obtained from studies of stellar spectra during the past year include those noted below.

New observations of reddened, distant stars have been compared with unreddened, nearby stars with the use of the new low-resolution scanner in the blue region of the spectrum. Discontinuities in the curve relating energy with wavelength have been detected near the still unidentified interstellar line at 4,430A., and they may be produced by other lines; these results may assist in the identification of molecules in interstellar space.

A high-resolution scanner was used to observe the spectrum-line profiles of supergiant hot stars. Changes in the line shapes have been detected in nearly all of these stars, sometimes in minutes, sometimes in days or weeks. It has been concluded that these observations are related to matter being ejected from these atmospheres, which seems to be a phenomenon common to all bright, hot stars. Models for hot supergiant stellar atmospheres expanding at several thousand km/sec have been computed for comparison with observations recently obtained from rockets in the far ultraviolet region of the spectrum.

Mass motions have also been detected in two interesting binary systems. Major changes have been observed in profiles of the hydrogen lines in the spectrum of the close binary system *U Cephei,* which has a period of 2½ days. These changes may be related to emission and absorption by the gases streaming between the components and may also be related to asymmetries in the light curve. A somewhat similar study is being made of the long-period (20 years) system *VV Cephei.* Analysis of the hydrogen alpha line shows that the hot secondary star has a gaseous envelope surrounding it, which appears as emission; the radial velocity changes observed for this line suggest that the system is rather less massive than indicated by other investigators, each star having a mass about twenty-five times that of the sun. The observations also indicate that a stream of gas is flowing from the extensive atmosphere of the cool primary star towards the hot secondary star.

The less massive but somewhat similar system of *32 Cygni* underwent eclipse in September and a series of 60 high-dispersion spectra were obtained between June and November. Preliminary analysis of the spectra confirms the presence of gas clouds of ionized calcium in the extensive atmosphere of the primary star. Examination of the spectra obtained during total eclipse indicates that this star, while having a very extensive atmosphere, may not be as luminous as had previously been thought.

In many binary systems such as Algol, the light from one star reflected from the other affects the shape of the light curve obtained near eclipse. Extensive computations are being made to determine the geometric elements of such systems and the temperature distribution over the heated stars from precise observations of the light variations.

Theoretical computations of processes taking place in model stars with masses fifty times that of the sun (about the limit for stability) have been made as the star evolves from the main sequence through the helium-burning stage. Rather large changes in luminosity occur as the temperature of the atmosphere varies, and these changes are considered to be the result of incipient instability characteristic of the large mass.

A statistical study of massive binary systems showed that the most massive system with completely determined masses is *V382 Cygni* whose components are 32 and 37 times that of the sun. The most massive system is probably Plasketts' star for which the components are inferred to be 50 solar masses each.

A one-day conference of well-known astronomers interested in the structure of the galaxy was held at the

Observatory following the meetings of the American Astronomical Society. The group strongly recommended that spectroscopic observations of the hot B stars at the Dominion Astrophysical Observatory be extended to the fainter limits now possible with the more efficient spectrographs. These should be accompanied by photometric observations and should be related to data obtained from radio telescopes. The greatest effort should be spent on regions where ionized hydrogen is present and which are related to the spiral arms of the galaxy, and on stars at distances more than six thousand light years. These recommendations will be implemented as well as possible, and observations of stars in the ionized hydrogen regions have begun.

Although capital expenditures on the 156-inch telescope have been halted, a consortium of Western Universities (WESTAR: Western Telescope for Astronomical Research) has been formed to seek funds to continue the project and has been given the 156-inch mirror blank and the large grinding machine. The design and optical staff assembled for the project has been transferred to the Dominion Astrophysical Observatory, but has been given permission to work with the University group as required.

Astronomical observations on Mount Kobau have been continued. A 16-inch Bollér and Chivens reflecting telescope was installed in April 1968, and 3,500 observations of standard stars and stars in clusters and associations were made with a four-channel photometer with a data acquisition system. The data have been reduced with the aid of the University of Victoria computer and will soon be ready for publication. A Polaris Image Monitor built at the Dominion Observatory was installed in August. Results obtained during the winter gave a good correlation between image motion measured with the image monitor and visual observations that have been made since June, 1967. It seems probable that previous estimates of seeing conditions on Mount Kobau have underestimated rather than overestimated the quality of the site. From July 1967 to March 1969, 184 nights were completely clear, 188 partly clear and 268 cloudy, with 2,326 hours considered observable. Thus, Mount Kobau must be considered a good astronomical site with the number of observable hours almost equal in summer and winter.

SEISMOLOGY DIVISION

New seismic observatories equipped with short- and long-period instruments were commissioned at Inuvik, N.W.T., and Port Arthur, Ontario. The latter station is operated by contract with the Department of Geology, Lakehead University. These two new observatories complete the development of a modern network of 25 widespread, fully instrumented seismic observatories throughout Canada, and represent the completion of the first stage of a program approved by the government nearly a decade ago. This network is complemented by four second-order local stations for more detailed study of Canadian seismicity. The seismic observatory program can now move into its second stage of continuous instrumental updating and calibration, with extension and modernization of data-handling and distribution services to keep abreast of the growing demands for seismic data and records.

The strong motion network in western Canada continued operation for earthquake engineering purposes: 14 stations are fully equipped and 57 locations have been instrumented with seismoscopes for detailed ground-acceleration studies under different foundation conditions.

In consultation with the National Committee for Earthquake Engineering, the basic decisions have been taken with respect to the revised earthquake zoning map for Canada for the National Building Code Revision of 1970, and the map has been produced. The technique and rationale used have been described in several papers published in the learned journals.

The largest earthquake in Canada during the year was magnitude 5.1 approximately 200 miles north and slightly west of Victoria. The usual number of minor shocks were reported in both eastern and western Canada. Micro-earthquake field studies were made in a volcanic region of northern British Columbia and in an area north and east of Quebec City, where differential vertical crustal movements have been defined, near to the La Malbaie centre of seismic activity in eastern Canada. Data reduction is continuing, but it is clear that few events can be associated with the volcanic area, although 8,000 micro-earthquakes have been detected from sources along the British Columbia-Alaska border. In eastern Canada fewer micro-earthquakes were observed than expected. These reconnaissance-type experiments have established clearly the technical requirements for experiments of this kind, and demonstrated the feasibility limits in Canada.

Quantitative earthquake-risk estimates were given on demand to engineering and insurance companies, and international exchange of seismic data continued on schedule and at a high level. An increase towards

the end of the year in public concern regarding earthquake risk should be noted, following the California patterns of prophecy, and considerable effort has been made to educate the general public in this respect.

Considerable progress was made in research into the problems of the detection and identification of underground nuclear explosions. Papers have been published on the positive identification levels achieved with the Canadian installations using a technique involving the relative excitation of long-period surface waves by an underground explosion and by an earthquake in the same general area. A continuing telemetering experiment was carried out at the Yellowknife array in order to evaluate a radio-linked system which will soon be necessary to replace the extensive, very old cabling on the array. Another long-period high-gain seismic field installation was made in Yellowknife. The data from these long-period installations at Yellowknife will allow scientific tests to be made of the applicability of the criterion for distinguishing earthquakes from underground nuclear explosions. These tests will make possible firm predictions about the lower limit of applicability, possibly in case that a major long-period array be established. The Division was represented at the international meetings held in Sweden in 1968 under the auspices of the Swedish International Institute for Peace and Conflict Research which produced a major report for governments, on "Seismic Methods for Monitoring Underground Explosions."

Other seismologists have continued research into the mechanism of earthquakes, surface-wave dispersion in Canada, the structure of the earth's core and into the character of seismic body-wave arrivals including synthetic seismograms.

The crustal group completed a radical re-interpretation of the data from the 1965 Hudson Bay experiment, and an interpretation of the crustal characteristics under the Yellowknife array. The reduction and interpretation of data from experiments in 1966 and 1967 was advanced. The group also carried out a large-scale crustal project in north-central Quebec along and on each side of the front separating the Superior and Grenville Precambrian Provinces. Three parallel reversed-refraction lines more than 400 km long were shot, and the University of Western Ontario, Dalhousie University, the Nova Scotia Research Foundation and the Geological Survey of Canada participated in a very successful project.

The heat-flow group drilled three holes in northern Ontario across a major geophysical feature, and continued measurements in mines and drill holes throughout Canada. Measurements were made on two lakes on Ellesmere Island, and from the ice in the western Arctic. Conductivity equipment and techniques in the laboratory were much improved, and further progress made in the preparation and interpretation of observations for publication.

During the year, a re-examination of the scientific programs under way was completed and background discipline papers in seismology and in heat flow prepared for the Science Secretariat, after considerable circulation and discussion within the geophysical community in government, universities and industry.

GRAVITY DIVISION

The first phase of the adjustment of the Canadian Gravity Net has now been completed with the adjustment of all excentres at key stations of the net. The second phase, that of plotting and editing some 12,000 ties between control stations, has been under way for several months. The final adjustment should be completed in late 1969.

The Canadian contribution to the First Order World Gravity Net (FOWGN) has been edited and adjusted and is now ready for inclusion with the available data from other participating countries. The joint U.S.-Canadian project for adjustment of the FOWGN has been postponed pending development of new editing and adjustment programs incorporating several new features.

At the request of the oil-exploration industry a gravity-calibration line extending from Cardston to Edmonton, Alberta, was established in the spring of 1968 using four LaCoste and Romberg land gravimeters. The 25 calibration stations cover a 500-mgal range in gravity.

Measurements on the North American Calibration Line with the Canadian Pendulum Apparatus have been successfully completed. The observations were made at Ottawa, Fairbanks, Edmonton, Denver and Mexico City and return in reverse order.

A system for the storage and retrieval of gravity data is now operational at the Gravity Division. A data file consisting of approximately 120,000 discrete gravity observations has been stored on magnetic disc, and can be extracted with the use of programs written for an IBM 360/65 computing system. With this system, the Gravity Division is now able to fill requests for data from both external institutions and from within the Division.

The new *Gravity Map of Canada* (scale of one inch to 40 miles) was published in September 1968 and is now available from the Map Distribution Office of the Surveys and Mapping Branch, Ottawa. All gravity data collected up to January 1, 1967, have been incorporated in the map.

A full program of field measurements was completed during the year. The investigations included the following areas:

(i) Regional gravity mapping of the Cordillera was completed between longitudes 114 and 121 and latitudes 49 and 51 and in the vicinity of Williams Lake. Stations observed numbered 565 at grid survey points supplied by the Surveys and Mapping Branch and the Mapping and Charting Establishment, Department of National Defence.

(ii) During the September 1968 cruise of the CSS *Parizeau,* of the hydrographic fleet, geophysical measurements along the Red Deer-Revelstoke-Victoria Cordilleran section were extended 300 nautical miles offshore with surface-gravity, magnetic and bathymetric measurements along lines ten nautical miles apart between Cape Flattery and Cobb Seamount.

Similar measurements were made along lines three nautical miles apart in the Strait of Juan de Fuca. In the Strait of Georgia and off the west coast of Vancouver Island between Cape Flattery and Ucluelet continuous seismic profiles were made on lines two nautical miles apart in addition to the gravity, magnetic and bathymetric measurements. The lines west of Vancouver Island were 70 nautical miles long extending from the coast to the foot of the continental slope.

(iii) More than 1,000 gravity stations were observed between Schefferville and the Labrador Coast.

(iv) Regional gravity coverage has been completed in the Kenora, Red Lake, and Sandy Lake areas of Ontario and along the shores of Lake Winnipeg, with the addition of 1,125 gravity stations during 1968.

(v) Regional gravity measurements in Lake Ontario and Lake Erie in 1968 totalled 272. The survey will be completed in 1969.

(vi) In 1968 about 950 gravity stations were established over the sea ice covering an area of about 60,000 square miles of the Arctic Ocean and 25,000 square miles of M'Clure Strait. In Baumann Fiord, Ellesmere Island, 163 gravity stations were observed over the sea ice.

(vii) A bench-mark survey was carried out in Nova Scotia, Prince Edward Island and New Brunswick. Some 800 stations were observed using LaCoste and Romberg meters.

(viii) Some 680 stations were established along roads in southern Manitoba. An elevation meter was used in this survey and the elevations obtained have an accuracy of better than ± 2 ft.

(ix) Some 650 stations spaced at intervals of one to three km were observed over the Morin Intrusion, Quebec, using road and helicopter transportation. A detailed study of this intrusion is in progress in co-operation with the Geological Survey of Canada.

Interpretational studies of the regional gravity anomalies in the following areas have been completed or are nearing completion: Timmins-Senneterre area, Burleigh area, Bear and Slave geological provinces, Coppermine, northern Saskatchewan, Gulf of St. Lawrence, Kinmount Geophysical Test Range, Ontario, Hudson Bay, Queen Elizabeth Islands and Arctic Continental Margins.

Recent studies of the isostatic response of the crust in Canada to loading show that the country is isostatically over-compensated due to incomplete recovery of the lithosphere from the displacement caused by the Pleistocene ice loads. The amplitudes of the free-air anomalies suggest that a substantial amount of uplift has yet to occur.

The recognition of the Charlevoix (La Malbaie), Quebec, crater and the Mistastin Lake, Labrador, crater raises the number of known ancient meteorite craters in Canada to sixteen. Gravity data are available for fourteen of these craters, notably for the Manicouagan and Sudbury structures, and are currently being interpreted.

A set of V/M horizontal pendulums has been operating continously during the past year at a mine site north of Ottawa and a second set of horizontal pendulums will be installed in the mine by the end of the year. The LaCoste and Romberg earth-tide gravity meter has been operated intermittently for several months in Ottawa and will be eventually installed at the mine site.

GEOMAGNETISM DIVISION

The Geomagnetic Division is responsible for producing charts showing the direction and intensity of the geomagnetic field over Canada and the neighbouring oceans, and for the magnetic information which appears on aeronautical and marine charts. The magnetic charts are based on measurements made in an

aircraft by an instrument designed and operated by scientists of the Division. In early 1969, British Columbia and the northeastern corner of the Pacific Ocean were surveyed in a pattern of parallel flight lines, 20 miles apart over the land and continental shelf, and 40 miles apart over the deep ocean. The total distance travelled in a chartered DC-6 aircraft was over 67,000 miles.

Magnetic charts must be revised every five years because the geomagnetic field is constantly changing. To bring the data from earlier airborne surveys up to date, measurements are made on the ground every few years at each of 100 carefully marked repeat stations, uniformly distributed over the country. During 1968, 25 such stations were occupied in Quebec, Ontario, Manitoba and the Arctic Islands.

Variations in the direction and intensity of the geomagnetic field were recorded continuously at magnetic observations in the following locations: Alert, Mould Bay, and Baker Lake, all in the Northwest Territories; Meanook, Alberta; Victoria, British Columbia; and Agincourt, near Toronto. Two new magnetic observatories began regular operation in June, 1968, at St. John's, Newfoundland, and at Ottawa. Agincourt magnetic observatory, which had recorded continuously at that location since 1898, was closed on April 1, 1969, because of artificial disturbance due to industrial activity and highway construction.

The move to the new Geomagnetic Laboratory at Blackburn, 10 miles east of the Dominion Observatory, was completed in May 1968. The facilities include a main building, housing offices and laboratories for instrument development, and 15 small non-magnetic buildings, separated at least 200 feet from each other, on a tree-covered site of 200 acres. The small buildings provide for the magnetic observatory and improved facilities for testing new instruments, for paleomagnetic research, and the training of staff.

It is hoped that the Blackburn site will be unaffected by artificial magnetic disturbances for many years. A favourable sign is that the federal Department of Forestry has acquired some 1,000 acres of land surrounding the site, to be used in tree-growing experiments to last a century or more.

Analysis and interpretation were completed of the variations of the magnetic and earth-current fields recorded at several locations in Ellesmere Island in 1967. A zone of unusual electromagnetic induction has been traced across the island, from Alert in the northeast to Greely Fiord in the west. The only possible explanation appears to be a long massive body of very high electrical conductivity, lying near the base of the crust. Further field work was planned for 1969 to trace the extension of the anomalous zone, to both east and west.

Similar observations obtained in southern British Columbia in 1967 confirm that a highly conductive layer exists near a depth of 30 km to the west of the Rocky Mountain Trench, while there is no evidence for such a layer to the east. The structures of the deep crust and upper mantle under the eastern and western Cordillera are evidently quite different.

Research in paleomagnetism in 1968 produced three results of general interest: the recognition of diagenetic magnetization processes in red beds and the development of techniques for their analysis; a study of the intensity of magnetization of basalts, which contradicts the proposed correlation between oxidation state and polarity; and strong evidence for the occurrence of polar wandering, based on the inconsistency between the motions deduced paleomagnetically for the ocean floors and the continents. Good progress was made in the instrumentation of the new paleomagnetic laboratories.

Polar Continental Shelf Project

The Polar Continental Shelf Project is a continuing investigation of the continental shelf fringing the Arctic coast of Canada, together with adjacent parts of the Arctic Ocean basin, the islands of the Canadian Arctic Archipelago and the waters between them, and other areas that may be of special interest. The Project serves in part to facilitate the Arctic researches and surveys of other units of the Department of Energy, Mines and Resources; in part it carries out, with its own personnel, work that is unique within the Department; it also serves as the vehicle through which the investigations of other government agencies are carried

out in the Arctic Archipelago and the Arctic Ocean; and it provides facilities and support for approved university researches in the area.

The Project's field-survey and research activities will eventually cover all the Canadian sector of the Arctic continental shelf of North America, those parts of the Arctic Ocean that are of interest to Canada and which can be reached with available logistics, and those parts of the archipelago and the mainland not studied by other agencies of the department. From 1959 to 1968 work has been concentrated in the region between Meighen Island and Banks Island, extending about 250 kilometres out to sea and the same distance back into the islands. Individual surveys and researches have been carried out throughout the Queen Elizabeth Islands and extended to the Mackenzie River Delta and Beaufort Sea in the southwest, and northern Greenland in the northeast.

Field activities in 1968 were carried out from late February to early November, and were coordinated mainly from Mould Bay, on Prince Patrick Island, and from Resolute, on Cornwallis Island. Approximately 100 persons were engaged in investigating the region of the continental shelf west of M'Clure Strait, and the adjacent islands and straits. Other work ranged over the Arctic Ocean from the Beaufort Sea to the Lincoln Sea, in the interior of many of the Queen Elizabeth Islands, and in the Mackenzie River Delta. Supporting activities such as transport and construction engaged for brief periods about 40 persons in addition to those employed directly on the field investigations and surveys.

In addition to the Department of Energy, Mines and Resources, nine other agencies were involved in or received assistance from the operations of the Polar Continental Shelf Project. Among them were five universities (one American), and Canadian government departments.

In 1969 (whose field season began toward the end of the fiscal year under review) the main emphasis of regional surveys was to be shifted from the western archipelago to the Beaufort Sea - Mackenzie Delta region.

The following is a summary of the work done in 1968, by major scientific field.

Aeromagnetic Survey—Measurements of the total residual magnetic field were made from a height of 330 metres over the continental shelf and continental slope west of Prince Patrick Island and M'Clure Strait, and over western M'Clure Strait. Approximately 39,000 line-kilometres were flown.

Geodetic and Topographic Surveys—Difficulties in interpreting some of the geophysical measurements made in 1967 led to a careful examination of Decca Lambda positions, in which the latitude and longitude of 28 stations extending seaward to 300 kilometres were determined accurately by repeated solar observations. This is believed to be the first large-scale test of the accuracy of low-frequency electronic positioning over an ice-covered ocean surface.

Geology, Marine—Samples of bottom sediments were obtained offshore from the western entrance to M'Clure Strait and adjacent parts of the continental shelf. These samples and collections are being studied in the laboratory for evidence of their age, source, conditions of transport and sedimentation, indications of change in sea level, and variations in climate in the geologically recent past.

Geology, Terrestrial—Logistic support was provided to parties from the Geological Survey (q.v.).

Geomagnetism—The Project provided the field support for repeat measurements of the magnetic field by members of the Observatories Branch at permanent magnetic stations at Cambridge Bay, Grise Fiord, Holman Island, Inuvik, Isachsen, and Winter Harbour.

Glaciology and Glacier Physics—A detailed study was started of the Meighen Island icecap to determine the energy relationships of the icecap, its relation to local climate, and its behaviour in the recent geological past. Meighen Island icecap has been studied annually since 1959. The relation between temperature and internal strain in the icecap was studied by means of a borehole that penetrates its entire depth. Measurements continued of the mass balance of the icecaps on Melville Island, which are the thinnest and driest of North American arctic glaciers.

Gravity—The regional gravity survey was continued over the continental shelf and slope offshore from Prince Patrick Island and M'Clure Strait, an area of 135,000 square kilometres. In addition, 75 gravity stations were completed in the Baumann Fiord area of southwestern Ellesmere Island.

Heat Flow—Measurements were made of the flow of geothermal heat from the floor of the ocean near the west end of M'Clure Strait. Five shallow oceanic and one borehole station were completed in this study.

Hydrographic Surveys—A detailed hydrographic survey of a small part of Great Slave Lake was undertaken at the request of the Department of Indian

Affairs and Northern Development to aid engineering studies for a proposed water-supply system. Survey personnel made 450 depth measurements through the ice. A regional bathymetric survey was carried out west of Prince Patrick Island and M'Clure Strait, and over western M'Clure Strait, by spot sounding through the ice. A systematic hydrographic survey was made of Baumann Fiord, southwestern Ellesmere Island, by spot soundings through ice.

Oceanography—Field support and equipment were provided for a study of the oceanographic conditions in the spring in Kane Basin, between Ellesmere Island and Greenland. Owing to a combination of natural and transportation difficulties, no useful scientific results were obtained; but the experience should help in planning future surveys.

Sea-Ice Studies—Systematic patrols were made of all major waters of the Queen Elizabeth Islands and of the adjacent Arctic Ocean and Parry Channel throughout the period of significant sea-ice activity. Information was collected on the nature, break-up, amount, distribution, disposal and formation of the sea ice and of certain tabular icebergs or "ice islands." These surveys, which have been carried on for a number of years, may lead to a better understanding of the causes and controls of sea-ice development and movement and, in turn, to better forecasts of ice conditions.

Miscellaneous—Support was provided for a number of studies, by other agencies, such as: a survey of insect life of central and northwestern Banks Island; an ethological study of the fauna of Bathurst Island, with particular attention to the relationship between wolves and muskox, the competition between various grazing species, the courtship and territorial behaviour of ptarmigan, and the breeding cycles of shore birds; a survey of the distribution of vegetation on Fitzwilliam Owen Island and a study of lichens, mosses and peat on Prince Patrick Island and Meighen Island; a study of the marine botany along the shores of several islands; and others.

MINERAL DEVELOPMENT GROUP

Mineral Resources Branch

The Mineral Resources Branch was formed from the previous Mineral Resources Division on October 1, 1968. It is organized into three Divisions—Research and Planning Division, Commodities Division, and Taxation and Legislation Division—with technical and administrative support groups. Most Branch projects are carried out on an interdivisional basis to ensure that each receives the professional contribution of various disciplines essential to its successful completion.

The Mineral Resources Branch conducts research on mineral policy and makes recommendations thereon. It conducts fundamental and applied research and field investigations into the economic and technical aspects of mining and mineral trade in a regional, national or international context. The work covers all aspects of the mineral industry from resources through exploration, development, production, processing, transportation, and consumption, and results in various types of reports.

ADVISORY AND CONSULTING SERVICES

The Mineral Resources Branch provides mineral-industry information to senior officers of the department and other government departments. These studies serve as a basis for policy decisions of the federal government and agencies and, upon request, provincial governments and agencies.

Regional Studies in Canada

A detailed report, *Mineral Resource Development, Province of Nova Scotia,* was prepared during the year at the request of the Atlantic Development Board. It was similar to those completed in 1966 on the province of Newfoundland and Labrador and in 1967 on the province of New Brunswick. The Nova Scotia report reviews and discusses the province's mineral industry in six chapters and outlines the direction that assistance by government, federal and provincial, might take to accelerate mineral-industry growth. At the Board's request, a consolidated report summarizing the findings and proposals of the three provincial studies was completed by the end of the fiscal year.

A report, *Mineral Industry Development in Manitoba to 1980,* was prepared at the request of Manitoba's Targets for Economic Development Commission (TEDCO). The provincial commission was formed to assess the outlook for Manitoba's economy and to make recommendations for the over-all economic development of the province. The Mineral Resources Branch provided an analysis of the mineral industry with forecasts of output, employment and investment; pointed out development opportunities; and examined such factors as government activities and potential infrastructure investments.

A preliminary analysis by the Branch on the outlook and problems of mineral development in northern Saskatchewan to 1980 was also completed. It was undertaken at the request of the Department of Forestry and Rural Development (FRED) as part of a total resource-and-economic appraisal that may result in a federal-provincial agreement for a comprehensive regional development program. A study was initiated late in the year on British Columbia's mineral industry at the request of British Columbia's Department of Mines and Petroleum Resources.

Northern Development

The Branch continued to give advice on mineral matters to the Department of Indian Affairs and Northern Development and to participate in interdepartmental activities concerned with northern economic development. Previous special studies concerned with regional economic mineral appraisals, mineral development opportunities, and possible infrastructure investment requirements were reappraised as circumstances changed. As representatives on various interdepartmental committees, Branch officers prepared special studies such as those on Canadian access requirements to tidewater on the Pacific Ocean, the economic mineral potential of the Yukon Territory and the District of Mackenzie as the basis for the development of a 10-year, $100-million northern-roads program, various mineral-property evaluations for appraisal of access-road programs, and the continuance of field investiga-

tions by mineral economists to advise on developments and outlook. Planning and research were initiated late in the year for a major comprehensive study on economic and transportation (rail and road) requirements to assist in broad economic development of northern British Columbia and Yukon Territory. The Department's responsibility for national energy development and economic policies required particular attention because of the discoveries of large petroleum resources in the far north of Alaska near Yukon Territory and the exploration and development undertaken on Canada's Arctic slopes and islands, with attendant transportation and marketing problems.

Science Policy

The Branch prepared several briefs on science policy as it relates to the mineral industry and the various disciplines and training associated with it. The topic has become of national as well as international concern as governments attempt to improve the decision-making process for allocation of resources to scientific research and the direction of economic objectives.

Interdepartmental Commodity Committees

The Branch is represented on a large number of interdepartmental commodity committees studying mineral-commodity problems of an industry, a region, or the nation. The committees usually meet on an *ad hoc* basis but may be regular and continuing. Of the latter type was the one formed to assist in the allocation of nickel to Canadian consumers during the nickel shortage. Consumers were limited to the amount of their 1966 purchases from domestic suppliers, a system that threatened to cause hardship for certain consumers. The committee therefore reviewed requests for increased amounts and made recommendations for justified needs to be satisfied from domestic production. Problems related to several other commodities (copper, iron ore, potash, uranium, coal, lead and zinc, aluminum, petroleum) were studied by interdepartmental committees on an *ad hoc* basis, those related to uranium controls, regulations, and stockpiling being of particular moment.

Taxation

Analyses and recommendations were provided to the Department of National Revenue with respect to tax benefits under the Income Tax Act which are applicable to the mineral industry. Reports were prepared on 24 applications for three-year tax exemptions, two applications for the special oil-pipeline depreciation allowance, and two applications for research grants under the Industrial Research and Development Incentive Act.

Advice was provided to the Department of Indian Affairs and Northern Development in the drafting of a proposed revised Yukon Minerals Act. These advisory services included both taxation and legislative matters. Study of the report of the Royal Commission on Taxation and its implications for the Canadian mineral industries was continued. Preliminary investigations were started on the degree of foreign ownership and control of the Canadian mining and mineral-processing industries, together with an assessment of benefits to Canada, and the behaviour of foreign companies as corporate citizens of Canada.

General Advisory and Consultative

As a result of the continuing in-depth study and analysis of all mineral commodities and subjects by its staff, the Branch provides information and advice on a broad scale to mineral-industry representatives and the general public through office interviews, correspondence, telephone and publications.

INTERNATIONAL ACTIVITIES

The Branch continued to participate in intergovernmental organizations and international associations that embrace mineral-industry matters. Canadian government representatives are provided with documents and studies; in some instances, officers of the Mineral Resources Branch attend the respective meetings.

An officer of the Branch represented the Department on the Canadian delegation to the International Lead and Zinc Study Group and attended the 12th Session in Geneva, in November 1968. The Branch contributed to the technical-economic studies and to the statistical services of the Study Group. It continued to review the trends in the world tin industry and participated in matters of concern to the Third International Tin Agreement to which Canada is a consumer signatory. Statistical data on Canada were also supplied to OECD groups including the Special Committee for Non-Ferrous Metals, the Nuclear Energy Agency, and the Special Committee for Iron and Steel. Data were also supplied to United Nations Organizations such as the Tungsten Committee, and the Committee

for Industrial Development. A paper was prepared for the latter by Branch officers, entitled "Steel Plant Location in Developing Economics, a Canadian Viewpoint"; it was a contribution to the Second Interregional Iron and Steel Symposium held in Moscow. An officer of the Branch attended the 36th session of the United Nations Economic Commission for Europe's Steel Committee and participated in a study tour of Poland's steel industry sponsored by the committee.

Since Canada became a member of the OECD, the Branch has had the prime responsibility of providing extensive statistical data and various studies on Canada's iron-ore and iron-and-steel industries to the OECD Special Committee for Iron and Steel. In mid-1968, this responsibility was passed to the Department of Industry, with continued Branch participation in the work of the Special Committee, particularly in the field of mineral raw materials.

A study was prepared on Canada's uranium production, reserves, and short-term demand, for the OECD Nuclear Energy Agency as part of its world study of the subject.

PUBLICATIONS

The Branch published reports in the *Mineral Information Bulletin* series on iron ore and primary iron and steel, along with its regular preliminary annual review of the Canadian mineral industry. Also completed were seven *Operators Lists*, the 1966 *Canadian Minerals Yearbook*, the eighteenth edition of the popular Map 900A *Principal Mineral Areas of Canada*, and oil and gas pipeline maps. Work proceeded on reports on beryllium, cadmium, zinc, petroleum and natural gas, chemical fertilizers, and zirconium and hafnium.

The Branch has a continuing program of educational mineral filmstrips designed for use in high schools. The photographic library and mineral-resource records centre continued to be enlarged. The Branch contributed several sections on minerals to the *Canada Yearbook*, and prepared papers for presentation at international meetings and for publication in technical journals.

Work was completed in 1967 on a comprehensive report on nickel which will be available for distribution early in 1969. The report will include chapters on history, ore deposits and resources; exploration; mining; processing; commercial forms, properties and uses; Canadian primary industry history, corporate structure, operations, production potential, position in the economy; foreign primary industry; and world supply and demand.

FOREIGN AID

The Branch, on behalf of the Canadian International Development Agency, formerly the External Aid Office, arranged 37 technical training programs for foreign trainees and provided consultation on 12 additional applications. These programs were sponsored through the various regional plans of the agency and through the United Nations. Training takes place in some cases in the Department of Energy, Mines and Resources, as well as in private industry, provincial government departments, and university graduate schools. Fourteen applicants completed their training during the fiscal year ending March 31, 1969. At the end of the period, 21 training programs were active and 10 planned programs were awaiting arrival of candidates. In addition to these post-graduate training programs, a number of foreign undergraduates attending Canadian universities were assisted in finding summer employment and surveying instruction. The Branch also participated in the recruitment of technical advisers for overseas missions to advise certain developing countries on mineral-development policies, planning and projects.

Arrangements were also made to have foreign mineral specialists and government representatives visit, upon request, certain Canadian mining and mineral-processing companies to become familiar with the Canadian mineral industry. The foreign-aid coordinator of the Branch conducted a mineral-resource investigation in Morocco at the request of the Canadian International Development Agency (CIDA) to determine the means by which a mineral-industry-development program there might be directed.

MINERAL OCCURRENCE INDEX

The Branch maintains an index of Canadian mineral occurrences for the use of those interested in mining and mineral exploration in Canada. The index contains comprehensive summaries of location, geology, history of ownership, development, and results of development work, supplemented by map and literature references, on more than 11,000 mineral occurrences. These summaries, each on individual cards, are arranged in conformity with areas of the National Topographic System. Provision has been made for revi-

sions to the index. Along with revisions, the descriptions of over one hundred mineral occurrences were being added each month to the Mineral Occurrence Index at the end of 1968.

Agreements for the exchange of mineral-occurrence information were in effect with the Nova Scotia Department of Mines, the Ontario Department of Mines, and the British Columbia Department of Mines and Petroleum Resources. The indexing of Canadian mineral occurrences has been intermittent in the Department since before 1900 until 1959. Since then it has been continuous.

ROADS TO RESOURCES

The Roads to Resources program is a national effort designed to provide access to areas potentially rich in natural resources. The administration of the agreements, which provide $7.5 million as the federal share for each province, was transferred to the Branch in October 1966.

Federal payments to March 31, 1969, were approximately $74,650,000. The balance, some $350,000, has been committed for the completion of the program in 1969-70.

Province	*Number of roads*	*Mileage completed*	*Federal contributions to March 31, 1969*	*Termination date*	*Status*
Newfoundland	10	270.78	$7,153,577	March 31/70	—
Prince Edward Island	30	425.9	7,500,000	March 31/68	Completed
Nova Scotia	16	356.3	7,488,792	March 31/66	Completed
New Brunswick	20	271.1	7,500,000	March 31/69	Completed
Quebec	3	179.0	7,500,000	March 31/67	Completed
Ontario	8	281.6	7,500,000	March 31/69	Completed
Manitoba	5	338.8	7,500,000	March 31/67	Completed
Saskatchewan	6	455.6	7,500,000	March 31/68	Completed
Alberta	2	415.9	7,500,000	March 31/67	Completed
British Columbia	1	213.0	7,500,000	March 31/68	Completed

THE EMERGENCY GOLD MINING ASSISTANCE ACT

The Act is administered in the Mineral Resources Branch under the direction of the Assistant Deputy Minister (Mineral Development).

Inspection engineers from the Branch conduct regular inspections of gold mines receiving assistance. They report on all aspects of the mining operations that affect the assistance payable under the Act. In particular, they determine the proper classification of exploration and development expenditures, review the allowance of costs which are in question and report upon mining and milling practices and the ore reserves of the mines.

The Audit Services Branch, Department of Supply and Services, examines interim applications for advance payments of assistance and carries out the final audit of the accounting records of each applicant.

The Act was passed originally in 1948 to assist gold mines in overcoming economic difficulties caused by rising costs of production and a fixed price for gold. The legislation had the objective of extending the operating life of the gold mines and thereby allowing their dependent communities to adjust gradually to diminishing economic support.

An amendment to the Act in December, 1967, extended its operation for a period of three years to December 31, 1970.

The amount of assistance payable to an operator depends on the amount by which the average cost of production per ounce exceeds $26.50. A gold mine that has an average cost of production less than $26.50 an ounce is not eligible for assistance. When calculated on the basis of all eligible ounces produced, the maximum assistance payable amounts to $10.27 per ounce.

There were 33 lode gold mines in receipt of assistance in 1968. Assistance payments are made to the lode gold mines on a quarterly basis.

The amounts paid to gold-mine operators to March 31, 1969, for the years 1948 to 1968 inclusive totalled $261,293,250.09 on a production of 57,155,704.611 fine ounces of gold produced and sold in accordance with the requirements of the Act. The amount paid out annually has remained fairly steady at around $11 million.

Explosives Division

The high rate of fatal accidents in the explosives industry during the early 1900's emphasized the need for control over explosives, and the first Explosives Act was drafted and introduced into the House of Commons in 1911. The early recognition of the hazard and the willingness of the industry to accept controls have combined to make the explosives industry one of the safest in Canada.

The Explosives Act is primarily an act of public safety to control the manufacture, authorization, storage, sale, importation and transportation of explosives by road. Control is exercised by a system of licences and permits supported by inspections and all licences are issued from the Explosives Division office in Ottawa.

The work, associated with the issuing of licences, has increased noticeably during the past few years and as a result, the Bureau of Management Consulting Services studied the operations of the Explosives Division and made a number of recommendations which should considerably streamline the licensing operations.

One of the prime responsibilities of the Explosives Division is concerned with the manufacture of explosives. The number of factories licensed under the Explosives Act increased from 42 in 1967 to 46 in 1968. This increase was largely due to the increased interest in manufacturing explosives at the place of use and a number of factories for the manufacture of slurry-type explosives supported by bulk mix trucks and bulk pump trucks have been located on several large open-pit mines. We expect this trend to continue.

During the year, a major amendment to the regulations was introduced concerning mainly the classification and the transportation of explosives. This involved a complete revision of Part VI, the regulations governing the transportation of explosives, and a change in the classification of the "blasting-agent" type of explosives to permit the transportation of 40,000-pound loads of explosives of Class 2.

Members of the Division investigated several accidents during 1968 and although there were a number of quite serious accidents in the manufacture, and transportation of explosives none resulted in any fatalities.

One particularly serious accident occurred during the manufacture of lead styphnate at the Canadian Arsenals Limited Cherrier Plant. Here an operator suffered severe injuries to his face, shoulder and arm. Recommendations following this accident resulted in a greatly improved operation.

Another accident demolished a propellant-mixing building when 10 pounds of dry nitrocotton detonated at the Canadian Industries Limited Valleyfield Plant. Fortunately the hazard was recognized and the operation was designed as a remote-control process and as a result no one was injured.

There were nine accidents in the transportation of explosives, but only one resulted in fire or explosion of the cargo. In this case, a truck carrying display fireworks to Montreal was involved in a highway traffic accident. A gasoline fire started and one of the saddle tanks exploded. This was followed immediately by an explosion of the fireworks in the truck. Fortunately, the driver and his assistant were able to get out of the vehicle and clear the area of persons before the explosion, and no one was injured.

For transportation of explosives in vehicles operating under a transportation permit all gas tanks must be equipped with fusible-alloy safety plugs to prevent an explosion of the gas tank. This appears to be sound practice for any vehicle transporting explosives in any quantity.

Members of the Explosives Division actively promote safety programs and regularly meet with members of the industry, federal and provincial government agencies and other groups involved with the handling of explosives. The Division also has available for distribution safety literature on the storage, handling and transportation of explosives.

A separate more detailed report of the activities of the Explosives Division is published regularly.

WATER GROUP

Marine Sciences Branch

The Marine Sciences Branch produces and distributes all Canadian navigational charts and tidal information. Its surveys of the geological and geophysical characteristics of the ocean floor provide basic information for mineral exploration. Its studies of oceanographic phenomena are designed to support fisheries, transportation, coastal engineering and defence.

The Branch is organized along regional lines, with offices in Dartmouth, N.S., Victoria, B.C., and Ottawa. The headquarters is situated in the Departmental complex in Ottawa.

In 1968 the Branch fleet had twelve ships which steamed a total of 188,990 nautical miles on operations. Three chartered vessels were also employed during the year. In addition to the ships, 180 sounding launches, workboats and small craft were in service. The expansion of the fleet continued with the commissioning of CSS *Limnos* to support research on the Great Lakes. The design, contract drawings and specifications have been completed for a second Great Lakes research vessel similar to CSS *Limnos* in the continuing design program for research vehicles.

The past year has seen considerable changes in the physical appearance of the Bedford Institute at Dartmouth. An extension to the existing jetty facilities, creating a small-boat marina, was completed in late summer and a 50-per-cent expansion of the laboratory wing of the main building was completed in February 1969. The addition of two more floors to the office wing was started in late winter and was scheduled for completion in the late summer of 1969.

HYDROGRAPHY

In 1968, chart-distribution totals reached another all-time high, with 309,200 charts being distributed. The Pacific Region showed a 12-per-cent increase, largely due to the interest shown by pleasure boaters in the new Gulf Islands chart series.

During the year the Canadian Hydrographic Service published 173 navigation charts. This total was made up of 23 new charts, 8 latticed editions of new charts, 43 new editions, 75 corrected reprints, 10 reprints and 14 special charts. In addition, 50 *Catalogue Index* pages, 7 *Information Bulletins* and 4 *Pilot Index* maps were published. New editions of Volume 2 of the *Pilot of Arctic Canada,* Volume 2 of the *Great Lakes Pilot*, the *Newfoundland Pilot*, the *Great Slave Lake and Mackenzie River Pilot* and the *Gulf of St. Lawrence Pilot* were published. Six supplements to existing Pilot editions were also issued.

The highlights among the charts published were:

(a) Two new coastal and two new offshore fisheries charts of the series of coastal and fisheries charts on the Atlantic Coast.

(b) Six new small-craft charts in Ontario.

(c) Reconstructed editions of three popular charts in the Strait of Georgia.

(d) The Canadian Power Squadron's new training chart.

(e) Four charts showing Canada's territorial waters and fishing zone limits for part of the Atlantic Coast.

(f) Four special charts for the Department of National Defence.

The revisory survey program continued on the East Coast and started in the Central Region. To date, nine new editions and ten chart-amendment patches have been issued and over thirty new editions are being processed as a result of information gathered over the last two seasons. Thirty-five charts checked have not required new editions because only minor changes were found.

The Chart Production Section installed a second Monotype Photosetter and is now completely equipped for photosetting all typeset material used in its cartographic work.

Pacific Region

Primary region activities continued to be hydrographic, although significant ship and personnel support was supplied for various oceanographic work conducted by other government and university agencies. In addition, the major investigation of water-circulation

patterns within the southern part of the Strait of Georgia, which has both hydrographic and oceanographic significance, was continued.

Hydrographic surveys carried out by field parties aboard the *Wm. J. Stewart, Marabell* and *Richardson* ranged throughout the Pacific Coast and into the Western Arctic. In the Strait of Georgia, CSS *Wm. J. Stewart* continued the Mini-Fix survey, completing the area from Active Pass to Burrard Inlet. Additional control sites were established to carry the work westward in the 1969 season. *Marabell* surveyed Departure Bay, including the Biological Station wharf and the B.C. Ferries wharf. Minor revisory surveys were carried out in Vancouver Harbour and at Northwest Bay, Haddington Island and Seymour Narrows. A survey of Knox Bay and Mayne Passage requested by the Department of National Defence was commenced.

On the northern coast of British Columbia, *Wm. J. Stewart* continued the Mini-Fix surveys in the Chatham Sound area and control surveys were made in Prince Rupert Harbour for the 1969 season's work. The site of the antennae for a new Loran-A station at Gray Point in the Queen Charlotte Islands was fixed at the request of the Department of Transport. *Marabell* completed a survey of Troup Passage and began a survey of Spiller Channel.

A shore party, equipped with a high-speed launch, completed a survey of Stuart Lake in the interior of British Columbia.

The year 1968 was relatively good for ice and weather in the Western Arctic. Hydrographic parties aboard CSS *Richardson* and CCGS *Camsell* concentrated their efforts mainly on Sachs Harbour, Kings Bay, the northwest approaches to Kugmallit Bay, and the river mouth and anchorage at Coppermine. *Camsell* made minor surveys at other western Arctic locations.

Current-meter observations were obtained by CSS *Parizeau* between Parksville and Welcome Pass as the first stage of a study of water circulation in Strait of Georgia, and synoptic temperature-salinity cruises were made in Juan de Fuca and Georgia Straits every five weeks through 1968, as a joint project with the Pacific Oceanographic Group.

An intensive tidal survey was made by shore parties in Georgia and Juan de Fuca Straits during 1968. Twenty-two gauges were operated for a one-year period in addition to the permanent stations in the area. Tide gauges and temperature recorders were maintained in the Gorge and Portage Inlet to assist a water-quality investigation being conducted by the Pacific Oceanographic Group.

The Tidal and Current Section completed the first phase of a study of tidal currents in First Narrows, Vancouver, for the National Harbours Board. The investigation is being made in support of a planned tunnel crossing of the harbour.

Operation of permanent gauge stations on the Canadian West Coast and Western Arctic Coasts was transferred to the Inland Waters Branch offices at Vancouver and Calgary, on April 1, 1968. The Tidal and Current Section has retained responsibility for providing tidal information, and for operating special gauges. New *tsunami*-warning gauges were installed at Tofino and Victoria, in cooperation with the Tides and Water Levels Section from Headquarters. (*Tsunami* is the name given to an extensive and often very destructive ocean wave caused by a submarine earthquake.)

Central Region

All 1968 field operations were shore-based as the Region continued to place the emphasis on mobility and flexibility. Support was provided by one helicopter, which moved between the field parties as required.

A party aboard a new 36-foot survey launch *Verity* started a revisory program; 19 charts in Lake Ontario were examined.

Hydrographers assigned to the Polar Continental Shelf Project completed a LAMBDA-controlled survey of M'Clure Strait and its western approaches and a reconnaissance survey of Baumann Fiord. On both surveys, soundings were made through the ice. A ground control survey in the Mackenzie Bay - Beaufort Sea area was made to site the LAMBDA chain in the area for the 1969 season. An intensive study was made of the use of hovercraft as survey vehicles.

Small-craft charting of the Trent-Severn Waterway and the coastal route in Georgian Bay from Port Severn to Parry Sound was completed. The eastern and western approaches to Owen Channel at the entrance to Georgian Bay were surveyed, thus completing the first modern survey of this dangerous area.

The Lake of the Woods survey was continued and the hydrographers obtained sufficient data for a second chart in the new series of charts of this popular lake.

Eight survey projects were carried out in the St. Lawrence River and Seaway areas, with the major effort being made on a re-survey of the river in the Batiscan area. Half of this latter job was completed. This party field-tested much of the newly developed

survey equipment and used the modified Hydrodist positioning system extensively in the Batiscan area. On the Upper Ottawa River, the surveys were completed upstream almost to Pembroke.

Field testing of semi-automated methods of processing field data and developments in positioning systems was continued. The electronics group in the Central Region provided valuable support to the survey parties and to the Canada Centre for Inland Waters at Burlington.

Atlantic Region

CSS *Baffin* began the first year of a two-year survey of the eastern portion of the Gulf of St. Lawrence. This is a combined hydrographic-geophysical LAMBDA-positioned survey, and is designed to satisfy the requirements of navigation, mineral resources, fisheries and defence.

Hydrographers aboard CSS *Kapuskasing* made a Hi-Fix-positioned survey off the eastern approaches to Fogo Island.

CSS *Acadia* continued the survey of Sir Charles Hamilton Sound on Newfoundland's northeast coast. A survey of the harbour and approaches at Ile aux Morts, Newfoundland, was made in support of a large fish-processing plant that has been established there.

CSS *Maxwell's* two main projects were a check survey of the eastern portion of the Strait of Canso and a survey of the harbour at Come-by-Chance in Newfoundland in support of the construction of two major oil refineries that will be supplied by tankers drawing up to 84 feet. *Maxwell* also made a survey of a wharf area in Long Harbour in support of a major phosphorus-processing plant and started a survey of Marystown, in Mortier Bay, in support of a ship-building and repair industry.

Hydrographers in the Eastern Arctic aboard CCGS *d'Iberville* surveyed the inner portion of Wakeham Bay in support of a mining development and made a reconnaissance survey of Allen Bay as part of a Department of Transport study to use Allen Bay as an alternative to Resolute Bay during severe ice conditions. On the return voyage, a team of geophysicists joined the ship and a series of geophysical hydrographic traverses were made of the continental shelf and slope from Frobisher Bay to the Strait of Belle Isle.

Chart-revisory surveys were continued in the New Brunswick - Prince Edward Island area aboard CSL *Tudlik*.

The hydrographic-development group at the Atlantic Oceanographic Laboratory had another active year. A detailed evaluation was made of the accuracy of navigation-satellite systems aboard CSS *Baffin* in the Gulf of St. Lawrence and CSS *Hudson* on the Mid-Atlantic Ridge. Four semi-automatic chart scalers developed by the group were used successfully in the field. Other developments in positioning systems were tested, and planning was initiated for the development of data-logging systems.

OCEANOGRAPHY

The oceanographic work of the Branch is designed to provide information on the large variety of marine conditions, which in addition to basic charting may benefit the economy and resource development of Canada.

Its activities range from basic studies on tides, waves and storm surges, (including the modification of these effects by coastal topography) to geological and geophysical studies of the Canadian continental shelves and the adjacent deep oceans. The chemical and physical processes of the sea affecting fisheries, defence and weather modification are also studied.

The major centres of oceanographic research are the Ottawa Headquarters region and the Bedford Institute at Dartmouth, N.S.

The Ottawa Headquarters group concentrates on special studies of national service and implication. It supports a national data centre—The Canadian Oceanographic Data Centre—and has specialized in tidal and water-level problems and on wave climate. A strong Systems Analysis and Programming Section supports these specialized activities.

The Systems Analysis and Programming Section has grown considerably in the past year, both in personnel and equipment, and consequently has been able to provide service on a greater scale to the other sections of the Branch as well as other oceanographic agencies.

A five-year wave-climate study was initiated in co-operation with Department of Public Works, Department of Transport, National Research Council and National Harbours Board, with the detailed work and expenditure being borne by Public Works and Energy, Mines and Resources. At the end of this five-year plan the project will become the responsibility of the Department of Energy, Mines and Resources.

The Chief Oceanographer has participated in the preparation of the final reports on pollution in Lakes

Erie and Ontario and the St. Lawrence River in conjunction with other federal government departments, the Ontario Water Resources Commission and the United States government. These reports will be published in 1969 under the auspices of the International Joint Commission.

Pacific Region

Weathership program. The program of oceanographic observations from the Canadian weatherships was initiated in 1952 with BT observations twice daily at Station P and bi-hourly en route to and from Station P. In August 1956, the program was enlarged to include the systematic oceanographic observations at Station P from one ship. This program continued regularly on each cruise of one ship until 1968, when it was expanded to the two weatherships *Vancouver* and *Quadra.*

The weathership studies represent the longest continuous record of time-series observations for the deep ocean anywhere in the world. It has provided basic information on the spectrum of oceanographic variability, decay of the seasonal halocline, vertical mixing and diffusion processes and internal waves.

Steps are being initiated now to add a buoy program to the weathership operations in cooperation with a number of Canadian and U.S. agencies.

Atlantic Region

Air-sea-interaction studies have been continued during the year. The stable platform, which was developed to help in measuring the energy exchange across the air-sea interface, was moored near the approaches to Halifax Harbour from April to October, 1968. Many excellent measurements of wind stress were obtained and it is expected that others, at higher wind speeds, will be obtained as a result of the re-mooring of the platform in the spring of 1969.

Sea ice is an increasingly important factor in the development of the national economy and it is therefore imperative that we have a better understanding of its formation, behaviour, and properties. Such studies have been under way for some time by the frozen-sea research group, which had a particularly successful field season in 1968. It was able to extract a six-ton block of ice from Cambridge Bay, Victoria Island, N.W.T., which, after detailed examination, provided new information of brine-drainage channels, salt rejection, and the dynamics of brine-induced convection in the water beneath the ice. A beginning was made on a major study of ice behaviour in the Gulf of St. Lawrence in cooperation with McGill University and the Department of Transport.

As a result of continuing studies of ocean circulation, the importance of time-dependent processes, the problems of variability, in the oceans has become much clearer. The conviction is growing that the key to the quantitative description of important physical processes in the sea not presently understood lies in the development of practical methods of observing and analyzing time-dependent phenomena, guided by meaningful theoretical models. Considerable progress was made in this facet of the program during the past year.

Although the applied-oceanography section is relatively young as a unit (three years), it has already doubled in size and its services are constantly in demand. It has become the central authority in the Institute for the development and evaluation of moored oceanographic buoy systems and is a prime user of these for the maintenance of standard oceanographic stations and for current measurements in the surrounding waters. The section was also called upon to help in the solution of a number of specific problems; for instance two pollution problems, one in Pictou Harbour and one in the Strait of Canso.

The highlight of the past year's efforts of the marine-geophysics group was the cruise "Hudson Geotraverse". The purpose of the cruise was to study the structure beneath the Atlantic in a one-degree-wide strip (45°-46°) from Cape Breton Island to the eastern flank of the Mid-Atlantic Ridge, via the Tail of the Bank. The traverse crossed most of the major oceanic provinces, and it is believed that the aim of the cruise—a better understanding of the origin and processes in the formation of the deep-ocean basins—was achieved. In addition, many important gravity and magnetic data were obtained on a joint hydrographic-geophysics survey in the Gulf of St. Lawrence.

Of all the disciplines represented in the Atlantic Oceanographic Laboratory (AOL), that of marine geology probably faces the greatest challenge and opportunity on the Canadian Arctic and Atlantic Continental Shelves. This immense area (about one million square miles) is as yet only superficially investigated but undoubtedly contains resources of great potential value. Reconnaissance investigations over the area, involving the techniques of sedimentology, micropaleontology, and geochemistry, begun some time ago, have been continued and expanded in 1968. In partic-

ular, there has been a shift to the more intensive study of specific areas, such as the Scotian Shelf, the Grand Banks, and the Labrador Coast, partly in response to the recent upsurge of interest in petroleum exploration of the Atlantic Continental Shelf.

In addition to cooperative ventures between sections within AOL, there has been considerable cooperation between AOL and the Fisheries Research Board unit at the Bedford Institute, the Marine Ecology Laboratory. Such studies as a complete physical and chemical oceanographic and biological investigation of St. Margaret's Bay, near Dartmouth, and the two pollution problems previously mentioned, are examples. There was also a large-scale cooperative cruise to the Caribbean that involved, in addition, scientists from universities, government, and industry in other parts of Canada, the United States, the United Kingdom and Venezuela. The usual good working relations with the Institute of Oceanography of Dalhousie University and other research establishments in the area were maintained and strengthened.

The Meteorological Research Section is primarily engaged in the design of instruments for measuring various parameters in or obtaining samples from the marine environment. This is usually, although not always, done at the request of other AOL staff who need the data for their research. Thus, the personnel of the section works on many different projects each year on a completely interdisciplinary basis. Some examples of completed equipment developed by the section are: the Bedford Institute Oceanographic Data Logging System (BIODAL), a multi-recorder precision sounding system, and an automatic flat-bed plotting table. Some continuing projects are: a radio-controlled launch, an automatic bathythermograph, an oblique echo-sounder, and a data-processing system.

Policy and Planning Branch

The Policy and Planning Branch advises on and recommends national undertakings concerning water, air, and other renewable resources. It helps to coordinate federal, interdepartmental, federal-provincial and international activities in use and study of air and water, and advises on the socioeconomic impact of such activities.

The Branch consists of three divisions and an administration. The library of the Water Group is also attached to the Branch.

POLICY ADVISORY, COORDINATION AND ADMINISTRATION DIVISION

This Division conducts and coordinates current and proposed studies for the development and management of water and other natural resources, and administers federal-provincial agreements in those fields.

During 1968-69 the Division reviewed federal water policies and activities as a basis for drafting new water legislation designed to initiate and encourage federal and federal-provincial activities for the comprehensive development and management of Canada's major river systems. Preparation for the new legislation included consultations with federal and provincial government officials as well as with ecologists, lawyers, engineers and economists. The proposed legislation places particular emphasis on cooperative federal-provincial activities for water-quality control and pollution abatement.

The Water Policy Advisory Section provides the secretariat for the Interim Interdepartmental Committee on Water. The committee, chaired by a senior official of the Department, reviews all federal water policies. Sub-committees develop proposals for regional water activities in the Atlantic Region, the Prairie Provinces and British Columbia. On the national scene, the sub-committee on water quality with the assistance of the secretariat carried out an extensive background study on federal policies and programs respecting water pollution in Canada in support of a coordinated interdepartmental approach to this problem. A preliminary national contingency plan for dealing with disaster pollution is now being considered. *Ad hoc* committees undertook special tasks, such as the preparation for federal action under an International Joint Commission reference concerning connecting channels in the Great Lakes.

Recognizing the growing pollution of the natural environment and the intimate interrelationship of air, water and soil quality the Division initiated studies of the level and extent of environmental pollution, the

cost of pollution control, jurisdictional and administrative issues, and the socioeconomic and ecological factors that must be considered. Much of the preliminary work will be done by consultants.

The Division is responsible for liaison between federal agencies and the Canadian Council of Resource Ministers. The latter is composed of eleven ministers—one from each province, together with the Minister of Energy, Mines and Resources representing the federal government. The Council is advised and assisted by a coordinating committee, for which the federal representative is an official of the Department. Among the projects undertaken for the Council was the preparation of papers for and participation in a workshop seminar on water resources in the fall of 1968. The seminar proved very successful in providing ministers and their aides with an opportunity to study and discuss basic issues in water policy and planning. The Council has been urged to sponsor a series of regional seminars.

The secretariat of the Interdepartmental Committee on Resources is furnished by the Division, and recently provided the Canadian Council of Resource Ministers with an updated inventory of federal-provincial cooperative resource-development agreements. The material, compiled in conjunction with similar information provided by the provinces, was to be published during 1969.

The National Advisory Committee on Water Resources Research, established in 1967, completed its first full year of operations. It consists of experts from both federal and provincial agencies, universities and private industry. The committee has two sub-committees, one on social science and one on natural science. Chaired by an official of the Department, the committee has three functions: to advise the Minister on needs and priorities for water-resources research in Canada; to help coordinate such research; and to review and make recommendations on applications for grants in aid of water research dispensed by government. In 1968-69 these grants amounted to $283,038; social sciences $93,950, and natural sciences $189,088. The committee's secretariat is provided by the Division.

WATER MANAGEMENT RESEARCH GROUP (WMRG) OF THE ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT (OECD)

The Water Management Research Group (WMRG) was formed in June 1967 by the Committee for Research Cooperation of the OECD; Canada is one of the 18 member countries. The Assistant Deputy Minister (Water) is the Canadian Delegate to the WMRG, with secretariat services supplied by the Policy and Planning Branch. The Director of the Branch has attended the WMRG meetings for or with the Canadian Delegate.

The purpose of the committee is to exchange information on water-management research in member countries; to identify research needs arising from developing national management in member countries; and to propose ways and means of cooperation in the required research, consistent with existing national programs, so as to result in maximum benefit to the member countries.

In 1968-69 three meetings of the WMRG were held—in Reading, Essen and Paris. The WMRG also sponsored several experts meetings; Canadian experts attended the meetings on documentation and information in the water field and on lakes and reservoirs (eutrophication).

PLANNING DIVISION

Through the Interdepartmental Committee on Water this Division undertakes and coordinates water-planning studies in cooperation with other federal departments, with provincial agencies, or through consultants. Such studies include the economic, legal, social, administrative, financial and physical aspects of regional and national water planning and projects. The Division has three sections: regional studies, general studies, and resources data.

The Canada-British Columbia Agreement for studies and flood control in the Lower Fraser Valley was signed on May 24, 1968. Staff from the Planning Division are on the Joint Program Committee directing studies relating to the reduction of flood damage. The agreement provides for an expenditure of a maximum of $18,000,000 by Canada and for a similar expenditure by British Columbia over ten years.

Officials have discussed an agreement for a comprehensive basin study of the Okanagan Basin with officials of the Province of British Columbia. It is expected that the study will seek to solve the problems of pollution-induced eutrophication and of future water demands. The study, involving provincial agencies and several federal departments, is being coordinated by the Planning Division.

In the Prairies, an *ad hoc* committee composed of officials from Canada, Saskatchewan and Manitoba discussed a proposed study of the Qu'Appelle River Basin in Southern Saskatchewan. Discussions on the scope of the study and financial arrangements are continuing.

Further progress has been made on the Northern Ontario Water Resources Study. A preliminary report on the existing economy and patterns of water use in the northern watersheds is being prepared in cooperation with Ontario. Part of the report will be an atlas depicting the present distribution of economic activity in five major river basins of Northern Ontario.

The Canada-Ontario Committee on the Canada Water Conservation Assistance Act Programs has continued with the preparation of a *Manual of Standards, Guidelines and Procedures for Water Resources Planning*. The Planning Division's contribution described the purpose, principles and methods of economic evaluation of water-resource activities. The manual was expected to be completed by the summer of 1969.

Division staff continued to provide advice and assistance to the Atlantic Development Board in connection with the first stage of a comprehensive study of the water resources of the Atlantic Region by consultants. Direction for the study comes from a federal-provincial supervisory committee made up of officials from several federal agencies and the four Atlantic Provinces. The head of the Atlantic regional unit is secretary to the federal-provincial supervisory committee.

Four study reports covering, (a) the supply of and demand for water in the Maritime Provinces, (b) the supply of and demand for water in Newfoundland and Labrador, (c) the legal framework, and (d) the administrative framework, are currently being reviewed prior to final submissions. It is expected that the reports, when completed, will comprise some 50 volumes of information and analyses of water problems in the Atlantic Provinces.

Officers of the Division have met with officials of the Province of New Brunswick to negotiate an agreement for comprehensive planning and development of the water resources of the Saint John and St. Croix River Basins.

The newly established Resources Data Section has been setting up a base for the collection, categorization, storage and retrieval of information to support the activities of the Division and Branch.

The General Studies Section has continued to help the regional units and divisions with economic analysis and project evaluation and other special assignments.

RESOURCES RESEARCH CENTRE

The Resources Research Centre carries out basic research on the best use of national resources through integration of existing knowledge in the economic, sociological and technological fields. It also advises other divisions and branches and administers grants in aid of geographical research in Canadian universities.

The Centre has continued to be concerned with a wide range of problems of resource management and utilization. Much of this activity has been concentrated in Northern Ontario and the Atlantic Provinces. Canada Land Inventory land-use mapping of western Newfoundland continued on behalf of ARDA. It will be completed when air photos become available for the small remaining area. Studies continued on the regional factors affecting resource utilization in Newfoundland, particularly marine resources. In Prince Edward Island the Centre has taken a leading part in a major program of rural management studies. This program involves a large number of federal and provincial agencies and is concentrated in land reorganization and improvement. Similar work went on in Nova Scotia and plans started for an extension to New Brunswick. Other studies include an examination of the social and economic implications of ice distribution and movement in the Northumberland Strait.

In the central region the Centre has been primarily engaged in a study of resources and economic activity in those Ontario watersheds that drain to Hudson and James bays. This study is almost complete. Farther west, plans were made for participation by the Centre in the comprehensive study of the water resources of the Okanagan Basin which is envisaged by the federal and British Columbia governments.

Lastly, the Centre has continued its long-term study of social and economic variations across Canada. Plans are being made for extensive research at the Canada Centre for Inland Waters, Burlington, Ontario, and the development of scioeconomic studies of marine resources.

Research into new resource-management techniques, such as air-photo interpretation of flood plains and simulation models for water-quality management and other purposes, is in progress.

Inland Waters Branch

The Inland Waters Branch provides, at the federal level, services in natural sciences and engineering needed for optimum management of Canada's water resources. It produces scientific or engineering data, research results, or engineering studies, appraisals or advice.

One of the Branch's major objectives is the collection and dissemination of information on water quantity and quality throughout Canada. This is being achieved through networks of observational and sampling stations on Canadian rivers, lakes, aquifers, glaciers and snow courses. Emphasis is placed on making the collected data readily accessible in the most usable form.

Also of major importance is the Branch's responsibility for providing to the Government of Canada advice on technical aspects of managing interprovincial and international waters. This takes the form of technical studies in support of international and federal-provincial programs and agreements relating to fresh water.

To ensure that Canada's water resources are being used wisely for the benefit of present and future generations, new concepts have to be developed and new knowledge acquired of the behaviour and occurrence of water in the hydrologic cycle. Standards and procedures for improved regulation and use of the country's fresh-water resources will have to be found, and methods for predicting the response of lakes and rivers to pollution as a basis for economic pollution control must be developed. Liaison with other government agencies, universities and industries must be fostered both nationally and internationally for exchanging knowledge in the water field. These are the chief objectives of the Inland Waters Branch in its endeavour to provide the Government of Canada with the information essential for the development and application of an effective national water policy.

The Branch undertakes a prolific publications program in order to make its scientific and engineering data and studies available to the scientific community. During the past year more than 50 scientific or technical publications or brochures were published by the Branch, and a number of papers were published in scientific journals.

The following sections briefly describe the role of the Inland Waters Branch in the activities of the Canada Centre for Inland Waters as well as the activities of the various Branch units that are not associated with the Centre.

CANADA CENTRE FOR INLAND WATERS

The Canada Centre was established in 1967 at Burlington, Ontario, as a new federal centre for water research. The Department of Energy, Mines and Resources, mainly through its Inland Waters Branch, but assisted by the Marine Sciences Branch and the Policy and Planning Branch, coordinates the activities at the Centre in collaboration with the Fisheries Research Board, the Department of National Health and Welfare, and the Association of Universities and Colleges of Canada.

A significant part of the Centre's work in 1968 was the preparation of major sections of the International Joint Commission report in connection with the pollution reference on Lakes Erie and Ontario and the international St. Lawrence River. This report, in three volumes, is being prepared in collaboration with the Ontario Water Resources Commission and United States federal and state agencies. The report will summarize available knowledge of pollution of the two lakes and the upper St. Lawrence River and will make recommendations for remedial measures based on present information. However, in the course of preparing portions of the report, significant gaps in our knowledge of the lakes became evident and the scientific operations of the Centre are being designed to deal with the more important unsolved problems.

During the year the Centre coordinated an extensive field program involving a number of interdisciplinary surveys on the Great Lakes. These surveys, along with the data collected from fixed moorings of instruments in the lakes and other studies, are designed to develop a body of information from which it will be possible to predict diffusion and movements of pollutants; determine temperature distributions and the availability of light for biological productivity; assist in assessing water budgets; determine the trends in chemical composition of lake waters under the impact of natural and man-made processes; assess extent and nature of water-level fluctuations; assess the problems of erosion and sedimentation; determine the role of sediments in the cycling of pollutants in lakes; determine the degree to which the ageing process or

"eutrophication" has progressed in the various parts of the Great Lakes; and assess the impact of pollutants on the lake environment. Research on subjects such as these will provide the basis for determining means by which pollution abatement and other water-management measures may be designed to take advantage of, and work with rather than against, natural lake processes. This will ensure efficient use of the large sums of money which are being spent on pollution abatement, water-level control, shore-erosion prevention, and construction of lake structures.

The Centre is presently housed in a 25,000-square-foot trailer complex and in an assortment of temporary buildings, which provide housing for laboratories, stores, workshops and a library, and office space for administration, scientific study, data processing and drafting. During the past year the development of a permanent site included the completion of land reclamation and construction of sewage, water-supply and electric-power facilities. Marine facilities, including a breakwater and berthing for major vessels and launches, were installed and are in use. Contracts have been awarded for foundations for the boiler plant, the research-and-development building and the workshop, launch-repair and warehouse building; these buildings are scheduled for completion during the summer of 1970. The main building containing laboratories, mechanical facilities and ancillary services, and a hydraulics building containing instrument-calibration and research facilities, are scheduled for completion in a phased program from 1971 to 1973. A water and wastewater-treatment research laboratory is also to be constructed in which pilot-scale studies will be undertaken to permit the development of plant-scale pollution control and water-treatment processes.

WATER SURVEY OF CANADA

The Water Survey of Canada conducts a systematic survey of streamflow, water levels and sediment transport throughout Canada and publishes the results annually. In addition it carries out snow and glacier surveys and water-power surveys, the latter mainly in areas of federal jurisdiction. The Water Survey has also been assigned the task of expanding its survey network to collect field data on behalf of other departmental agencies responsible for the collection and interpretation of data on water quality, groundwater, snow, ice, and tides. During danger periods on rivers subject to floods, a flood-warning service is maintained in cooperation with the provinces concerned. Although all of these activities are designed to meet the requirements of the federal government, an increasing portion of the total effort is aimed at satisfying needs of the provinces.

The Water Survey of Canada and its predecessors have collected and published basic streamflow and water-level data on a national basis for more than half a century; the sediment survey has been in operation since 1961. These surveys are being expanded steadily and at present are conducted from 30 district and field offices extending across Canada. Planned expansion in 1969 will see district offices established at Regina and Fort Smith to provide closer liaison with agencies in Saskatchewan and the Northwest Territories, respectively.

In 1964, the Quebec Department of Natural Resources assumed responsibility for the collection of hydrometric data for most rivers in Quebec; however, collection of data for a number of navigable and international streams in Quebec remains the responsibility of the Water Survey.

During the year under review some 60 stations were added to the Water Survey's gauging network, bringing to approximately 2,250 the total number of streamflow and water-level stations. Sediment data are gathered at 82 of these stations, an increase of five stations during the year. The above total also includes 130 water-level stations operated in the field for the Tides and Water Levels Section of the Marine Sciences Branch; most of these stations are located in the Great Lakes-St. Lawrence River system. The Water Survey also participates in the collection of hydrologic data for some 40 research watersheds established for the International Hydrological Decade.

About mid-year, hydrometric-network planning, aimed at providing a sound basis for further network expansion, was greatly intensified by enlisting the services of two consultants for planning the British Columbia and Ontario networks. By agreement with the Department of Indian Affairs and Northern Development (IAND), the Water Survey of Canada carries out the hydrometric survey in the Yukon and Northwest Territories; the Water Survey also collaborates with IAND in assessing the water resources in these areas.

Intensive sediment surveys on the lower Fraser River continued so as to provide a sound basis for the maintenance and improvement of the navigation channels in the river. Similar work on the South Saskatche-

wan River is under way to determine the effect of sediment deposition in Lake Diefenbaker and degradation in the river downstream of the dam. A terrestrial photogrammetric study to determine the extent of shoreline erosion of Lake Diefenbaker was also undertaken.

Automatic data-processing was initiated in 1966 when two major projects were undertaken—the storing of historical hydrometric data on magnetic tape, and the developing of automated procedures for the computation of current hydrometric data. Approximately 31,000 station-years of record, representing all historical daily-discharge data to 1967 inclusive, were keypunched and converted to magnetic tape. Also, special equipment for digitizing charts has been purchased for the development of automated streamflow computations. These systems are now partly operational and will be fully operational in all districts across Canada early in 1970.

Engineers of the Water Survey of Canada are members of, or participate in, the activities of some 20 engineering boards, committees and special studies in connection with various aspects of national, international and interprovincial water problems. These responsibilities include major streamflow measurements on the interconnecting channels of the Great Lakes, on Northern Ontario rivers and on the Nelson River.

HYDROLOGIC SCIENCES DIVISION

The Hydrologic Sciences Division undertakes research into the physical processes governing the behaviour of water in the hydrologic cycle to improve methods of water management. In addition, it takes part in such international research as the International Hydrological Decade and the International Field Year on the Great Lakes, and enters into joint research with universities, provincial authorities and other government departments and agencies in order to increase the understanding of the basic processes of the hydrologic cycle, with particular emphasis on Canadian situations and applications.

The Division consists of three operational subdivisions—Glaciology, Groundwater and Water Science. The Division also provides administrative services required by the Secretariat of the Canadian National Committee of the International Hydrological Decade. The preliminary design of a hydraulics laboratory to study the behaviour of moving water under environmental conditions, to be situated at the Canada Centre for Inland Waters at Burlington, has been completed. Although it is expected that it will eventually result in the formation of a separate Division, the hydraulic nucleus is being formed within the Hydrologic Sciences Division.

Glaciology Subdivision

The annual mass-balance data for representative glacier basins in western Canada and the eastern Arctic together with energy-balance and water-discharge data, continued to be collected. Each eastern Canadian basin showed a net positive mass balance. In addition, photogrammetric measurements are being made annually in selected basins in order to determine glacier movement.

A project to develop a hydrologic model of a glacier basin has been initiated. This model will be applied to meltwater from ice and snow in the upper reaches of the North Saskatchewan River and should lead to a method of predicting the contribution to runoff from snow and ice in glacier basins.

A Glacier Inventory Section was formed within the Subdivision to complete ice and permanent-snow inventories in Canada. In order to obtain an inventory of water stored as ice in temperate glaciers, an instrument to measure the thickness of temperate glaciers has been developed by the Glaciology and Water Science Subdivisions, through contract with industrial firms.

The continuous small discharge of water from Summit Lake, B.C., through a channel beneath the Salmon Glacier was confirmed through the use of a dye-tracer experiment. This lake periodically empties in a catastrophic manner causing flooding in the valley below. A project has been initiated to discover the mechanism that triggers this phenomenon.

An Ice Science Section to investigate the fundamental properties of ice as related to ice deformation and movement has been established and X-ray apparatus for studying dislocations in ice has been assembled. Complementary studies of the stress-strain relationship of single-crystal and polycrystal ice are in progress and the effect of impurities on the strength of ice is being investigated.

A series of seven maps showing the glacier distribution in the Arctic regions on a scale of 1:1,000,000 was completed during the year. A project involving the Subdivision and the National Parks Branch, Department of Indian Affairs and Northern Development, will produce, in shaded relief, a map of the Peyto Glacier in

Alberta in combination with an illustrated text comprising historical, geographical, geological and other information of interest to tourists.

Groundwater Subdivision

The demand for information pertaining to the management of water resources along the eastern seaboard has led to the establishment within the Groundwater Subdivision of a Maritime Research Section. The Section has been empowered to obtain information on seawater intrusion into coastal aquifers, to develop hydrochemical pumping-test techniques for coastal well fields and to develop geophysical methods to study groundwater flow in fractured rocks.

In preparation for the International Field Year on the Great Lakes (1971-72), considerable effort is being made to study groundwater flow in the Lake Ontario Basin. This study includes the development of a parametric model of the Northern Lake Ontario Basin, an assessment of the groundwater inflow into Lake Ontario and the construction of hydrogeological maps of the basin. Data, which are being provided by the Ontario Water Resources Commission through a cooperative arrangement, will be processed through the groundwater-data-storage system associated with the Groundwater Observation Well Network (GOWN) in order to provide the required maps. Retrieval programs are being written by members of the Hydrologic Sciences Division. The study involves close working relationships with agencies in the United States. A number of provincial governments have shown interest in this project because, in due course, GOWN will be capable of providing the basis for maps showing such features as bedrock topography, aquifer delineation, etc., based on data obtained from local wells.

As part of the program to obtain an inventory of Canada's water resources, a method has been developed, using standard maps and a pencil follower, to compute the areas of lakes greater than 100 square kilometres. The information is stored in such a manner that it can be augmented with depth measurements when available and updated as necessary.

In the Ottawa Valley region, a project to trace buried river channels by hydrochemical techniques has been initiated and approximately 1,800 wells have been tested between Ottawa and Rigaud. Apart from hydrogeological interest, the data from these samplings have proved to be of considerable interest to the Ontario Department of Highways in connection with highway construction plans.

The program to develop computer models of groundwater flow systems has been further extended to include a number of boundary conditions commonly encountered in nature. This program leads to the determination of flow systems based on the physical properties of the environment.

Water Science Subdivision

The Water Science Subdivision seeks the basic physical and chemical knowledge that will be required for the effective and economic use of Canada's water resources.

Although little is known about the structure of water and aqueous solutions, it influences much of the behaviour of water, and a better understanding of the structure is necessary for the future development of effective water-treatment methods. Some research projects currently undertaken in this Subdivision are therefore concerned with the properties of solutions of halides, especially chlorides, which are pollutants produced by the chlor-alkali industry and from municipal street wash in winter; also under study are the structural effects of phosphates and nitrates, compounds known to be involved in the eutrophication of natural water bodies. By eutrophication is meant the increase in nutrients, particularly phosphates and nitrates, that stimulate the excessive growth of plant and animal life, whose decay depletes the water of oxygen. The amount of dissolved oxygen can therefore be used to indicate the "health" of natural waters; for this reason the diffusion of oxygen in water and its rate of replenishment through the air-water surface are under study.

Other projects relate to understanding the form in which toxic metallic compounds may exist in natural water bodies, and the manner in which pollutants can be removed from solution by decomposition on the surface of naturally occurring minerals. A small instrumentation group to serve the needs of the Division and to undertake special instrumentation projects has also been established.

International Hydrological Decade Secretariat

The Secretariat's duties are guided by the 26-member Canadian National Committee which coordinates the country-wide scientific investigation and assessment of water resources under the International Hydrological Decade.

In addition to coordinating the studies and organizing the annual meeting of the Canadian National

Committee, the Secretariat organized an annual hydrology course, two workshop seminars, a visiting lecture tour, met Canada's international IHD commitments and provided assistance to provincial and university agencies involved in holding seminars and workshops in hydrology. It also published annual progress reports on the Canadian IHD program, the results of seminars, the results of surveys and a general-interest *News Bulletin.*

GREAT LAKES DIVISION

The Great Lakes Division seeks to provide the knowledge and understanding of the chemical, physical and sedimentological behaviour of Canadian lakes needed for optimum management of the lakes. This task encompasses all Canadian lakes, but the emphasis at present is on the Laurentian Great Lakes because of their economic importance.

To carry out its functions, the Division conducts applied research and collects scientific data, and engages in limnological instrument design, development and evaluation, augmented by a modest amount of basic research. Also, it encourages and promotes Great Lakes research in Canada and plays a leading role in coordinating research and data collection with its counterparts in the United States. Scientific support as well as administrative and technical services are provided to the various divisions and agencies at the Canada Centre for Inland Waters.

Physical Limnology

During the first part of 1968, a major effort was directed to examining circulation and thermal and turbidity features in Lakes Ontario and Erie, and reporting on these to the International Joint Commission on pollution of these lakes. Later in the year, the emphasis was shifted to studies of lake processes, with the aim of improving knowledge of lakes and devising techniques for predicting lake phenomena. The study of lake processes included water movement, diffusion, and remote sensing as well as air-lake studies and water-level studies. Progress was made in the mathematical representation of the physical processes important in lake circulation, and work was begun on the preparation of an atlas of Great Lakes data.

During the year, attention was turned to lakes other than the Great Lakes. Although relatively small at present, this effort is expected to increase over the next few years.

Preparations for 1969 studies have centred on meteorological, physical, chemical and geological processes in western Lake Ontario. Involving two 7-week periods of concentrated measurements, these studies are feasibility investigations prior to the International Field Year on the Great Lakes in 1971-72.

Limnogeology

Early in 1968, the Limnogeology Section was transferred from Ottawa to join the rest of the Division at Burlington.

The 1968 studies were designed as the first part of a continuing series. They fall into the following categories: sedimentology, stratigraphy, paleoecology, inorganic and organic geochemistry. The sedimentology section carried on sampling and underwater studies in Canadian nearshore areas and in the western end of Lake Ontario, grid sampling in the Niagara-on-the-Lake area and in Georgian Bay, and a preliminary assessment of sedimentation in Lake Diefenbaker, the newly formed reservoir of the South Saskatchewan River project. The stratigraphy section continued long-term projects of coring and bottom sampling in Lakes Erie and Ontario. In the paleoecology section, the environmental relationships of chironomidae, small organisms found in the Great Lakes, are under study; being extremely sensitive to eutrophication, chironomid forms will provide delicate indicators of the paleo-environment. The geochemistry and sedimentological studies are showing that Lake Ontario is composed of four major depositional basins separated by various sills or divides whose presence would seem to affect lake productivity. From these, and various smaller research projects and equipment trials, a wealth of information is being harvested.

Chemical Limnology

The Chemical Limnology Section is responsible for the evaluation of the chemical balance of the Great Lakes with respect to nutrients as well as organic and inorganic materials. Study of the 1968 monitor-cruise data for Lakes Erie and Ontario indicates that more sampling stations and more frequent sampling and analyzing for total phosphorus and total nitrogen are needed in order to improve our understanding of the nutrient budgets of the lakes. Accordingly, plans for 1969 called for an intensive year-round chemical monitoring of Lake Ontario, with special emphasis on these nutrients.

Rain monitoring was expected to begin in mid-1969 to determine the portion of the nutrient budget of the Great Lakes supplied by rainfall.

A variety of salt solutions are being studied to determine the deviation from ideal behaviour of salts in aqueous solution. The fundamental physical and chemical properties of aqueous solutions must be known before we can completely understand the behaviour of natural waters.

In the engineering area, significant advance was made in the preparation of current-meter data for computer analysis, and a fast-response, non-wetting wave probe was developed for detailed analysis of small-scale waves in connection with air-water interaction research. Numerous other engineering problems tackled include developing improved structures to house instrument systems, automating the collection and translation of data, developing dye-diffusion methods and calibrating equipment.

In technical operations, CSS *Limnos* and the charter vessel *Theron* were used during the Great Lakes studies in 1968. Both ships were operated in Lakes Erie and Ontario, but the *Theron* also carried out a monitor cruise on Lakes Huron and Superior. The chartered tug *Lac Erie* and seven smaller launches were also used in Great Lakes studies during 1968.

The computer and data personnel continued to summarize data, and contributed considerable support in abstracting and plotting data, computer programming and undertaking statistical analyses for the scientific staff.

Appointment of a full-time librarian in 1968 permitted development of library services for both the Great Lakes Division and other components of the Canada Centre.

ENGINEERING DIVISION

The Division conducts field and office engineering investigations and studies leading to reports and recommendations on the development of water resources. It establishes ranges of engineering costs and estimates benefits relative to direct engineering considerations such as hydro-electric power generation, and water supply for domestic, industrial, irrigation or other purposes. The Division provides technical advice on water matters to various federal and provincial departments and agencies; examines and reviews proposals for water conservation and control, including hydrology, hydraulic and structural design features, and comparison of project benefits and costs; maintains continuing inspection and review of water-conservation and control projects to which Canada is contributing financially; undertakes negotiations with respect to federal participation in water projects and participates in federal-provincial and international boards and committees established for water investigation, development, control and regulation.

The Division helps to plan water policies and development by taking part in inter-disciplinary task forces.

To cope with its manifold tasks, the Division has grouped its country-wide investigations and studies into four regional sections—Atlantic, Central, Western and Pacific. Three service sections provide services in engineering hydrology, field investigations, and project design and appraisal to the regional components. Except where specifically noted, the Division's activities are located in Ottawa.

Engineering Hydrology Section

In 1968, the water levels of the Peace River, Lake Athabasca and the Mackenzie River were well below normal, causing difficulty to water consumers and navigation. This difficulty was attributed to relatively low natural runoff in the Mackenzie basin in the spring and summer of 1968 and to the holding back of water in the new Peace River reservoir, which began filling in December 1967. The Division carried out calculations to estimate the effect on downstream levels and flows from the filling of the reservoir. The first generating units at the dam were brought into service in 1968, thereby releasing water from storage. It is evident, therefore, that future effects of storage of water in the reservoir should not be as severe as in 1968.

The Section continued studies of flood flows in Nova Scotia and Ontario and updated studies of the total surface-water supply in Ontario. Technical advice was provided to the Atlantic Development Board in connection with the Board's study of water resources of the Atlantic Provinces.

Field Investigations Section

The Division completed the third year of field investigations and engineering-feasibility and cost studies of proposals for water-resource development on four major river basins in Northern Ontario. Storage, diversion and power sites were located, but the preliminary design and costing of structures for alternative

schemes are continuing, and reports on water yield, power potential, cost and physical benefits for alternative development possibilities are in preparation.

Project Design and Appraisal Section

The Canada Water Conservation Assistance Act empowers the Government of Canada to provide financial assistance to the provinces in the construction of major works for the conservation and/or control of water. During the year, the Division's activities under the Act were concentrated on conservation and flood-control projects for the Upper Thames Conservation Authority and the Halton Region Conservation Authority, both in Ontario, and on projects in North and West Vancouver and Alberni, in British Columbia. In Manitoba, similar service was provided under ad hoc agreements with respect to construction of the Red River Floodway, which was virtually completed during the year, and construction of flood-control dykes around several towns in the Red River Valley.

The Canada-Ontario Committee on Canadian Water Conservation Assistance Act Programs, established during 1967, made substantial progress towards the completion of a manual of standards and procedures for planning water management in Ontario.

Atlantic Region Section

The study of the feasibility of developing tidal power in the Bay of Fundy continued during the year. The Engineering Division provides back-up support to the Atlantic Tidal Power Programming Board, which is carrying out the study under an agreement between the Governments of Canada, Nova Scotia and New Brunswick. An engineer of the Division acts as secretary to the Board and to the Board's associated Engineering and Management Committee.

The first phase consisted of a field program and preliminary engineering studies to determine the best arrangements of dams and related structures for tidal power plants in the Bay of Fundy. During the year, work progressed on the second phase which includes analyses of the power potential and preliminary marketing and transmission studies, as well as civil-engineering studies of constructiom methods to determine the most economical scheme of development.

Pacific Region Section

During the year, the Division's responsibilities in the Vancouver area increased, and a Pacific Regional Office was established to carry out the functions of the Division in British Columbia and in the Yukon Territory.

The Regional Office participates in the ten-year federal-provincial Fraser River flood-control program which was authorized in 1968. The regional engineer serves on the Fraser River Joint Program Committee and acts as Chairman or Vice-Chairman in alternate years. The Division cooperated with provincial-government engineers in studies to develop design criteria for dykes, river-bank stabilization and internal-drainage works in the Lower Fraser Valley, and also provided engineering review of the Alberni flood-control project initiated by the province under the Canada Water Conservation Assistance Act.

Engineering support is provided to the Chairman of the Canadian Section, International Columbia River Treaty Permanent Engineering Board, and the regional engineer serves the Canadian Section as secretary and as alternate member to the chairman. The Division analyzed flood control and power operations, prepared reports on implementation of the treaty and on operation of the treaty storages, and reviewed technical reports and special operating programs prepared by the power entities. Engineering support on matters of a federal-provincial nature that come within the scope of the treaty was also provided.

Central Region Section

The Division provides advice on the regulation and control of the waters of the Great Lakes - St. Lawrence system, and an office is maintained at Cornwall from which the regulation of Lake Ontario is supervised by Division members representing the International St. Lawrence River Board of Control under the aegis of the International Joint Commission. The Division also provides technical advice to several other boards established by the Commission, including the International Lake Superior Board of Control which is responsible for regulating the outflows of Lake Superior, the International Niagara Board of Control, the American Falls International Board and the International Great Lakes Levels Board. The latter board, under a reference to the International Joint Commission, is conducting a study to determine the feasibility of further regulating any or all of the Great Lakes, and the Division is making a major contribution to this study.

The Division also participates in the coordination of physical data through membership in several subcommittees of the International Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, a joint Canada-U.S. organization. As part of its contribution to the International Hydrologic Decade, the Division holds membership on the Steering Committee for the International Field Year on the Great Lakes, which is an international observational and research program designed to provide an integrated group of studies aimed at solving the basic problems of hydrology, meteorology, physical limnology and geology of the Lake Ontario basin.

Western Region Section

Work continued on the Saskatchewan-Nelson Basin Study, an examination of the water resources of the Saskatchewan-Nelson Basin, including potential additional supply by diversion or storage. The study is under the direction of the Saskatchewan-Nelson Basin Board. The secretary of the board is an officer of the Division. The Division has accepted a contract from the board to develop a mathematical model to produce synthesized flow sequences at thirteen points throughout the basin. Work on this contract was about half completed at the end of the fiscal year.

WATER QUALITY DIVISION

The Water Quality Division collects, interprets and disseminates data on the quality of fresh water in Canada, conducts applied research in water and wastewater treatment and provides analytical laboratory support for water resources research and field investigation undertaken by the Department, other government agencies, universities and private industry. In applied research, the Division seeks to develop new and improved technology for the best use of Canada's freshwater and for control of water pollution.

Resources and Surveys Subdivision

The Resources and Surveys Subdivision continued to expand the water-quality monitoring and surveillance network which was first set up to collect baseline water-quality data across Canada and to measure the pollutional effects of major municipal, industrial and other wastewaters and surface runoff. Approximately 260 permanent sampling stations were in use during the year, coinciding in almost all cases with gauging stations which are operated by the Water Survey of Canada. Most of the network stations were sampled either bi-weekly or monthly, with samples shipped for analysis either to the Ottawa laboratory or to the regional laboratories at Moncton or Calgary.

Expansion of the network, on the basis of a planned program covering the next several years, was most notable in western and northwestern Canada and in the Atlantic Provinces. This activity, ranging as it does from the Exploits River in Newfoundland to the west-coast rivers of British Columbia and the Mackenzie River in the northwest, points up the magnitude of the water-resource-evaluation task in Canada.

Collaboration with other government departments and provincial agencies and universities on research and experimental river basins throughout Canada, and in support of the Department's commitments to the International Hydrological Decade, was continued, as was the water-quality study of the headwaters of the Saskatchewan River system, in support of the Eastern Slope (Alberta) watershed program. A cooperative geochemical and water-quality study of the Mackenzie River in northwestern Canada was initiated, and the Division participated in the initial planning of a comprehensive water-resources study of the Okanagan Basin, which is under joint consideration by the governments of Canada and British Columbia.

The selection and acquisition of robot monitoring devices received high priority during the year. This is in keeping with the growing requirement for continuous measurement of water quality in locations where industrial or urban discharges may cause variations in water quality not readily determined by manual sampling and analysis on a repetitive basis. One robot was installed in the Columbia River near the International Boundary, on the basis of a joint agreement with Cominco Limited, and a second in the Ottawa River at the City of Ottawa Water Filtration Plant. Preliminary plans were made for housing such units in mobile trailers so that additional robots, to be acquired, can be moved from site to site, as required. As the successful automation of more and more analyses is effected, the use of robots will be expanded.

Monitoring of water quality in streams in the base-metal-mining area of New Brunswick continued. These studies, which are to determine the effects of mine-wastewater discharge on salmon fisheries, are being carried out in cooperation with the New Brunswick Water Authority, the Department of Fisheries, the Fisheries Research Board, and mining companies in the area.

Planning for the computerized storage and retrieval of water-quality data received from the laboratories and from other federal and provincial agencies was completed. Although a national water-quality-data centre may not be fully realized until the planned data-processing facilities at the Canada Centre for Inland Waters are available, current planning is intended to make automated printout of Departmental data available in 1969. Publication of water-quality reports for all of the major watersheds and for groundwaters in many areas will then be undertaken.

Water Pollution Research Subdivision

Although it is intended to expand this Subdivision to provide a broad inter-disciplinary capability in water and wastewater-treatment research, activities in the current year were limited to the participation of the available staff in field and laboratory studies of pollution from base-metal-mining operations. Following field studies, which were undertaken to examine the formation of acid in the waters receiving wastewaters from such mining operations, laboratory studies were begun to determine the kinetics of acid generation and, thereby, to facilitate the preparation of proposals for pilot-scale wastewater-treatment research. Also undertaken were studies leading to the identification and measurement of trace quantities of proprietary flotation agents used in base-metal milling, and of the contribution to water pollution by mine and mill wastes carried to the receiving waters in colloidal suspension.

Preliminary planning of a pilot-plant laboratory, to be constructed at the Canada Centre for Inland Waters at Burlington, was carried out; the proposed facilities are to be made available for applied research on water and wastewater treatment from bench-scale to pilot-scale in prototype equipment. The active participation of other government agencies, universities and industry is expected to make the facility a focus of inter-agency collaboration in this very important activity in water-pollution control.

Water Chemistry Subdivision

During the year, emphasis was placed on the strengthening of the analytical laboratory capability and on developing methodology to provide the necessary broad basis of support for the growing water-quality-data collection and water and wastewater-treatment research. Priority was given at the laboratories at Ottawa, Moncton, Calgary and Burlington to the acquisition and use of automated analytical equipment to increase the ability of the laboratories to conduct many of the analyses which are carried out routinely. Emphasis on the determination of water-quality parameters used to evaluate pollution from municipal, industrial and agricultural sources also continued to grow. Plans were made during the year for the enlargement in 1969 of the laboratory work areas at Ottawa, Moncton and Calgary, to accommodate not only the continually growing workload resulting from expanding field work but also the continually growing range of analyses which are now required in the evaluation of water pollution.

The Burlington unit, housed in temporary trailer laboratories, continued to staff shipboard and shore-based laboratories for the water-chemistry-monitoring cruises carried out by the Great Lakes Division, as well as to provide support for research being conducted on the Great Lakes by the Fisheries Research Board.

The Regional Laboratories at Moncton and Calgary continued to operate at capacity, carrying a major responsibility for the expansion of the water-quality networks in the eastern and western regions and providing direct support to government and private water-resource studies and special research projects.

The Division continued to assist the Department of National Defence and the Department of Public Works on boiler-water-treatment investigations pending the re-assignment of this function in 1969.

The development of essential analytical methodology for the measurement of water-quality and pollution parameters continued to be a major undertaking of the Water Chemistry Subdivision. The need to adopt methods to measure substances having very low concentrations in water is becoming more evident as the significance of even trace quantities of some pollution parameters becomes appreciated. The analyses of nitrogen and phosphorus are examples of these micro-methods. Equipment was acquired for the measurement of pesticides and petroleum-based hydrocarbons in water, both of major concern in water pollution.

The Division continued its participation in the activities of the American Society for Testing Materials, and maintained liaison with the U.S. Department of Health, Education and Welfare, Public Health Service, and the U.S. Water Pollution Control Administration to keep abreast of new analytical procedures and to participate in methods evaluation.

ENERGY DEVELOPMENT GROUP

The Energy Development Group pursues the broad mandate given the Department to examine energy in all its forms—coal, oil, gas, uranium, and conventional and nuclear generated electric power—to ensure that national development policies are related in the most effective and economic way to Canadian needs. The work of the Group is organized in terms of the principal energy sectors: electrical energy, oil and gas, coal, uranium and atomic energy.

As the size and complexity of Canada's energy industries have increased to meet the demands of a rapidly expanding economy, there has developed an urgent need for a body responsible for the coordination of energy policies in the total energy context. Not only must the expansion of one energy resource be carried out in full awareness of other energy alternatives, but the implications of such developments for other national and regional economic factors must be fully understood and reflected in government policy. This role of coordination of energy programs and policies rests with the Department of Energy, Mines and Resources, with the Assistant Deputy Minister (Energy Development) being the Department's principal adviser on energy matters.

There are many changes taking place in all areas of energy development. In the field of electrical power generation, for example, Canada is in a period of wide-ranging development. In British Columbia, Quebec, Manitoba and Newfoundland—areas rich in water resources—hydro-electric projects with an ultimate total potential of over 15 million kilowatts are now under construction. This potential alone is equivalent to all the electrical capacity that was installed in Canada up to the year 1956. Other provinces are building conventional coal or oil thermal electric plants, while Ontario will have over 5 million kilowatts of nuclear capacity under construction by 1970. Thus, the developments in electrical power generation have implications for all energy sectors. Against this background of change the Energy Development Group is cooperating in studies and joint programs from Newfoundland to the Yukon. A joint federal-provincial study of power-supply alternatives for the Island of Newfoundland was completed within the past year. The final report on the Bay of Fundy tidal-power studies was scheduled for the fall of 1969, and a joint study with the United States of possible markets for Yukon River power has been initiated.

Change and expansion are also very much in evidence in other sectors of the energy economy, and the Energy Group's activities are concerned with the related policy and development. New oil-supply patterns are in the offing, particularly as the result of a major oil discovery in Alaska and exploration in Canada's north and offshore areas, while North American markets are calling for more and more Canadian natural gas. Canada has entered a new period of major coal development based on the establishment of economic markets for coal from the western provinces. After several years of depressed activities, the uranium industry is moving into a period of exploration comparable to that of the mid-1950's. In keeping with changes in this sector, a new uranium policy has been developed.

The dynamic energy economy in Canada results from the growth within each sector and from inter-energy competition. Consequently, policy considerations in any sector must have regard to the total energy picture. The following individual projects and developments relative to each of the energy sources must be studied and assessed in terms of inter-relationships with other energy sources whenever policy recommendations are to be made. All studies and recommendations are directed towards the maximum development of Canada's energy resources to ensure adequate supplies of low-cost energy to the domestic consumer, to encourage exports of energy exceeding domestic requirements and, in total, to meet the rising energy demands of a modern industrial nation in a manner best suited to its political, social and economic objectives.

ELECTRICAL ENERGY

Atlantic Provinces Power Development Act

Responsibility for the Atlantic Provinces Power Development Act was transferred to the Minister of Forestry and Rural Development (subsequently the Minister of Regional Economic Expansion) in July 1968, but the Energy Group continued its advisory role in respect to the administration of this Act.

Capital assistance to date under this Act has helped to establish an interconnected power system in New Brunswick and Nova Scotia and an island-wide transmission system in Newfoundland.

During the year, the coal-subvention provisions of this Act were reviewed and recommendations prepared on the future use of this element of support. Study continues on the capital-loan provisions and the relationship of this type of assistance to the broader regional economic objectives of the new Department of Regional Economic Expansion.

Newfoundland Power Supply Study

A study of the generation-expansion alternatives for the Island of Newfoundland, sponsored by the Energy Group of the Department as a joint undertaking by the federal government and the Newfoundland and Labrador Power Commission, was completed. The conclusions of this study were reviewed in detail but are subject to further study when specific data concerning the future development of hydro-electric power on the Churchill River in Labrador, below Churchill Falls, become available.

Trans-Canada Grid Study

The report of the Federal-Provincial Working Committee was presented to the Federal-Provincial Ministerial Committee on Long-Distance Transmission and was tabled in the House of Commons on 11 December, 1968. The recommendations for reinforcement of regional interconnections are being followed as opportunity arises to encourage such strengthening of electrical ties. The Energy Group participated in discussions on two such interconnections during the year.

Yukon River Development

An exchange of notes took place between Canada and the United States on December 19, 1968, which provides a basis for discussion of the market potential for power from possible development of the Yukon River. This represents an initial step towards assessing the advantages to area development from hydro-electric power which could be generated by the diversion of part of the headwaters of the Yukon River to a generating station on tidewater in southeastern Alaska or northern British Columbia.

Initial discussions have taken place with representatives of the Alaska Power Administration and the United States Department of the Interior. While responsibility for the study rests with the Department of Energy, Mines and Resources, the Government of British Columbia, the B.C. Hydro and Power Authority and the Department of Indian Affairs and Northern Development are also participating. The market study is being coordinated with activity related to the transportation study of the region being carried out by the Department of Transport.

Quebec – New Brunswick Intertie

The Energy Group carried out a study of the technical feasibility of, and the possibility of federal government support for, a proposed high-capacity DC interconnection between the power systems of New Brunswick Electric Power Commission and Quebec Hydro; this included an assessment of the possible benefits of such an intertie to the Maritime Power Pool comprising New Brunswick, Nova Scotia and, in the future, Prince Edward Island.

Atlantic Tidal Power Study (Bay of Fundy)

The Energy Group continued to participate in the study of the Bay of Fundy tidal-power-development scheme, the transmission requirements to market this power, and the impact of such a development on the regional power system and on regional economic development. The technical elements of the tidal-power investigation were essentially completed during the year, and preparation of the final report commenced.

Nelson River Development

A review committee, required by the Federal-Provincial Nelson River Agreement, was established and held its first meeting. The Assistant Deputy Minister (Energy Development) is the chairman of this committee, which will review progress in implementing the agreement. This agreement provides for the construction by Canada of a transmission system, comprising a 560-mile transmission line and terminal facilities between the Kettle Rapids power development on the Nelson River and a terminus near Winnipeg; upon completion the facilities constructed by Canada will be leased to the province of Manitoba which will also operate and maintain the system.

Columbia River Development

The Assistant Deputy Minister (Energy Development) continued his duties as Canadian chairman of the International Columbia River Treaty Permanent Engineering Board which is charged with ensuring that the objectives of that Treaty are met.

The Permanent Engineering Board staff, located in Vancouver, conducted continuing studies relating to the operation of the Canadian Treaty projects, Duncan, Arrow and Mica, leading to the drawing up of the Operating Agreement provided for in the Columbia River Treaty.

The Assistant Deputy Minister also continued as federal chairman of the B.C.-Canada Columbia River Advisory Committee which assists a federal-provincial committee of ministers to facilitate implementation of the treaty by Canada. The federal chairman of the ministerial committee is the Minister of Energy, Mines and Resources.

Research

Consultation was provided to the Department of Industry, Trade and Commerce leading to approval of a development project by a Canadian electrical manufacturer in high-voltage direct-current-transmission equipment. Discussions are continuing in relation to establishing a possible test site for prototype evaluation in a later stage of the development.

The Energy Group assumed responsibility for a review of the national interest in the establishing in Canada of high-voltage and high-power electrical research facilities, and for a consequent study on the possibility of providing federal assistance for specialized research facilities of this nature.

OIL AND GAS

The oil-and-gas industry is one of the most dynamic sectors of the Canadian economy, and its growth in the past 20 years has had a major impact on regional and national development. The Energy Development Group continuously appraises trends in oil and gas exploration and production, transportation, processing, and marketing in Canada and on an international scale. The appraisal of industry developments forms the basis for studies and recommendation on policy. The Department coordinates these studies when several government departments are involved. The Department is concerned with supply and demand as they relate to short- and long-term planning.

During the period under review, important oil discoveries were made in northern Alaska, and many other events of a national and international nature had major implications for the oil-supply-and-demand pattern in North America. To assess the importance of these events to the Canadian economy, the federal government established a Task Force on Northern Oil Development. The Task Force, chaired by the Deputy Minister of the Department, is concerned with engineering and economic assessments of transportation methods, both pipeline and tanker, that might be used to transport and market oil from Arctic areas to continental and world markets. Particular interest centres on the results of the trial voyage of the tanker *Manhattan* through Arctic waters from the Atlantic Ocean to Alaska to determine the feasibility of establishing a year-round tanker route from the Prudhoe Bay oil area in northern Alaska to markets on the east coast of North America and in Europe.

The Energy Development Group advised other departments of the federal government on oil and gas policy related to the responsibilities of those departments and provided information to industry and the general public on oil and gas developments in Canada and abroad. Close liaison on oil and gas matters was maintained through field work, meetings and conferences. A member of the staff serves on the National Advisory Committee on Petroleum Statistics established by the Dominion Bureau of Statistics in 1968.

Participation in the Science Council of Canada study of the earth sciences involved an appraisal of the contributions of geology, geophysics and geochemistry to oil and related mineral development in Canada. The Science Council study was particularly concerned with the scope, direction, and effectiveness of scientific activities in the development of economic resources to meet the huge energy and mineral demands of the future.

COAL

The coal industry has been going through a period of major change in which the industry in Nova Scotia and New Brunswick has been re-adjusted to reduced markets and higher costs, while that of western Canada has been entering into major export contracts and proceeding with the development required to meet delivery schedules under these contracts. With the establishment of the Cape Breton Development Corporation, a Crown company, to administer the coal mines of Cape Breton at lower production levels and to encourage the development of a more diversified economy and the concurrent rationalization of the New Brunswick coal industry, the federal assistance formerly provided in the form of subventions has been replaced by more progressive developmental measures. In western Canada, where the coal industry is entering a new

economic phase, subventions will not be required and federal-government interest and support is being expressed in terms of coal research and the provision of suitable harbour facilities.

With the phasing out of subvention obligations, the government has proposed that the Dominion Coal Board be dissolved. The remaining responsibilities of the board would be carried out in the Department of Energy, Mines and Resources. In anticipation of this change, Departmental officials worked closely with the Board's staff to ensure a smooth transition and continuing attention to coal-industry matters. At the same time, the industry was encouraged to establish an industrial association to act on its behalf in maintaining effective liaison with the federal government.

During the past year arrangements were completed to phase out by 1971 all transportation subventions, as authorized in 1962, to Alberta and British Columbia producers shipping coal by rail to Vancouver for transshipment to foreign markets. For the industry in the Maritime Provinces, arrangements were completed with the New Brunswick government for a new form of financial assistance by the federal government which will provide for the gradual phasing out of operations at the Minto coal field and the development of alternative forms of industrial activity.

Although the large coal imports into central Canada from the United States continue, the growth in coal exports to Japan from Alberta and British Columbia gives promise of a trade balance in coal by the mid-1970's. To further encourage economic trends in the industry, coal policy has been undergoing a major change. Instead of subsidization, largely designed to retard the decline of non-productive mines until alternate sources of employment could be found, the government now emphasizes resource development and product research for new coal markets. This is in line with one of the fundamentals of Canadian energy policy—that of encouraging maximum development of economic sources of supply for domestic and export markets.

URANIUM AND ATOMIC ENERGY

With market prospects for Canadian uranium improving as planning and construction of nuclear power plants proceeds throughout the world, attention has been directed towards a review of Canadian uranium policy. The present policy was announced in 1965 and provided for exports under safeguards to ensure that Canadian uranium was to be used only for peaceful purposes, and it also provided for the stockpiling of uranium so that Canadian mines could continue operating while markets were being developed. One aspect of the review would be to ensure that the policy take full account of the Canadian public interest in the new circumstances of growing world requirements and, at the same time, act to curtail the spread of nuclear armaments.

Administration of the federal government's uranium policy will be designed to encourage the growth of the Canadian primary and secondary uranium industry through maximization of its opportunities in the world uranium market. To this end, the Energy Group continued its coordination for departments of the federal government concerned with uranium policy. Matters under study included stockpile programs, possibilities of the establishment of uranium-enrichment facilities in Canada, and export opportunities.

RESOURCE ADMINISTRATION DIVISION

The Resource Administration Division administers and manages the federal interests in mineral resources offshore from Canada's west and east seacoasts and in the Hudson Bay - Hudson Strait region, as well as those federally-owned mineral rights in the provinces that become available for disposition. During the year the Division was transferred to the Energy Development Group from the Mineral Development Group.

In addition to the foregoing the Division gives policy recommendations and advice in regard to the offshore resources, provides representation and expertise in dealing with interdepartmental, federal-provincial and international offshore matters, and provides for coordination between government and industries concerned with utilization of offshore areas.

Offshore Mineral Rights

There have been differences of opinion between the federal government and the governments of the coastal provinces concerning their respective rights to the mineral resources off the west and east coasts. As a step towards resolving these differences, the federal government, in April 1965, after considerable consultation with the provinces, referred the question of ownership and jurisdiction over the resources of the seabed and subsoil off the west coast to the Supreme Court of Canada for an advisory opinion. The reference was pleaded in March 1967. In November 1967, the court

handed down the opinion that ownership and jurisdiction over these resources lie with Canada and are, therefore, the responsibility of the federal government.

The Prime Minister made a comprehensive announcement of the offshore situation in the House of Commons in December 1968, and followed this up with a further announcement in March 1969. In brief, he announced the establishment of mineral-resource-administration lines to divide areas of federal and provincial administration. The areas landward of the lines were to be administered by the appropriate provincial government, which would receive all mineral resource revenues accruing therefrom, and the areas seaward of the lines were to be administered by the federal government. The Prime Minister further announced that the federal government is prepared to place half the revenues accruing from mineral exploitation within the federally-administered areas off the east and west coasts and in the Hudson Bay region in a single national pool to be distributed among the provinces on a basis acceptable to them.

Offshore Exploration

Expenditures in excess of $18 million were made by industry on Canada Oil and Gas Permits during 1968, about $5 million more than was spent the previous year. This brought the total expenditures by the various companies engaged in exploration in Canada's offshore areas to more than $60 million. In this connection, the Division authorized more than 30 separate offshore exploration programs and ensured that they were carried out in accordance with federal requirements.

Highlights of 1968 included: (1) the continuation of extensive drilling off the west coast, with nine exploratory wells completed and abandoned during the year (one of these, Shell Anglo Sockeye B-10, reached a depth of 15,656 feet and was the deepest well drilled in Canada during the year); (2) the marked increase in demand for Canada Oil and Gas Permits, with eight times as many issued as during the previous year; (3) the announcement that two $12-million semi-submersible drilling units would be constructed at Halifax for extensive drilling off the east coast, one program to begin in 1969 and the other in 1970; and (4) the announcement of the first drilling program for Hudson Bay, to be carried out in the summer of 1969.

Canada Oil and Gas Permits

A total of 2,393 Canada Oil and Gas Permits covering 161.5 million acres were issued in offshore areas during 1968 as follows:

East Coast	1,463 permits	103,932,678 acres
West Coast	23 permits	964,976 acres
Hudson Bay	907 permits	56,587,207 acres

This brought the number of offshore Canada Oil and Gas Permits (except on the Arctic coast) to 5,356, covering 382 million acres, as follows:

East Coast	3,367 permits	255,254,816 acres
West Coast	256 permits	15,772,623 acres
Hudson Bay	1,733 permits	110,609,115 acres

The total revenues received during the fiscal year 1968-69 on behalf of offshore permits, including permit fees, transfer fees, forfeitures, maps and exploratory licences, amounted to $641,564.95, most of which was derived from permit fees.

Mineral Claims

Offshore mineral claims are issued for mineral rights other than oil and gas rights under the Canada Mining Regulations. A mineral claim usually covers an area approximately 1,500 feet square (about 52 acres). Five offshore mineral claims were recorded during 1968 off the east coast. This brought the total number of mineral claims to 356, distributed as follows: east coast, 161; west coast, 108; Hudson Bay, 67. Revenues received from the issuance of mineral claims and prospecting licences during the fiscal year 1968-69 amounted to $1,296.

Federal Lands in the Provinces

During 1968, twenty-three oil and gas leases were issued, five in Alberta and eighteen in Saskatchewan. This brought the total number of federal oil and gas leases in the provinces to 271. The revenues received during the fiscal year 1968-69 on behalf of oil and gas leases, including royalties, lease sale bonuses, rentals, extension fees, lease fees and assignment fees, amounted to $310,785.92, most of which was derived from royalties.