CANADA

Department of ENERGY, MINES AND RESOURCES

annual report 1967-68

Hon. J. J. Greene, Minister

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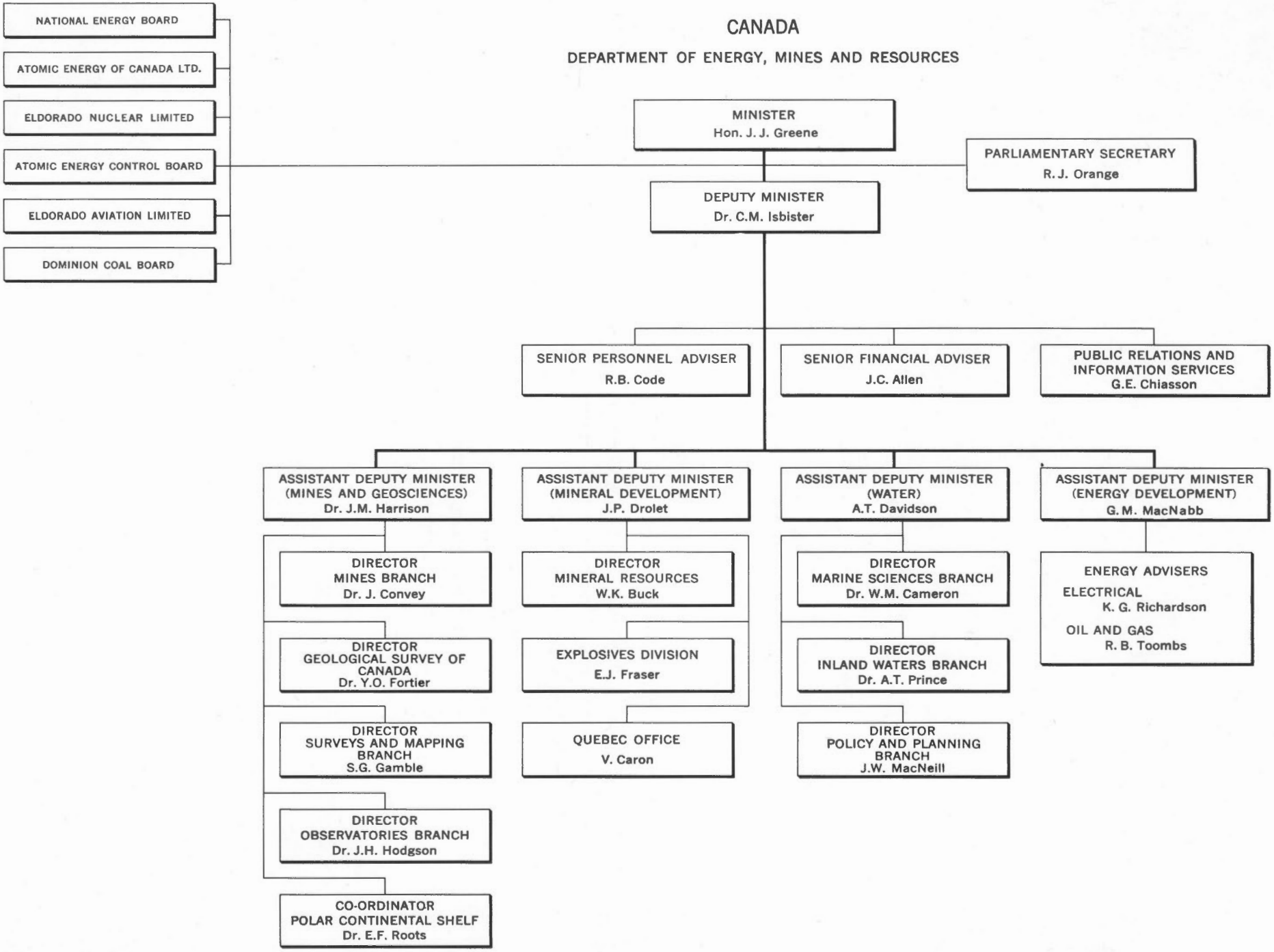
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INTRODUCTION

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 administrative and advisory 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. It has a staff of about 5,000 and an annual budget of approximately $114 million.

This report on the Department's operations is the first to cover a complete fiscal year rather than a calendar year, that is, from April 1967 to March 1968, inclusive. It is also the first report period during which the major units of the Department functioned according to the reorganization and expansion initiated in 1966. Noteworthy in this respect is the consolidation and expansion of water research in the Inland Waters Branch, the further development of a Water Policy and Planning Branch, and the organization of the Energy Development Group which in 1967-68 participated in a number of key studies and policy developments.

The programs of the Mines and Geosciences Group, are basic to many aspects of industrial growth and endeavour; and in 1967-68 the demands for information and services in this field reached new levels. The Surveys and Mapping Branch achieved a higher mapping output than in previous years, a gratifying advance due almost entirely to the introduction of new techniques and equipment, without an increase in personnel. Another important achievement was the completion of the topography for the 1:250,000 mapping of Canada. The Geological Survey of Canada sent out 99 full-time field parties and carried out two large helicopter-supported reconnaissance projects. Responding to the needs of the mineral industry, two new divisions were organized within the Mines Branch – a Fuels Research Centre and a Mining Research Centre. The scientists and technicians staffing these divisions concentrate especially on rock mechanics and operations control, on the one hand, and the processing of Canadian fossil fuels on the other.

The Observatories Branch further improved its time service: international time-keeping is now so exact that at current rates the atomic clocks at Ottawa and Washington would drift apart only by one thousandth of a second in the next forty years. The branch's geophysical observations were again expanded.

The Mineral Development Group, whose backbone is the Mineral Resources Division, played an important role in advising on and evaluating Canada's position in the Kennedy Round of negotiations under the General Agreement on Tariffs and Trade (GATT), which concluded in Geneva in June 1967. It also participated in many other reviews and formulations of mineral policy. The Resource Administration Division (during the review period still a part of the Mineral Resources Division) continued to review and grant exploration permits for Canada's offshore areas in the Atlantic, Pacific, and Hudson Bay, and held about $15 million in guaranty deposits in March 1968. Some 40 per cent of Canada's continental shelf area is now under exploration permits.

Of paramount importance in 1967-68 were the department's water programs and the abatement of water pollution.

Three new survey vessels were commissioned by the Marine Sciences Branch of the Department's Water Group, and another ship was readied for pollution studies on the Great Lakes. The Bedford Institute was being expanded. The Inland Waters Branch made a start in establishing the Canada Centre for Inland Waters at Burlington, Ont., by setting up a 25,000-square-foot trailer complex housing officers and research facilities. The Department will co-ordinate the research carried out at the Centre, in collaboration with other government agencies, universities, and private industry. The Policy and Planning Branch evaluated and elaborated the guidelines on pollution control promulgated by the Conference on Pollution and Our Environment, and helped to shape government water policy in other ways.

In Energy Development, officials participated in reviewing prospective Maritime and Newfoundland power developments, progress of the Atlantic Tidal Power Study, the Trans-Canada Grid Study, and several other regional and national ventures in producing and transmitting electrical energy. The Group also participated in studies of Canada's energy fuels – oil, gas, coal, and uranium.

MINES AND GEOSCIENCES GROUP

Surveys and Mapping Branch

The past fiscal year has seen substantial achievement. The output of all divisions was higher than in previous years, a fact that is borne out in more detail in the reports which follow. This increase in production was due almost entirely to the introduction of new equipment and techniques, personnel strength being essentially the same as the previous year.

The Geodetic Survey continued to extend and strengthen the national survey framework. The investigation of minute movements in the earth's crust continued, and a number of deep bench marks (some extending to 90 feet) were established to ensure that the markers would not be subject to the influence of surface changes such as frost effect. The Topographical Survey continued to use the aerodist for establishing horizontal control in wilderness areas and more conventional techniques to increase the density of the Geodetic network in other parts of Canada. The topography of 1:250,000 coverage of Canada was completed during the past fiscal year, except for three small islands in Hudson Bay which will be mapped as soon as control is secured by the Hydrographic Service.

The Legal Surveys and Aeronautical Charts Division continued the delineation and recording of Crown Canada Lands for their orderly and efficient use. In aeronautical charting four new types of charts were produced, and two existing series were extended to improve coverage. In map and chart printing, a new record of 31 million impressions was set during the past year. This increase of 6 million impressions over the previous high was made necessary by the heavy increase in both new map and chart production and the revision and reprint load.

The Interdepartmental Committee on Air Surveys carried out air photography in all provinces and both territories to meet requirements of ten federal departments. An increase in the use of colour photography by scientists and engineers was apparent. A new set of specifications for contract aerial photography was written and distributed during the year.

The Branch continued to provide technical advice to the External Aid Office in connection with control surveys and mapping projects carried out under the Canadian Technical Assistance Program as well as practical training connected with the same program. Senior Branch officials represented Canada at the Commonwealth Survey Officers Conference in London and at the International Union of Geodesy and Geophysics in Switzerland.

The annual meeting of federal and provincial survey directors was held in Fredericton, New Brunswick. The Branch sponsored two international conferences. The first was part of Canada's activity in the Pan American Institute of Geography and History, and brought approximately 40 experts from Latin America to Ottawa to study problems in regional and urban development with their Canadian counterparts. The second international meeting was in cooperation with the Canadian Institute of Surveying and the International Society of Photogrammetry. About 200 experts gathered in Ottawa to study advances in photo-mapping.

In the field of research, investigations into automated mapping systems continued sufficiently to crystallize the Branch's policy on the establishment of a pilot assembly line for the production of topographic maps. The new section, charged with program coordination, was established during the year under review. It has developed computer programs to control inventory, indicate reprint needs and plan revisions. In the years to come this section will be vital to all Branch planning.

Toward the end of the fiscal year the Branch made preparations to absorb the Toponymy Division, the Thematic Map Section and the Map Library from the Geographical Branch which was being dissolved.

GEODETIC SURVEY

Twenty 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 Geodetic Survey continued and expanded several 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, Manitoba and Saskatchewan, scale control was provided in existing networks; in the Northwest Territories from Dubawnt Lake to the Hudson Bay, also from Whitefish Lake (latitude 63°) to a point 60 miles north of Lac La Ronge in Saskatchewan. Three map-control points were established at Lynn Lake, Manitoba, for the Mapping and Charting Establishment. In British Columbia municipal control was established in the Greater Vancouver and Victoria areas. A loop from Trail to Creston via Proctor on Kootenay Lake was completed. In Saskatchewan scale control was completed in the Hague-Fife Lake net. In Southern Ontario a number of new stations for municipal control were established and a number of destroyed stations were re-established. In Northern Quebec horizontal control was extended from Richmond Gulf to Great Whale River. Ten stations of a triangulation network across Robeson Channel, N.W.T., were established to provide a control net for future studies on possible crustal movement between Ellesmere Island and Greenland. A local control net was established in the Port Hawkesbury, N.S., area. The Geodetic Survey co-operated again this year with the Topographical Survey in the establishment of a first-order aerodist network north from Lake Nipigon-Kenora and extending west to the Brandon-Dauphin triangulation net in Manitoba.

First-order levelling was carried out in the Northwest Territories and six provinces. In the Northwest Territories the line from Hay River to Fort Smith was completed, closing a 1,400-mile loop. A new line was completed between McMurray and Edmonton with a connection to Smith. In British Columbia the line from Prince George to Hudson Hope and an old line from Matsqui to Vancouver were re-levelled. A new line was levelled along the shore of the Peace River from Bennett Dam to Finlay Forks. In Saskatchewan the Geodetic Survey, in co-operation with the Topographical Survey and the Saskatchewan Survey Office, completed a new line between Lumsden and Fort Qu'Appelle. A winter levelling party completed 115 miles of levelling between Warrens Landing and Cross Lake in Northern Manitoba. In Ontario the line between Toronto and Kingston was re-levelled and a new line was run from Ottawa to Plantagenet. All connections to National Capital Commission monuments in the Ottawa-Hull area were completed. A new line between Amos and Mattagami in the Province of Quebec was completed. An inspection party checked 1,042 bench marks in southeastern Quebec. A number of deep bench marks were established between Toronto and Trois-Rivières – a new program started during this fiscal

year. In New Brunswick two new lines, from Bathurst to Newcastle via Caraquet and from Shediac to Sackville via Cape Tormentine, were completed. Demonstrations with the equipment for establishing deep bench marks were given for U.S. survey agencies.

Four astronomic parties worked in the Yukon Territories and four provinces. In the Yukon, a precise astronomic position for the U.S. Secor station at Whitehorse was determined, including azimuth observations. In British Columbia, 30 deflection stations and three Laplace stations were established in the Vancouver area, the Okanagan and Kootenays. Three Laplace stations were established in Alberta and a precise astronomic position was determined for the U.S. Secor station at Lynn Lake, Manitoba. Two Laplace stations and one deflection station were established in northern Quebec. A consolidated up-to-date list of astro-geodetic deflections of the vertical was prepared for the 14th General Assembly of the International Association of Geodesy in Lucerne, Switzerland.

A Research and Development group was set up last fall. Among other activities, a start was made on a long-range program to determine geoidal cross-sections and contours in Canada. New electronic-computer programs were developed for processing and analysis of data. The levelling section carried out preliminary tests with laser equipment. In the laboratory the usual maintenance and checking of all divisional electronic and radio equipment was performed and courses in electronic distance-measuring equipment were given to personnel in and outside our division.

The staff members again attended a number of national and international meetings and symposia. One member attended the Conference of Commonwealth Survey Officers held at Cambridge, England, and three members attended the 14th General Assembly of the International Association of Geodesy, as part of the International Union of Geodesy and Geophysics Meetings, in Lucerne, Switzerland.

TOPOGRAPHICAL SURVEY

In this year, the Topographical Survey experienced a high rate of production in new mapping and a heavy demand for special products. One highlight of the year was the virtual completion of the 1:250,000 series of maps for all of Canada; several islands in Hudson Strait remain to be mapped at this scale but bad ice conditions there in 1967 prevented necessary surveys. With emphasis on the 1:250,000 mapping thus reduced, it was possible to concentrate more effectively on 1:50,000 mapping, and the production rate at this scale was almost doubled. Mapping cleared for reproduction remained at about the normal level and consisted of 26 maps at the 1:25,000 scale, 418 at the 1:50,000 scale and 23 at the 1:250,000 scale, representing areas of 1,160, 76,500 and 117,000 square miles respectively. Included with the 1:50,000 mapping are 74 maps compiled previously by the Mapping and Charting Establishment, Department of National Defence, and transferred to this Division for editing.

Under the agreement whereby this Department prints the 1:50,000 mapping produced by the British Columbia Department of Lands, Forests and Water Resources, the Topographical Survey accepted 36 map sheets for review prior to clearing to Map Compilation and Reproduction for publication.

At the request of the Observatories Branch, the Topographical Survey embarked on a long-term program of blanketing the western mountainous regions of Canada with reliable height data required for gravity studies. Accurate positioning of the control points is inherent in the program, and the accumulated data will greatly assist future detailed and revision mapping. It is expected that provincial and Defence Department support will speed the effort.

Field Surveys. The Geodetic and Topographical Surveys again collaborated in using the aerodist system of trilateration to extend first-order geodetic control into northwestern Ontario and southern Manitoba, establishing 26 new positions. This operation included 6,000 line miles of aerodist-controlled photography required for 1:50,000 mapping control of 105,000 square miles of immediate interest to the Inland Waters Branch.

In 15 days in September, the aerodist system was used to correlate eight Geodetic Survey positions around the Gulf of St. Lawrence to provide control for hydrographic surveys. Aerodist-controlled photography was obtained for revision mapping of a major part of Anticosti Island.

The tellurometer traversing and trigonometric levelling, a basic requirement for the gravity program mentioned earlier, covered 27,500 square miles in southern British Columbia with about 300 control points, and incorporated positions established by provincial and other surveys.

Another air-supported operation assigned to a Mapping and Charting Establishment field party obtained control for detailed mapping of 24,500 square miles around Ross River, Y.T., where important mining and prospecting development is taking place. This party also made observations on the Steele Glacier to make possible a new plot of its progress.

For several years, the Department has been assisting municipalities and other local bodies to establish co-ordinate systems of control surveys. Spirit levelling became an important part of this service in 1967. Six field parties undertook surveys of this nature in the Canso Strait area, Liverpool and Lawrencetown in Nova Scotia; Ottawa, Niagara Falls, St. Catharines, Welland, Barrie, Orillia, Kitchener, Waterloo, Brantford and London, and for the Department of Highways, in Ontario; Grande Prairie in Alberta; and Vancouver, B.C. Reconnaissance for the following year's work has become an accepted part of these assignments.

The Division continued the service of issuing notification lists and distributing advance information prints of new mapping. The latter amounted to over 1,000 prints per month.

Air Surveys. Work on the 1:250,000 series of National Topographic Series maps consisted of clearing the last 30 sheets through the final stages of compilation. With this mapping virtually completed, it was possible to use staff and plotting instruments more effectively, and this has resulted in a marked increase in production of 1:50,000 mapping. Modern equipment and new procedures are greatly assisting progress toward more economical production of detailed mapping and revision of older mapping. Work began on revision of the 1:25,000 map series in Vancouver and Calgary.

There was a continuing demand for special mapping, ranging in size from a simple plot taking one day to mapping 5,400 square miles of the Slave River lowlands for the Department of Agriculture, a project that required several months. Most of these requests came from other branches within the Department, particularly Marine Sciences and Inland Waters. Photomaps and controlled mosaics, introduced in 1967 as map substitutes, proved very popular with all users of specialized maps and accounted for about one-half of the 80 individual or group projects undertaken.

LEGAL SURVEYS AND AERONAUTICAL CHARTS

Legal surveys in Indian Reserves, national parks and the territories were carried out as usual. Of particular interest is the large modern subdivision undertaken at Morphy, west of Yellowknife, as a new settlement for the Indians presently located at Fort Rae.

Sixteen field parties were engaged on legal surveys in the public lands of Canada. In addition, contracts were arranged with 23 private survey firms for government surveys, and technical instructions were issued for 167 surveys on Crown Canada Lands for private and provincial agencies. Surveys on 73 Indian Reserves accounted for the major part of the field work. The survey of six new historic sites in the Maritimes and lot and parcel surveys in Banff and Jasper townsites completed the work in the provinces. In the territories, establishment of local control networks for legal surveys was continued with new ones established for the Yellowknife and Carcross areas and extensions made to those at Vangorda Creek and Ross River. Subdivision surveys were carried out at Eskimo Point, Rankin Inlet, Dawson Landing, Fort Simpson, and Pine Point in the Northwest Territories, and at Ross River and Whitehorse in the Yukon. Photo control for the extension of large-scale mapping was established at Eskimo Point, Rankin Inlet, Baker Lake, Fort Resolution, Fort Simpson, and Fort Smith.

Two commissions for interprovincial and territorial boundaries were active in the period from April 1, 1967. The survey of the north boundary of British Columbia was ratified by Parliament. The resurvey of the southerly 240 miles of the Manitoba-Saskatchewan boundary was begun and approximately 100 miles of trial-line survey were completed.

Survey documents entered in the Canada Lands Surveys Records numbered 631 plans and 216 field books. About 53,200 document extracts, publications and astronomical field tables were dispatched, and information on 2,294 airline distances was provided for official purposes.

In aeronautical charting four new kinds of charts were produced, and two existing series were extended to improve coverage. An aeronautical chart at the scale of 1:1,000,000, designed to meet the needs of civil and military visual air navigation, was produced to test its national and international suitability. An air-facilities-planning chart of the province of Saskatchewan was produced at provincial request, and an information chart was developed and produced for passengers on Department of Transport aircraft.

The Board of Examiners for Dominion Land Surveyors met ten times. Six centres were selected for the 1968 annual examinations. Of the 30 candidates examined three passed their preliminaries, five their intermediates, and five qualified for the Dominion Land Surveyor commission.

INTERNATIONAL BOUNDARY COMMISSION

The International Boundary Commission continued the joint annual maintenance required for the effective definition and marking of the boundary between Canada and the United States. Inspections were carried out on various parts of the line, and three Canadian field parties completed maintenance on five sections.

The Commissioners for Canada and the United States made joint inspections of conditions along the boundary, including the work of field parties completing maintenance on various sections of the line from New Brunswick westward to Saskatchewan.

The three Canadian field parties completed the following maintenance operations:

1) On the New Brunswick-Maine boundary: 34 miles of 20-foot-wide vista were treated with herbicides to retard undesirable growth. One hundred and eleven monuments were inspected, and five were repaired.
2) On the Highlands section of boundary between Quebec and Maine, 19 miles of 20-foot-wide vista were recleared and stump treated with herbicides, 494 monuments were inspected, seven monuments repaired, and one ornamental monument established.
3) On the 45th-parallel section of the boundary, between Quebec and Vermont, distance measurements were made by geodimeter between monuments along 23 miles of the line. Fifty-four monuments were inspected during the course of the geodimeter work.
4) In the Great Lakes district the positions of buoys marking the line through western Lake Erie were checked; observations were made to improve the location of five control stations along the Detroit River and one reference monument on the St. Clair River.
5) An aerial application of herbicides was made to retard undesirable growth on an 80-mile section of boundary in the Kootenay district of British Columbia.

Altogether, Canadian parties recleared 19 miles of boundary vista, treated 133 miles of vista with herbicides, measures 23 miles of line with geodimeter, inspected 659 monuments of which 12 were repaired, and located 10 boundary monuments and markers.

MAP COMPILATION AND REPRODUCTION

Map and chart production for the year was slightly higher than for the previous year.

Maps received from the Topographical Survey for reproduction numbered 288. These included 30 at the scale of 1:25,000; 229 at 1:50,000; and 29 at 1:250,000.

Maps received from the Mapping and Charting Establishment for plating and printing numbered 62. These included 2 at 1:25,000; 47 at 1:50,000; and 13 at 1:250,000.

Maps and charts printed numbered 4,455. Of the total, 2,060 were printed on the large offset presses and 2,395 on multilith.

In the spring of 1967, the status of the 1:50,000 series stood at 28.9 per cent published for 6,304 sheets of a potential 21,814. The status of the 1:250,000 series stood at 88.9 per cent published, or 878 of a potential 918.

The conversion of the eight-mile series to 1:500,000 was 86.8 per cent complete, with 191 maps.

Thematic Mapping Unit. With the dissolution of the Geographical Branch, various divisions of that branch were transferred to other parts of the department. The Division of Regional Geography was incorporated within the Map Compilation and Reproduction Division and renamed the Thematic Mapping Unit. The following is a summary of that unit's work during the past fiscal year.

Multi-color maps: A map, entitled *Territorial Evolution of Canada* and published in English and French, showed the growth of Canadian territory and boundary changes from 1667 to 1949. Another map was entitled *Atlantic Provinces and Economic Activity*. A composite of seven maps showing the economic geography of the Atlantic provinces was produced for the Atlantic Provinces Economic Council.

Urban Analysis Series: A number of maps of Toronto showed density of buildings, land slope and elevation, and broadcasting facilities. These maps were prepared for the Emergency Measures Organization. Another series of maps portrays soil types and elevator services in a region of Saskatchewan.

Work continued on the desk atlas of Canada. In the Urban Analysis Series, research and field work were completed for 22 maps of Montreal. Cartographic work continued on 15 maps of Toronto and 21 maps of Montreal.

Research and cartographic processing were done on a revised edition of the Natural Resources Map of Canada.

AIR-PHOTO AND MAP DISTRIBUTION AND CIRCULATION

National Air Photo Library. During the period under review, 6,620 requisitions for photographic work, the highest annual total in the Library's history, were prepared for processing. These requisitions covered 711,905 reprints from federal government air-survey negatives (contact prints, enlargements, multiplex diapositives, mosaics, lantern slides, etc.).

The Library received 97,385 new photos, bringing the total of the Library collection to well over three million.

In addition to the air-photo requirements of the various federal government departments, the Library fulfilled requests from provincial government departments, municipalities, exploration and development companies, educational institutions, religious groups, publishing firms, professional societies, and private individuals.

Twenty-five thousand copies of a new pamphlet *How to order air photos* were distributed, and a further 15,000 copies were ordered for future distribution.

Progress continued on the program to copy, on 70-mm film, some 800,000 prints from nitrate-base negatives. Over 200,000 prints have been copied to date. The purpose is to preserve this pictorial history of Canada accumulated between the years 1920 and 1940.

Preparations have almost been completed for the Western Branch of the National Air Photo Library. This unit will be located in the Institute of Sedimentary and Petroleum Geology of the Geological Survey of Canada at Calgary, and will maintain a file of federal government air-survey photos covering the four western provinces, Northwest Territories, Yukon, and the Arctic Islands.

Mail was received from over 50 universities, and 14 nations.

Map Distribution. During the past twelve months, distribution facilities for maps, air charts, and *Canada Air Pilots* were further integrated. Automatic data-processing equipment is being installed to control the more than 22,000 items in the map inventory. The accounting system was modernized and adapted to a monthly printout of customer account statements on an IBM 407 computer.

The number of maps and air charts distributed to civilian clients rose to 1,871,492 during the past year, and the distribution to the Canadian Forces rose to 1,852,075 during the same period. This was an increase of 18 per cent over the previous fiscal year.

This office acquired the distribution of the *Canada Air Pilot* series from the Department of Transport. Since most of the items in this category are being printed in the Surveys and Mapping building, the transfer made for greater efficiency.

Bulk holdings of maps now stand at 16,789,244, an increase of only 598,626 maps and air charts during the year. More topographic maps were distributed than printed.

The distribution facilities for maps and air charts are being expanded with the establishment of a new distribution centre in the new Institute of Sedimentary and Petroleum Geology in Calgary. It will carry a complete stock of maps covering the four western provinces, the northern territories, and the western arctic islands.

SECRETARIAT, CANADIAN PERMANENT COMMITTEE ON GEOGRAPHICAL NAMES

Departmental reorganization resulted in the transfer of the former Toponymy Division, Geographical Branch, to the Surveys and Mapping Branch, where it became the Secretariat, Canadian Permanent Committee on Geographical Names. This unit maintains name records, advises the Permanent Committee and mapping agencies on nomenclature and conducts regional investigations into geographical names. It is also responsible for advising on geographical terminology and for the production and maintenance of the Gazetteer of Canada.

During the fiscal year 1967-68, the secretariat investigated almost 11,000 names, and nearly 4,000 new names were officially approved. The nomenclature was verified for 159 maps and charts, and over 500 inquiries concerning geographical names from members of the committee, the mapping agencies, other government departments and the general public were answered. Work continued on the *Gazetteer of Quebec* and the revision of the *Gazetteer of Manitoba* was completed. The second edition of the *Gazetteer of British Columbia* was published in early 1967 and the first edition of the *Gazetteer of Newfoundland and Labrador* in early 1968. Work was begun on the revision of the *Gazetteer of Saskatchewan.*

Field investigations were carried out in the Muskoka Lakes region in Ontario and a comprehensive study began of the nomenclature of New Brunswick.

The committee contributed four preliminary papers to the first United Nations Conference on the Standardization of Geographical Names held in Geneva in September 1967, at which Canada was represented by the chairman, the executive secretary and two provincial members of the committee. The annual meeting was held in Fredericton, where the committee endorsed the use of a standard orthography for the Eskimo language. During the year, the committee approved the naming of a feature in honour of the late Governor General George Vanier and the changing of the name Lake Saskatchewan to Lake Diefenbaker.

Geological Survey of Canada

The Geological Survey is responsible for the systematic geological investigation in Canada, and as the major organization engaged in this field in Canada its studies are nation-wide. During the report period, the Survey marked its 125th anniversary, and, in conjunction with Canada's Centennial Year, it hosted several national and international symposia. The main objectives of the Survey are to investigate systematically, describe and explain the geology of Canada in order to determine the nation's potential mineral resources and to provide industry and other governmental agencies with basic data required for the discovery of mineral deposits. The Survey also carries out research that will contribute to our knowledge of how and where the rocks of the earth and their contained mineral deposits were formed, research and development of new instruments and methods as aids to the search for mineral deposits and for geological investigation,

and assists in operational research training in the geological sciences and the supporting techniques to meet the requirements for qualified manpower.

In 1967-68 the Survey provided support for 26 doctorate-theses projects through summer employment. A total of 70 graduate assistants were employed in the field and 37 in the office; 123 student assistants were attached to various field parties and 53 were assigned to office duties.

During the 1967 summer season 99 full-time field parties conducted investigations designed to continue the systematic geological investigation of Canada. In addition there were 75 part-time projects, most of which were collecting support data for other research. Two large, multi-discipline, helicopter-supported reconnaissance projects were carried out. One of these initiated a two-season mapping program in the rugged terrain of northern Labrador and northeastern Quebec. The other saw the mapping in one season of Hudson Bay Lowland, an area of more than 130,000 square miles. The activities of the smaller parties ranged from detailed studies of recently discovered base-metal deposits in Yukon Territory to aeromagnetic investigation of Baffin Bay and the North Atlantic Ocean; from a mineralogical study of asbestos deposits to a study of indicator minerals in eskers; from marine geological investigations of the North Atlantic to dam-site investigation in northern Ontario and geological engineering studies near the site of the new Welland Canal.

To stimulate and support geological research at Canadian universities, 90 grants totalling $185,000 were awarded to 21 universities.

The scientific results of the Survey's work are published as memoirs, bulletins, papers, geological maps and to some extent as contributions to scientific journals. During the period covered by this report, 3 memoirs, 9 bulletins, 1 economic geology report, 2 miscellaneous reports, 78 papers and 16 geological maps (excluding those used to illustrate the preceding reports) were issued. About 350,000 copies of reports and maps were distributed, mainly from the Ottawa office, although about 10 per cent of the total distribution was from the Vancouver office.

The Geological Survey library, the most extensive of its kind in Canada, had a circulation of 50,712 items during the report period. In addition nearly 6,000 inquiries were answered, of which about 1,500 required information searches.

In addition to the headquarters in Ottawa the Survey maintains offices in Vancouver, Whitehorse and Yellowknife. The Calgary office was incorporated into the newly formed Institute of Sedimentary and Petroleum Geology, a division of the Survey, at the beginning of the report period.

BIOSTRATIGRAPHY

Fossils are of great importance to the geologists who need to know the regional and intercontinental equivalents of stratified rocks, knowledge that is of great importance in the search for the fossil fuels—oil, natural gas and coal. During the report period paleontologists of the division prepared 158 reports on 2,818 lots of fossils. Although most of the collections were submitted by Survey officers, about 475 came from industry, universities and individuals. In Canada and elsewhere more than 30 experts on particular groups of fossils or students working under the supervision of such experts studied Geological Survey material, studies that either resulted in reports to scientists or in publications. Nineteen geologists from universities, oil companies, and from other countries made use of the Survey's fossil collections or consulted with staff members.

Investigations on the petrology of Canadian coal and Paleozoic palynology were continued and fundamental research on the origin and effects of geological conditions on the various coal constituents was undertaken. Drilling by the Nova Scotia Department of Mines at the Pictou coalfield, carried out under the guidance of the Survey's Coal Research Section, was completed and revealed the presence of 300,000 tons of mineable coal. Research on coking coals was continued with emphasis on the Crowsnest coalfield, which is of particular interest because of the recently completed long-term sale of coal from this field to Japanese interests.

CRUSTAL GEOLOGY

The prime objective of the Crustal Geology Division is to study and interpret the folded, metamorphosed and igneous rocks that form the earth's crust in Canada in order to provide basic data required to forecast, find, and evaluate our mineral resources and to provide scientific knowledge on the origin and evolution of the earth's crust under Canada. Sixteen field parties carried out studies in the Cordilleran and Pacific Margin region, twenty on the Canadian Shield, six in the Appalachian region, and six on projects designed to support research into geochronological and petrological subjects.

In the Cordilleran region current activities consist mainly in the completion of the reconnaissance phase of the regional investigations in which data and conclusions on structure and stratigraphy are integrated to develop a broad tectonic picture. During 1967 field work was completed on several systematic reconnaissance projects including Operation Selwyn, a 25,000-square-mile mapping program in southeastern Yukon, and McBride, Lardeau, Mount Waddington and Alberni map-areas in British Columbia. Detailed studies were carried out in the Anvil Range of central Yukon to aid mineral exploration in the region surrounding the Faro, Vangorda, and Swim base-metal deposits. As most of the geologists associated with Cordilleran geology are stationed at the Survey's Vancouver office, they are frequently consulted by businessmen engaged in the exploration and exploitation of the mineral resources of British Columbia and Yukon Territory and this provides a useful and practical public service.

The Precambrian Shield Section is responsible for the study of the nearly 2,000,000 square miles of "foundation rock" which forms the Canadian Shield and which contains so much of Canada's metallic mineral wealth. Thanks to the advent of the helicopter and other recent improvements in transportation, the reconnaissance study of the Shield is almost complete; the only large unmapped tracts remaining are central and northeast Baffin Island, parts of northern Labrador and Quebec, Southampton Island and northern Melville Peninsula in the central Arctic, and certain areas along the north shore of the St. Lawrence River.

The major reconnaissance carried out in 1967 was Operation Torngat, during which 30,000 square miles of rugged terrain in northern Labrador and northeastern Quebec were mapped with the use of helicopters. Helicopter support was also shared by parties working in southern Keewatin District on problems concerning granitic and metamorphic rocks and a sedimentological and stratigraphic analysis of the Hurwitz Group. A study of volcanic rocks in the Shield was continued by the sampling of 782 volcanic units in the Timmins-Kirkland Lake-Noranda region.

Several members of the staff continued specialized research by spending periods of several months at universities and research institutes in Canada and the United States. A series of seminars was given by guest experts, staff members, post-doctoral fellows and Ph.D. candidates during the year. These seminars kept the sectional staff abreast of recent developments in Precambrian geology.

The Appalachian, Eastern Lowlands and Atlantic Margin Section studies the composition, stratigraphy and structure of post-Precambrian rocks in these various regions of Canada (including the Hudson Bay Lowland) and evaluates the implications of these features on the potential for mineral and petroleum resources. Field investigations were carried out in Burgeo, Burlington Peninsula and the Great Northern Peninsula in Newfoundland, in Cobequid Mountains and Antigonish areas of Nova Scotia, and in McKendrick Lake area of New Brunswick. A major helicopter-supported reconnaissance of the lower Paleozoic rocks of Hudson Bay Lowland was carried out; a map including the preliminary results of this investigation which covered 130,000 square miles was published early in 1968 and was of considerable interest to oil companies.

Members of the Petrology Section continued studies of ultramafic and granitic rocks, the role of water in metamorphic and igneous rocks, meteorites, and ocean-bottom sampling off the East Coast. The section also provided advice and specialized petrographic services to staff officers, and looked after the rock, thin-section and meteorite collections of the Survey.

The year under review was an eventful one for the Geochronology Section whose members are responsible for research, development and services in isotope geology, and for co-ordinating the Survey's age-determination and stable-isotope-investigation program. New facilities became available and new experimental procedures were perfected, so that it has been possible to inaugurate new methods of isotopic dating. The age-determination program was continued, and 215 K/Ar sample extractions were completed. Suites of rocks were collected from 12 localities for Rb/Sr whole-rock isochron dating and isochron ages were successfully completed for 10 of the suites. The Canadian Isotopic Age Data Centre, established to meet Canada's international obligations to the International Council of Scientific Unions, will include data derived from research at the Geological Survey along with those from other Canadian and foreign institutions.

EXPLORATION GEOPHYSICS

The Exploration Geophysics Division makes geophysical surveys as an aid to the understanding of the geology of Canada and carries out research on the development of new methods and instruments. During 1967-68 aerogeophysics was accelerated with the installation of a high-resolution magnetometer in a Queen Air aircraft, the lease of a Skyvan aircraft for gamma-ray spectrometry and remote airborne sensing, participation in an airborne infrared scanning program, and increased airborne electromagnetic work.

In October 1967 the Geological Survey and National Research Council sponsored the Canadian Centennial Conference on Mining and Groundwater Geophysics which was attended by more than 550 delegates representing 51 countries. Officers of the division were deeply involved in this most important conference as they were in an Earth Science Symposium on Hudson Bay which was held in Ottawa in February.

During the 1967 field season about 25 parties were active for varying periods of time. Their activities included seismic studies, ground gamma-ray spectrometer survey and palaeomagnetic measurements. The co-operative aeromagnetic project with the National Aeronautical Establishment was continued and investigations were carried out in the Arctic, over the North Atlantic Ocean, and near Ottawa. Contracts were let for aeromagnetic surveys in the area of the Polar Continental Shelf, in central Baffin Island, and in the District of Mackenzie.

GEOCHEMISTRY, MINERALOGY AND ECONOMIC GEOLOGY

This division studies mainly those aspects of geology that contribute most directly to our knowledge of the occurrence of economically important elements and minerals, the search for mineral deposits, and methods that may be useful in prospecting. The division contains the following sections: Geochemistry, Geology of Mineral Deposits, Mineralogy, Analytical Chemistry, Geomathematics and Data Processing, and a Special Projects unit.

The major research projects during 1967-68 were (1) the co-ordinated study of the geology of mineral deposits by a group of economic geologists, each of whom is responsible for a group of economic elements; (2) the development and testing of geochemical prospecting methods; (3) mineralogical studies of ore and rock-forming minerals; (4) the long-term implementation of a geochemical census of economic elements in the crustal rocks of Canada.

In the first category, work was continued on the preparation of a map showing the distribution and general geological environment of nickel deposits in Canada; a study of iron-sulphide, carbonate and oxide mineral-phase relations was initiated; a metallogenic index map for copper deposits in the Cordilleran region was nearly completed; study of the geochemistry of carbonate-lead-zinc deposits was continued; studies of lithium, tin, and beryllium and a metallogenic study of the Cassiar batholith were continued; a major report on uraniferous conglomerates was completed; a metallogenic map for Canada (a contribution to the International Geological Congress held in Prague, August 1968) was prepared; and development work on chemical field tests for detecting rare-earth elements was continued.

Geochemical techniques designed specifically for Canadian conditions are being developed and studies are in progress on the migration of elements from known ore deposits in glacial tills, the soil and stream sediments derived from these tills and the vegetation growing on them. Rapid analytical methods and computerized methods of data interpretation now make it possible to study seriously the composition of the rocks of Canada. Such data will be of value not only to geology but to other disciplines such as agriculture and health. These data are also expected to be of great value in developing deep-exploration methods. Thus it seems possible that geochemical methods can establish the probability of ore deposits in certain rocks at depth, and drilling may be carried out on the basis of this probability.

Mineralogical studies made by the division cover the physical and chemical properties of minerals and the geological significance of mineral associations and textures, and use X-ray diffraction, X-ray emission and absorption, and electron-beam techniques. The Survey's mineralogists provide a wide range of services to staff members, compile and publish data on Canada's minerals, examine rock and mineral specimens and prepare rock and mineral collections for sale as a public service, and catalogue and develop the National Mineral Collection and the Systematic Reference Series. During 1967-68 more than 6,500 sets of rocks and minerals were sold and 868 samples examined.

Chemical and instrumental analyses were continued to provide compositional data on geological materials. A total of 68,668 individual determinations were made. Work continued towards the development of geomathematical and data-processing techniques. Three senior staff members carried out special projects. A revision of *Prospecting in Canada,* which has sold about 30,000 copies so far and ranks as one of the Department's best sellers, was nearly completed during the report period and a report on the Walton, Nova Scotia, barite-sulphide deposit was completed. The co-ordinator of the Geological Survey's uranium research carried out field studies and organized study sessions at the

Vancouver office, the Institute of Sedimentary and Petroleum Geology, Calgary, and at Ottawa. These sessions helped to alert those working in areas favourable to uranium deposits and to brief them on the guidance to be offered in response to public enquiries about uranium prospecting.

INSTITUTE OF SEDIMENTARY AND PETROLEUM GEOLOGY

This division of the Geological Survey is a natural outgrowth of the regional office set up in Calgary in 1950. Its task is to discover, through field and laboratory research, the geology of the western and northern sedimentary basins from the International Boundary to the Arctic Islands and between the Canadian Shield and the Rocky Mountain Trench. The scientific work of the Institute is carried out by 6 research sections, which in 1967-68 were made up of 33 scientific and professional staff, 19 technical staff and 13 administrative support staff. The Institute collaborates closely with other government agencies, universities, scientific societies, and industry.

Field work was carried out by several parties of the Arctic Islands Section mainly on western Devon Island and Ellesmere Island. Five staff members of the Structural Geology Section undertook investigations in Canada's sedimentary basins. Studies of structural fabrics in coal measures in the Cordilleran and Appalachian regions were continued. Members of the Paleozoic Stratigraphy Section provide basic research towards establishing a stratigraphic and historical framework both in outcrop and subsurface for Paleozoic rocks in Western Canada. During 1967-68 plans were made for Operation Norman, a two-season helicopter-supported reconnaissance designed to map 115,000 square miles in the District of Mackenzie. One member of the section planned and conducted a graduate seminar at the University of Calgary. The Mesozoic Stratigraphy Section carried out studies in Saskatchewan, Alberta, northeastern British Columbia, Ontario, and the Arctic Islands. These studies, designed to determine the lithological variations, stratigraphic relationships, and the potential as source rocks and/or reservoirs of oil, gas, and coal, for Mesozoic rocks, are carried out in collaboration with areal geological, paleontological and palynological studies. The Paleontology Section of the Institute is responsible for research in paleontology and biostratigraphy in western and northern Canada. A total of 1,104 lots of fossils were examined and 40 individual reports were prepared. In addition 13 reports on 384 lots of fossils were prepared by outside experts for Survey officers. The Petroleum Geology Section, formed late in 1967, held extensive discussions with key members of industry and with provincial and federal government organizations in order to establish the Survey's role in relationship to the oil industry. As a result of these discussions it is felt that the general areas of interest in which the Institute could be most useful include the following: (1) broad, regional subsurface studies; (2) geochemical investigations, particularly organic geochemistry; (3) detailed paleontology; (4) broad studies of already discovered oil and gas accumulations.

QUATERNARY RESEARCH AND GEOMORPHOLOGY

This division was formed during the report period by the amalgamation of former units of the Geological Survey and Geographical Branch. It provides scientific knowledge of unconsolidated deposits and landforms, the processes that modify the landscape, and the history and physical and biological environments on the earth during the Quaternary, including information pertinent to forestry, agriculture, engineering, groundwater, and mineral exploration.

Members of the Regional and Stratigraphic Projects Section undertook field work in seven provinces and the Northwest Territories in 1967 in order to prepare geological and geomorphic maps and reports designed to provide both a regional scientific framework and information of value to those engaged in studies of forest and agricultural soils, groundwater occurrences, engineering factors in construction, and mineral exploration. Inventory mapping of the glacial and related deposits in the Prince George, British Columbia, area was completed and reconnaissance studies of the glacial geology and geomorphology of southern Ellesmere Island were begun during the report period. Among the other projects undertaken by the section during the 1967 field season was the mapping of the Quaternary geology of the Hudson Bay Lowland. The completion of this work filled a large gap in the knowledge of the geology of this part of Canada. Studies were undertaken in southwestern New Brunswick to provide areal data pertinent to groundwater occurrence.

The Sedimentology and Geomorphic Processes Section investigates processes of landscape change involving slope movement and erosion, frost action (including permafrost), weathering, sediment movement, and sediment accumulation. These studies provide basic data, background information for interpretation of rocks and soils of earlier time, and information that is significant in forestry, agriculture, and in engineering studies and mineral prospecting. During the past year the work of the section has included an analysis of the stratigraphy, sedimentary structures, texture, and mineral composition of varved sediments and an interpretation of their depositional environment. Reports on sedimentation in Lake Erie and Lake Ontario were prepared for the International Joint Commission.

The Paleoecology and Geochronology unit provides radiocarbon dates and analyses of fossil materials (particularly pollen). It also determines variations in radiocarbon content of modern materials as background for other research, investigates the chronology of fossil-bearing deposits, and conducts research on changes in environment and in plant and animal distribution during the Quaternary.

The Engineering and Indicator Geology unit applies Quaternary studies to engineering and mineral exploration. Research is carried out on those aspects of geology that affect the engineering behaviour of soils, and geological investigations of engineering sites or problems are made by the unit on request from governmental agencies. Methods of mineral exploration that involve tracing indicator materials in glacial or other unconsolidated deposits to their bedrock source are also undertaken. An interesting application of this technique resulted in extensive prospecting in the Kirkland Lake area of Ontario for kimberlite, which in South Africa is the host rock for many diamond occurrences.

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 so as 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 mineral sciences, the emphasis is on the composition and properties of useful minerals. The complicated sulphides occupy much attention, as do multi-oxide 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 Division carried out both fundamental and applied studies concerning improved properties and processing of metals and alloys for many diverse applications in industry, public service and national defence.

To mark Canada's Centennial, a seminar was presented on June 12 and 13, at which twenty papers on the work of the Division were presented by staff members. Visitors from across Canada, Great Britain and the U.S.A. attended, and many took the opportunity to visit the laboratories and to discuss technical matters with Divisional staff.

As in previous years, the Division continued to meet many requests for consultation and technical advice on metallurgical problems from industry as well as from other government departments and agencies. A total of 43 *Investigation Reports* and 23 *Test Reports* were issued in connection with work done on such problems. Some 116 requests for metallurgical information were received and dealt with for the Technical Information Service of the National Research Council, and 126 reports and publications were prepared and issued during the period.

The facilities of the Divisional laboratories were extended to six outside organizations including the Steel Castings Institute of Canada, Canadian Zinc and Lead Research Committee, National Aeronautical Establishment, Falconbridge Nickel Mines, Canadian Westinghouse, and Noranda Research Laboratories. These organizations supply one or more employees who work on specific assignments in conjunction with Divisional staff.

Outside activities of staff members included 50 lectures and papers presented to learned societies and technical groups in Canada and abroad, in addition to the Centennial seminar referred to previously.

The work of the Division may be divided into two broad classifications: research, both fundamental and applied, and investigational activities which may be urgent as well as long-term. Investigation of failed or damaged metal components, particularly in

industrial and military equipment, has long been an important service, especially when it is possible to recommend preventive measures. During the past year many such investigations were made. They included examination of cast ship's propellers, steel plate from ship's hulls, broken spring from large ore-sizing-screen installation, gun barrel, rail steel, and ruptured and corroded boiler tubes among ferrous components. Of some technical and historical interest was an investigation of some wrought-iron nails recovered from sunken ships in Georgian Bay in an attempt to establish the age of the vessels. The metallurgical character of some of the nails indicated manufacture in the period 1800-1870. Investigational work on non-ferrous alloys included examination of defective small-arms ammunition cases, manganese-bronze ship propellers, magnesium alloy components of military shot, and defective connectors for solar cells. At the request of the Ontario Fire Marshall's office a section of extruded aluminum-alloy window frame recovered from a hospital fire was examined to estimate the temperature of exposure.

In other fields investigation of failures of welded gas pipelines continues to provide useful information for improvement in material and welding quality. Investigations of welding problems associated with rocket launchers and battery connections in space satellites indicate that Mines Branch work keeps pace with the latest scientific developments.

The Division acts as the examining aauthority for the certification of industrial radiographers on behalf of the Canadian Government Specifications Board. In 1967, written examinations were held at nine centres across Canada and practical tests conducted in Ottawa, Edmonton and Victoria. During this time, 83 junior-grade and 30 senior-grade industrial radiographers were successful in their examinations for certification. There are now 180 senior-grade and 430 junior-grade certified industrial radiographers in Canada.

Radiographers can now be certified in the category of "Aircraft Structures." Practical tests on aircraft are conducted at the Air Force Base, Trenton, Ontario, under the direction of the examining authority.

Fundamental and applied research provides many of the bases for current and prospective improvements in materials and processing technology. Work of the Division in these areas is directed to matters of particular significance to the Canadian scene, particularly in iron and steel research. Studies of the solidification process and the development of controlled-cast structures, it is hoped, will lead to material improvement in casting quality and superior mechanical properties. Research into new and improved melting and refining techniques, degassing and inclusion elimination as well as alloy development are all important continuing activities. The direct measurement of oxygen content in molten steel by means of an electronic probe has been developed to the stage where commercial interest has been aroused.

Research of more fundamental nature is being done in such areas as the physics of liquid metals, studies of segregation using radioisotopes, fatigue characteristics of zinc, brittle fracture, hot-working and recrystallization of face-centred cubic metals, studies of forgeability, among many other projects. All of these relate directly or indirectly to applied research and development problems, it being an objective to maintain a realistic balance between research in fundamental metal science and applied metallurgy.

FUELS RESEARCH CENTRE

The production of mineral fuel is undergoing many changes all over the world, and this is strongly reflected in the activities of the Fuels Research Centre, which is concerned

with the numerous aspects of chemical-process engineering required to transform coal, low-grade petroleum and natural bitumen into industrially acceptable products.

A most significant turning point for the coking-coal industry of Western Canada occurred during the year. This was the signing of contracts for the export to Japan of about 5½ million tons of coal per year over the next fifteen years. Deliveries are to begin during 1970-71. Contracts for an additional two million tons per year may be concluded in the near future. Over the fifteen-year delivery period this would expand the total market for Western Canadian coking coal to 1½ billion dollars.

To insure the continuance and expansion of these markets, the Fuels Research Centre has attempted to maintain and improve its processing capability on the pilot scale, so as to reduce new technical innovations to practice as quickly as possible. This service is essential for the Canadian coal industry, as its wide geographic dispersion prevents this type of work from being performed by individual companies. The advanced state of Japanese technology and scientific facilities requires that Canadian laboratories maintain the highest standards to insure a satisfactory dialogue with this purchaser.

In this connection, the progress on the relocation of the Fuels Research Centre on the western outskirts of Ottawa is encouraging. The indications are that at least some of the buildings will be ready for occupancy in the fall of 1968. A program to modernize the laboratory facilities associated with the relocation has been under way during the past year in preparation for this move. The purchase of new equipment for the construction of a modern 18-inch oven, which will carbonize an 800-pound charge of coal, is substantially complete, and installation will commence as soon as the state of construction at the Corkstown Road site permits. This particular research is conducted by the Metallurgical Fuel Engineering Group which works closely with the metallurgical industry to find new techniques of matching Canada's coal resources to the special needs and requirements of this industry.

Satisfactory progress has been made during the year on the removal of pyrite from Cape Breton coals destined for use in the local steel industry in the form of coke. This experimental work has made it possible for engineering consultants to arrive at a cost estimate of pyrite removal acceptable on an industrial scale and employing established coal-cleaning technology.

The outcome of this engineering study was sufficiently encouraging to justify further work in the laboratory to grind the coal to much finer levels to liberate the pyrite. The fine grinding of coal creates new problems, as this operation impedes the elimination of moisture. It also becomes necessary to reconstitute the coal into particles sufficiently large to be suitable for carbonization. Considerable progress was made during the year on the agglomeration of coal fines by the formation of spherical agglomerates in water with coal tar.

The research of the Hydrocarbons group of the Fuels Research Centre, in broad terms, has been directed to three main areas: the evaluation of Canadian petroleum resources (including engineering studies of transportation and comparisons of Canadian fossil fuels); a better understanding of the fundamental chemical structure of these raw materials; and, finally improved processes to beneficiate Canada's heavy crude oils to supply the needs of the future.

A directory of Canadian oil analyses and reservoir data has been compiled and is in the process of being submitted for publication. This directory includes most of the crude-oil analyses performed over several decades in the laboratories of the Fuels Research Centre and is fairly representative of all significant Canadian oil fields. Typical field data and secondary recovery data are also included for most of the more important

oil pools. It is hoped that this publication – one of the most complete of its kind – will provide interested research workers with the documentation needed for comparisons of various oil reservoirs in all the oil-producing provinces of Canada.

Emphasis in applied petroleum research is the development of processes and equipment for the conversion of Canadian low-grade crude oils, bitumens, coal tar, and petroleum residues to more useful and more valuable products. One of the most important preliminary process steps is the removal of finely divided mineral matter from heavy oils. Mild thermal cracking to reduce the viscosity of the oil has been found to facilitate the removal of mineral matter by centrifugation without having any deleterious effect on the subsequent hydrogenation steps.

An important contribution to the safety of mining in Canada has been made by the Canadian Explosive Atmospheres Laboratory. This laboratory conducts research to reduce the hazards associated with using electrical equipment in the explosive atmospheres that commonly occur in coal mines. One special aspect of this service that has increased rapidly during the year has been the approval of fire-resistant conveyor belting certified by this laboratory as safe for underground use. The provinces of Saskatchewan and British Columbia now require all underground belting to meet this standard. This requirement arises from the rapid growth of the potash industry in Saskatchewan and the more stringent view taken by the mining inspectorate of British Columbia concerning the dangers associated with the combustion of conveyor belting in any underground workings.

The certification of coal-cutting equipment, compressors, electric motors, diesel engines, and performance tests on gas detectors is proceeding at an accelerated pace. There are strong indications that the demand for this service will increase annually.

The research of this laboratory has concentrated on two areas: the transmission of flames through narrow gaps that simulate those present in flame-proof equipment; and the ignition of combustible gas-air mixtures by sparks of inductive circuits. New equipment has been designed and built to study the energy release in sparks produced by instruments for testing intrinsically safe circuits.

Air pollution has recently aroused public concern. One special aspect of this problem involves the control of air pollutants caused by combustion. Research in this field is carried out by the Canadian Combustion Research Laboratory at an accelerated pace to alleviate some of the pollution in the major population centres. A significant advance has been made during the year in the development of a new plume-rise equation, which predicts the manner in which stack gases are dispersed from tall chimneys. This will make it possible for smoke stacks to be designed in a much more satisfactory manner as regards health standards.

The changing pattern of fuel use in many areas of Canada, from coal to oil, has emphasized the need to find new methods of reducing the amount of acid soot production that occurs on burning heavy oils. Research to overcome this atmospheric pollutant has made considerable progress. Additives have been found which suppress sulphur-trioxide production. This enables electrostatic precipitators to be used to virtually eliminate the release of soot into the atmosphere. These additives have an additional benefit in that they substantially reduce the corrosion in the cooler parts of large thermal power stations.

MINING RESEARCH CENTRE

Research Orientation. Government enterprise is needed in Canada to supplement the broad mining research carried out by companies and universities that requires lengthy and uninterrupted effort and whose ultimate benefit accrues either to the entire industry or the economy of the nation. To support basic studies on problems common throughout the industry, many cooperative projects are pursued with separate companies, the cost being shared by company and government.

With declining average grades of orebodies and deepening mines, there is a growing need for conservation, in the sense of making extraction less wasteful. Therefore, some of the Mining Research Centre's research concentrates on the more complete extraction of ore values from mineral deposits. This is a field that is particularly suited for government research, since the expenditure of money on ways and means of processing difficult ores may not always appeal to individual companies, which may find it more profitable to look for new orebodies abroad.

Operating efficiency is good in the Canadian mineral industry, but it could be better. With the world's third largest mineral industry, Canada should be a leader in mining technology. Research on systems as well as on physical problems will improve the competence of Canadian management and technical personnel, so that investors will have more confidence in native enterprise and thereby reduce the need for so much foreign investment.

Research Programs. Rock-breakage research is concerned with freeing the ore from the host rock and breaking it down to a pulp suitable for processing. Improvements can be made in drilling and blasting, on which the industry is currently spending $100,000 per year, leading to payoffs many times greater than the research cost. As a result of a survey made by the Mining Association of Canada some three years ago, the fundamentals of non-explosive rock breakage are also being studied with the prospect of evolving novel methods of mining.

Research on ground and dust control is concerned with the stability of the host rock after the ore has been excavated and with the maintenance of atmospheric conditions suitable for human activity. Mines, faced with growing competition for technical personnel from other industries, are having to make great efforts to improve working environments. Environmental conditions vary widely, according to commodity – salt, potash, coal, asbestos, base metals, gold, uranium – and no single answer will solve all the problems.

Mining systems engineering is being introduced to apply advances made in other types of research to mine operations. Operations research conducted by a group of engineers, physicists and mathematicians is expected to produce new analytical tools for mine managers and engineers, such as computer-program packages complete with operating instructions.

Communications. An information office is being set up in the Mines Branch to serve industry and the universities. It is being increasingly recognized that one of the functions of a central agency serving industry is to cull from the vast outpouring of research and technical data those elements that are important for the solution of immediate industrial problems. Before long this office will be able to supply on request (through a direct telex link) bibliographies of articles pertinent to specific problems as well as copies of papers containing practical data.

The Canadian Advisory Committee on Rock Mechanics has guided the Mines Branch in stimulating research and the training of post-graduate students in universities. The grants in aid began in 1962 with $10,000 and, thus far, have disbursed $320,000 to Canadian universities. This has helped to increase significantly the number of graduate students coming out of the mining departments of Canadian universities and to expand the volume of coordinated rock-mechanics research throughout the country.

MINERAL SCIENCES

During the period under review, the work of the Mineral Sciences Division has continued to be concerned with a number of major research programs. To the eight such programs described in the previous annual report there has been added one dealing with the use of applied mathematical techniques in the mineral industry. In addition, late in 1967, personnel was reorganized in order to achieve a closer alignment of the groups with the projects under study. Included in this reorganization was the creation of a group concerned with crystal structure, another with crystal growth, while the former mineral physics section has been divided into three groups concerned, respectively, with solid-state studies, mineral surface phenomena, and with instrumentation repair and maintenance. The description that follows will give a résumé of the progress achieved in the main research programs.

Sulphide Research. A wide variety of experimental techniques has been and continues to be applied to the study of many natural and synthetic mineral sulphides, arsenides, sulpharsenides and antimonides. The techniques include single-crystal growth by the vapour-transport and Czochralski methods, phase-equilibrium studies, investigation of the optical and magnetic properties, crystal-structure studies leading to information on bond types, also chemical, analytical and infrared spectroscopic studies. The sulphides so far included within the scope of the program include those of zinc, iron, copper, cobalt, nickel, cadmium and lead and many complex sulphides and related compounds containing two or more cations. Electron-probe microanalysis has proved to be very useful in following the distribution of elements in complex natural and synthetic sulphides. The various techniques, when combined, have gone a long way towards explaining the structure and properties of these minerals.

Oxide Phase-Equilibrium Studies. The work on the phase-equilibrium of multi-oxide systems continues to be a significant long-term line of research. The investigations of the systems $CaO\text{-}Nb_2O_5\text{-}TiO_2$ and $CaO\text{-}Ta_2O_5\text{-}SiO_2$ have been largely completed during the review period. Interesting differences between the behaviour of tantalum and niobium have been revealed by a comparison of the results obtained on the $CaO\text{-}Ta_2O_5\text{-}SiO_2$ system with those obtained on the analogous niobium system investigated some years ago in this Division. The $CaO\text{-}Nb_2O_5\text{-}TiO_2$ system has given interesting results related to the mineralogical occurrences of minerals having the perovskite and pyrochlore structures. Further work has been done in the hope of resolving some of the complexities of the $CaO\text{-}Al_2O_3\text{-}Fe_2O_3\text{-}SiO_2$ system. Preparations have been made to investigate the phase-equilibrium relationships in the Sn-O system; these will have metallurgical and technological significance in the electronic-ceramic field.

Analytical Chemistry Research. Much work has been done in continuation of the study of the absorption spectra of minerals and of solutions of inorganic complexes. The

use of ligand field theory has yielded much information concerning the configuration of the complexes and explaining the optical properties of the minerals, such as colour and pleochroism. The technique of atomic absorption spectroscopy has been found very useful in the analysis for a variety of metallic ions in otherwise intractable contexts. An accurate determination of the mass absorption coefficients of many atoms in the X-ray spectral region is under way for use in quantitative X-ray microprobe analysis.

Standards Work. The analytical personnel of the Division continue to be heavily committed to standard analytical procedures in both the national and international fields, collaborating in this work with the ASTM, the International Organization for Standardization, the Canadian Standards Association and the Spectroscopy Society of Canada. Most of this work involves the devising of acceptable standard methods for the analysis for metals, both as major and trace constituents, in a wide variety of ores, alloys, minerals and metallic products.

Piezoelectric and Magnetic Ceramics. Work on the preparation of piezoelectric materials based on the lead zirconate-titanate solid-solution series, being conducted on behalf of the Defence Research Board, was wound up at the end of the current review period with the expiry of the contract. Certain aspects of the study of factors affecting the sintering behaviour and electromechanical properties of these compositions still remain to be written up and/or published. The work on "hard" or permanent-magnet types of ferrites based upon lead/strontium/barium hexaferrite has been continued throughout the year. A study of the mechanism of formation of lead hexaferrite under various conditions has been completed and submitted for publication. Considerable work on the properties of mixed strontium/barium hexaferrites has been done. The work done in co-operation with a Canadian industrial organization with a view to characterizing its iron oxides and assessing their reactivity in the formation of ferrites continued sporadically throughout the year.

Canadian Ore Mineralogy. The comprehensive mineralogical investigation of the silver-cobalt deposits of the Cobalt-Gowganda area continued throughout the year. The study is concerned with the distribution of the metals amongst the various arsenides, sulpharsenides and antimonides present. The study of a suite of unusual minerals found in the deposits at Seal Lake, Labrador, also continued during various portions of the review period.

Surface Phenomena on Minerals. The surface properties of minerals, particularly with reference to their flotation behaviour, continue to be of interest to the Division. Studies during the past year have included the adsorption behaviour of oleic on hematite, of xanthates of sulphides, and of the double layer existing at the liquid-solid interface when a range of mineral oxide samples is contacted by aqueous solutions containing certain anions. Electrophoretic studies associated with bacterial leaching have been started, as has also a program of measurement of the contact angles at mineral/liquid interfaces.

Work on the adsorption behaviour of semiconducting materials in contact with electrolytes has been started. The initial working material in this study is synthetic single-crystal PbS.

Applied Mathematics. Work on sampling of particulate materials and of mineral deposits has been started with a view of ultimately exerting better grade control and of making more reliable ore-reserve estimates.

Crystal Structure. Studies of a number of materials such as certain sulphides and also some calcium vanadates are being made on behalf of the Defence Research Board. In this connection much work has been directed towards interfacing the automated four-circle goniometer equipment with an "on-line" computer. This system is now operating satisfactorily.

In addition to the above-mentioned research projects, the Division continues to conduct a large number of service investigations employing a variety of techniques such as wet-chemical and instrumental analyses, X-ray, infrared and emission spectroscopy, X-ray diffraction, electron-probe microscopy, differential thermal, thermogravimetric and neutron-activation analyses. These service investigations are conducted on behalf of other divisions of the Mines Branch, other government departments such as the Department of National Defence, the Department of Transport, the Canadian Government Printing Bureau, the Royal Canadian Mint and the R.C.M.P. Assistance is also rendered on request to industry and to universities in those areas where the Division has specialized facilities not available at these establishments.

EXTRACTION METALLURGY

In the Extraction Metallurgy Division, research was carried out on hydrometallurgical and pyrometallurgical processes, on electro-plating technology, and on causes and prevention of metal corrosion. At the same time, fundamental studies were made of the kinetics and thermodynamics of metallurgically important chemical reactions. Research covered fields of broad general interest to the metallurgical industry. Division staff kept in touch with metallurgical companies through the formal activities of co-operative industry-Mines Branch organizations such as the Canadian Gold Metallurgists (now Canadian Mineral Processors) and the Canadian Uranium Producers' Metallurgical Committee, through the publication of research results in technical journals, membership in professional societies, and many informal contacts.

It has been known from earlier work conducted in the Division that uranium can be extracted from Elliot Lake uranium ores by bacterial action almost as effectively as by the strong sulphuric-acid leaching now in general use. The rising cost of sulphuric acid has made bacterial leaching increasingly attractive economically, and as a result a project was initiated to adapt a semi-static leaching system, developed here earlier for acid leaching, to a bacterial leaching process. The results obtained so far indicate that adequate leaching rates can be obtained, along with substantial reductions in reagent and heat requirements, and that extractions will be only slightly less than with conventional acid leaching.

The leaching processes used for extracting uranium also yield substantial amounts of rare-earth elements as by-products. Because of the continued demand for refined rare earths, a research program was initiated to develop processes that will recover marketable rare-earth products economically from uranium-extraction effluents.

The establishment of a tungsten-mining and treatment operation in the Northwest Territories had earlier prompted the development of an improved method for the production of high-purity tungsten products from mineral concentrates. In some recent work the process was further improved by more efficient cation-exchange removal of impurities from the leach solutions, thus yielding tungsten products of even higher purity.

Mathematical analyses and mathematical simulation of metallurgical processes, which are beginning to receive attention in the metallurgical industry, are being developed and utilized in the Extraction Metallurgy Division as an important research aid in metallurgical research. These techniques have been applied to the evaluation of variables in both physical and chemical metallurgical systems.

In view of the electrical and hydrocarbon-fuel resources of Canada available to the metallurgical industry, further development work was carried out on the combination shaft-and-electric-arc furnace. The combination is designed to increase the efficiency of electric smelting by pretreating the incoming feed with the hot reducing electric-furnace off-gases, and augmenting these in some cases by oil or natural gas. This unit has now been improved by the installation of a better auxiliary-fuel-combustion system, and a rotating hearth in the electric arc furnace to improve charge distribution within the furnace. In the initial work on melting pre-reduced iron pellets, a saving of 33 per cent of the electrical-energy requirements of the furnace was achieved by preheating with natural gas in the shaft furnace.

A long-term program has been devoted to the improvement of industrial electroplating technology, particularly the prevention of hydrogen embrittlement of certain high-strength steels during electroplating. The improvements have consisted in the development of better cleaning and pickling procedures as well as plating baths. This program, which had already embraced the plating of zinc, cadmium and copper, was extended to the electroplating of silver, with the development of precise mathematical relationships between the bath components. The development of improved plating baths for the electrodeposition of brass is also under study, and a 70:30 brass can now be plated on high-strength steels of type 1062 without embrittlement.

Another long-term program has concerned the prevention of metal corrosion in industrial environments caused by the sulphurous acid formed from sulphur dioxide in the atmosphere. In earlier work, the causes and prevention of corrosion of mild steel were investigated, and addition agents such as sodium oxalate and hexamine were found to be effective in the prevention of corrosion when added to sulphurous-acid solutions in contact with the steel. In the course of these studies, mathematical expressions were developed for calculating corrosion rates. Similar expressions have been developed for calculating corrosion rates of tin, lead, cadmium, chromium and aluminum. In view of the importance of zinc as a material of construction and protection, a similar program was carried out with this metal, and here again the addition agents sodium oxalate and hexamine were found to be effective for the protection of zinc against sulphurous-acid attack.

In the basic research of the Division much effort was devoted to studies of the kinetics and thermodynamics of metallurgical reactions of importance to Canadian industry. An extended program was continued on the dissolution of the copper-bearing minerals digenite, chalcocite and chalcopyrite to clarify the mechanisms of the leaching reactions by experiments done on pure or synthetic minerals under specific conditions. Experimental work was completed on the kinetics of the thermal decomposition of zinc sulphate and zinc oxysulphate to zinc oxide, and also the thermodynamic relationships between various products in the manganese-sulphur-oxygen system, these last being of importance in certain industrial processes for atmospheric-pollution control. A study was initiated on the kinetics of the chlorination of cupric and cuprous sulphides with chlorine gas to yield copper chloride and elemental sulphur, and a literature survey was made and calculations completed on a theoretical study of the possibilities of chlorinating manganese, lead and zinc sulphides for recovering elemental sulphur and the appropriate metallic chloride. This program was extended to correlate the relevant data for the thermodynamic properties of molybdenum and tungsten in sulphur-chlorine and sulphur-oxygen systems.

The analytical facilities of the Division were substantially increased during the year by the installation of a Phillips 1220 X-ray fluorescence unit, which was particularly required in support of the rare-earth research. Atomic-absorption analyses were further developed for metallurgical analyses including gold, copper-nickel, tungsten-process products and smelting slags. As a preliminary to development of equipment and methods for on-stream analyses, improved analytical methods for alkyl xanthates and other flotation reagents were developed.

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 technical advice to industry and other government departments.

Research to improve basic processes for concentration of metal ores included studies of grinding-process control, filtration of ultrafine suspensions, gravity concentration of asbestos and iron ore, and flotation of iron, tin and molybdenum ores. Papers on these processes were prepared for publication at national and international conferences.

Applied research was conducted to assist mining and metallurgy in development of new mines, improvements in existing plants, and better utilization of resources. Treatment processes were developed for important new mine projects, including copper-nickel, copper-lead-zinc, copper, gold-silver, niobium, tantalum, gold-silver-copper, gold, and lead-zinc ores.

A pilot plant was operated on a copper-nickel ore for three months to supply information on the feasibility and design of a new mine now being planned. Pilot-plant development of a tantalum ore has resulted in the construction of a mine as a source of this metal, hitherto produced only from imported placer concentrates. Laboratory and pilot-plant development of a process to recover iron and nickel from asbestos-plant tailings has led to a large industrial research project supported by the Department of Industry and the asbestos companies.

Fundamental studies were made concerning the effect of grain size and small quantities of special additives on the piezoelectric properties of lead-zirconate-titanate ceramics. The composition and properties of selected clays and shales from Quebec and the Maritimes useful to the ceramic industry were investigated. A quantitative relationship was established between the pierceability of rocks and thermal properties, such as thermal conductivity and thermal expansion. Methods of forming ceramics by isostatic and hot pressing were studied. A major study was carried out in which parameters were established for producing dead-burned magnesia from Ontario magnesite. Numerous samples of clays, shales and other industrial minerals were evaluated for use as ceramic raw materials for the ceramic and mining industries.

Assistance was given to industry by investigating improved manufacturing processes of coated and semi-coated expanded shale aggregates for use in lightweight concrete. A test procedure was developed for the Department of Transport, Marine Regulation Branch, for inclusion in the Canadian Concentrates Code, to determine the flow-moisture point in a mineral concentrate for shipment in marine vessels. Assistance was provided in compilation of pertinent information on samples of rocks, ores and minerals collected in the Geological Court, EXPO '67, for publication in a special brochure. Help was given in the planning of the relocation of the geological mosaic map of Canada from its site at the Canadian Pavilion to the grounds of this department after serving its time as an exhibit.

The method developed for accelerated testing of concrete is gradually being accepted for field uses by the construction industry. Hydro-Quebec has specified its use in some of

its concrete dams, and the City of Montreal installed the required facilities for this test in its concrete-testing laboratory in Montreal.

In the industrial minerals mill applied research projects on the flotability of non-metallic minerals, drying with radiant heat on vibrating conveyors, recovery of weakly magnetic minerals, and electronic sorting were advanced. Studies of materials handling with vibrating equipment and of ultrafine grinding with a vibrating mill were completed. Investigational work was performed on 31 materials originating in seven provinces, the Northwest Territories, and India. Particular emphasis was placed on a barite-fluorite ore from Cape Breton Island.

The division continued the long-term investigations related to asbestos and gypsum. A static method for determining the length-diameter relationship of chrysotile asbestos fibre has been developed, and further improvements based on additional study were made. Surface properties of chrysotile were studied on the basis of zeta potential, and dielectric properties of the fibre are being explored as a possible means of beneficiation. A simple, rapid method for surface-area measurement of chrysotile was developed by modification and use of a junior gas chromatograph. A study of the utilization of by-product synthetic gypsum derived during wet-process manufacture of phosphoric acid for the production of gypsum plaster was completed. A technique involving autoclave calcination of the wet gypsum slurry, based on French and British patents, was used to produce a satisfactory plaster. Beneficiation of gypsum containing clay and shale impurities is now under study.

Observatories Branch

The Observatories Branch is concerned with two major disciplines, astronomy and geophysics. Astronomy is studied in major observatories at Ottawa, Penticton and Victoria, and at a number of field stations. A major effort in 1967-68 , combining the resources of both the Ottawa and Victoria observatories, was the continuing site-testing at Mt. Kobau, B.C.

There are three geophysics divisions: Seismology, which operates 27 seismograph stations plus an array for the detection and identification of nuclear explosions and which sends field parties to all parts of Canada; Geomagnetism, which studies the present and past geomagnetic fields through nine permanent observatories and a major laboratory, and conducts field surveys in all parts of Canada; and Gravity, which is involved in field work in all parts of Canada.

Because the public has a deep interest in astronomy a service must be provided to answer questions in astronomy and related subjects and to receive the public at the major observatories. The Ottawa observatory has produced the first five of a series of pamphlets on astronomy; these are in an attractive format and have been received with enthusiasm by educators and others. The series is currently being expanded. The observatory is also producing a series of illuminated wall displays on the various phases of its work.

Visitors to the Ottawa observatory numbered over 6,000 for the period under review; this number was made up of more than 100 group tours and about 3,000 visitors during the Saturday evening visiting program. The Victoria observatory received 32,000 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 their number.

ASTRONOMY DIVISION, OTTAWA

This Division carries out studies of fundamental star positions, provides the time standard for Canada, distributes time throughout Canada by wire and radio and carries out fundamental studies of the sun and of meteors and meteorites. It is also cooperating actively in the site-testing on Mt. Kobau.

The measurement of star positions requires very great accuracy. An instrument of new design, the Mirror Transit Circle, has been under development in Ottawa for several years. During the past year improvements have been made in the insulation and shielding of the piers and support members of the instrument because it was found that temperature fluctuations were distorting these members and producing erratic measurements. A number of modifications to the electronic controls to improve the facility of observations have also been incorporated.

The standard instrument for the measurement of time is the Photographic Zenith Tube. The PZT is a transit telescope especially adapted to measuring earth rotation and latitude variation, and when used with atomic timekeepers is a sensitive detector of irregularities in earth rotation. A PZT has been operated in Ottawa for many years. A second one, built jointly by the U.S. Naval Observatory and the Dominion Observatory, has recently been placed in operation. The original PZT will soon be moved to Calgary, where, in cooperation with the Royal Greenwich Observatory which is on the same latitude, it will be used in a long-term experiment to detect continental drift. During the year the Ottawa PZT was used on 168 nights for a total of 3,335 star transits.

As part of the plan to improve the time service, an atomic frequency was installed as the control element for the time signals. Also, the 7,335-kHz channel of CHU was improved with a new transmitter operating into a vertical antenna. The time laboratory acquired a second caesium resonator to serve as standby. Time may now be resolved to one tenth of a microsecond. Comparison by means of the Flying Clock Experiment conducted by the Hewlett Packard Company of California indicates that the atomic clocks at Ottawa and Washington will drift apart one thousandth of a second in about 40 years if they maintain their present rates.

Engineering plans have been completed for the establishment of a prairie network of automatic-camera stations for a meteorite observation and recovery (MORP) program. The first station will be established near Saskatoon early in the new year. The Meanook-Newbrook (25-mile baseline) observatory has continued to secure unique photographic records of meteors and their spectra which yield information concerning their space trajectories and their chemical composition.

Extensive film records of solar-image definition were obtained on Mt. Kobau, B.C., for a period of six weeks in mid-summer. The films are being used to evaluate the quality of daytime observing conditions at this site. Engineering plans for a new solar spar telescope, to be located near Ottawa, have been completed and most of the component optical parts acquired. The spar is an equatorially-mounted platform that will carry several refractor telescopes for simultaneous time-lapse photography of active solar regions in different wavelength bands. The spar telescope will be used to detect transient events in the solar atmosphere, particularly those events that affect the Earth-Sun environment.

In addition to the solar site-testing on Mt. Kobau, efforts have been directed to the establishment of two telescopes. The one is a Polaris Image Monitor which is designed to track Polaris accurately and will measure the fluctuations in brightness and position caused by atmospheric turbulence. The other is a 16-inch reflector which will be used for

photographic and photoelectric photometry. Both of these telescopes will give valuable information concerning the properties of the Mt. Kobau site.

DOMINION RADIO ASTROPHYSICAL OBSERVATORY, PENTICTON, B.C.

This observatory operates three major radio telescopes – 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 designing 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 accurately varied. One of the 8.5-m paraboloids for this telescope has been mounted and equipped with receivers. Work on the phasing cables, feeder systems and spectrometer is proceeding at University of British Columbia. Soil tests have been made for foundations of the rail lines. Engineering studies are under way to design the track and bogies for the two antennas.

Another development going forward is an attempt to produce a display for an array-type radio telescope which will show a two-dimensional picture of the sky. The techniques involve ultrasonic waves and a laser beam. Preliminary experiments have produced a spectrometer and an interferometer synthesizer. It is hoped that this technique will permit operation of low-frequency instruments in the presence of man-made interference.

The routine programs of the Observatory include the following:

(1) A catalogue of accurate fluxes for 180 sources has been prepared with the 22-MHZ telescope. Observations now use beam scanning over a small range in declination.

(2) The new 10-MHz receiver system has been used for improved mapping of the regions around several deep absorption features. Comparisons with both 22-MHz results and high-frequency data will yield information on the physical conditions in ionized-hydrogen regions.

(3) Observations for the 1,420-MHz continuum survey are almost complete over the entire visible sky. A catalogue of 615 radio sources has been published, giving important statistical properties of radio sources. A few tens of radio sources not previously catalogued have been discovered.

(4) A survey of neutral hydrogen in the galazy is providing data on the kinetic temperature of the gas and differential rotation at high galactic latitude.

There have been a number of cooperative ventures with other groups. Close cooperation is maintained with radio astronomers at the University of British Columbia who, as mentioned earlier, are cooperating in instrumental development. A joint experiment with the University of Calgary succeeded in detecting radio pulses from cosmic-ray showers at 22 MHz. The most exciting cooperative work has been in the "Long Baseline Interferometer" in which the NRC radio telescope in Algonquin Park and the telescope at Penticton, 3,000 km apart, were effectively worked in unison to obtain measurements of the angular diameters of eleven quasars. This experiment involved the cooperation of many groups.

Early in 1968 it was announced in Cambridge that four rapidly pulsing radio sources had been discovered. This may perhaps be one of the most important astronomical discoveries of the decade. These sources, though weak, have been observed at 113 MHz.

DOMINION ASTROPHYSICAL OBSERVATORY, VICTORIA, B.C.

As a result of new instrumentation developed for the spectrographs attached to the 72-inch and 48-inch telescopes and put into operation during the year, new, far-reaching observational programs are being undertaken by the scientific staff and results important to the astronomical community are expected. On the 72-inch telescope an off-axis spectrograph with an f/5 camera, using gratings giving dispersions of 15 A/mm and 60 A/mm, has been installed. The efficiency relative to the former prism spectrographs has been increased by a factor of four, and with the higher dispersion 8th-magnitude stars can be photographed in about an hour, while with the lower dispersion 11th-magnitude stars are now within reach. In addition, programs involving stars which vary rapidly in light and in spectrum and therefore require good time resolution can now be launched. The Observatory has been studying the structure of the galaxy by the analysis of spectra of the hot stars for more than forty years. These programs will now be extended to fainter stars, but because of the large number of stars involved, details concerning the observational programs have not yet been decided. On the 48-inch telescope a large mosaic grating, made up of four separate six-inch gratings, has finally been commissioned for the coude spectrograph; the only other similar instrument now in use is attached to the 200-inch telescope on Mt. Palomar. An image slicer, the design for which has been patented recently, has also been installed on this spectrograph. This device uses multiple reflections and directs starlight, formerly wasted, into the spectrograph. It was made possible through the development of high-reflectance coatings for the mirrors, but it also uses a concept not formerly considered for astronomical spectroscopy. With these new improvements, an almost fourfold gain of speed has been achieved for the coude spectrograph, and sixth-magnitude stars can now be photographed at the highest dispersion (2 A/mm) in a few hours. The analysis of several peculiar stars, both hotter and cooler than the sun, is now being made with some of these spectra. The staff was brought up to its full complement during the year with the appointment of two research scientists and a scientific officer.

A few of the important results obtained from analyses of the observations made here include: Statistical studies of spectroscopic binaries indicate that there may be two principal groups of stars in the solar neighbourhood with different characteristics as related to their mass and absolute luminosity; additional studies of stars in the Hyades cluster are being made to test this relation. Investigations of eclipsing stellar systems reveal rather large differences between the diameters of giant stars as calculated from the length of eclipse and from theoretical formulae linking temperatures with radii; the problem may be related to uncertainties in our knowledge of the distribution of energy in these stars in regions cut off by the earth's atmosphere. Plates of 1967 Nova Delphini are being measured to study motions in the expanding shells created by the nova outbursts; this nova is quite unusual because it has remained close to its maximum brightness for many months and also because there have been rapid changes in the velocities observed in the spectrum from day to day. Even more rapid changes were observed with the new photoelectric spectrum scanner in the spectrum of the newly-discovered variable star CH Cygni. A new study of stellar associations has shown that Petrie's calibration relating the luminosity of a star to the strength of its hydrogen lines requires a correction of -1.3 magnitudes for the very hottest stars. In the field of theoretical investigations, the evolution of hot main-sequence stars with masses between 7½ and 15 times the sun has been followed until their hydrogen has become exhausted.

During the year the 72-inch telescope was used on 175 nights and the 48-inch telescope on 164 nights with a total of 1,248 hours of usable clear sky – rather more than the average over the past ten years and nearly equal to the average of the 50 years of observing at Victoria.

SEISMOLOGY DIVISION, OTTAWA

A new seismic observatory was commissioned at Churchill, Man. The seismic station operated at Fanshaw Dam, London, Ont., was closed down because of rapidly worsening environmental effects and replaced by a more modern local seismic station at Sudbury, Ont., operated in cooperation with Laurentian University. The total number of seismic stations operated by the Department remains at 23, complemented by four second-order local stations.

A major extension of the strong-motion network in western Canada for earthquake engineering continued: 14 stations are now fully equipped and 57 locations have been instrumented with seismoscopes for detailed ground-acceleration studies.

Calculations were completed for the preparation of a new earthquake-zoning map for Canada for the National Building Code definition of earthquake loads. These calculations use all the researched data accumulated on Canadian earthquakes to 1963. The quantitative ground-acceleration estimates have been examined by the National Committee for Earthquake Engineering and form the basis for the code revision, which will be implemented in 1970. Some details require final resolution with the engineering profession, but the general proposals of the Division have been adopted by the appropriate authorities.

No major earthquakes occurred in Canada during the year, but a number of minor shocks were felt in both eastern and western Canada. Research studies of microearthquakes continued, and a number of seismic regionalization studies were published.

Quantitative earthquake-risk estimates were given to engineering and insurance companies; an increase in demands for advice was noticeable for large engineering works and other critical structures.

International cooperation in the study of earthquakes and the dissemination of readings and records to international and national research agencies and workers continued at a high level. There was an increase in the machine-compatible data flow.

A seismic-array-processing laboratory was brought into operation in Ottawa, employing a small general-purpose "in-house" digital computer with considerable peripheral equipment. The "in-house" capability for the data-processing of array magnetic tapes has proved an outstanding success, and a number of fundamental papers have been published on array seismology and detection and identification problems.

Other seismologists have continued research into the mechanism of earthquakes, into surface-wave dispersion and into the mantle-core transitional zone, deep within the earth. A large body of results has been published from experimental and theoretical studies of the character of seismic body-wave arrivals.

The crustal-seismic-refraction group completed a major experiment on the ice northwest from Prince Patrick Island, N.W.T. A profile some 200 km long was shot with the use of three field parties and 20 large shots. Later in the year six explosions in a lake on southern Vancouver Island were recorded by six moving field parties in British Columbia. This work successfully reversed an earlier profile. Finally, in cooperation with the University of Alberta, four large explosions were detonated near Revelstoke, B.C., to test for deep faulting in southern Alberta. A critical analysis of the 1965 Hudson Bay

experiment was submitted for publication, and the reduction and interpretation of data for the major experiment of 1966 was considerably advanced during the year under review.

The heat-flow section drilled four holes in northern Ontario across a major geophysical feature. Measurements were made in eight provinces as part of the continuing study of approximately forty active sites, well distributed throughout Canada. Probe measurements were made from the ice in the western Arctic and an unsuccessful attempt was made to obtain data in Great Slave Lake. Laboratory and theoretical studies continue on the feasibility of making quicker, cheaper but still useful determinations of heat flow through lake bottoms. The first interpreted values from the heat-flow field program were published.

GRAVITY DIVISION, OTTAWA

Work on the unified adjustment of all gravimeter-control-station ties in Canada began in 1967. During the year four computer programs were developed to process, plot, edit, and adjust control-station operations. Analyses of the performance of four LaCoste meters were made and a field evaluation of the rebuilt Canadian pendulum apparatus on the North American Calibration Line was successfully completed.

The reduction of data for the Canadian contribution to the First Order World Gravity Net consisting of some 1,000 gravimeter measurements in Canada, Europe, the United States, South America, Australia, and the Western Pacific is now under way. When the gravimeter measurements of other agencies become available the Division will participate with the 1381st Geodetic Survey Squadron (GSS) USAF in a joint program to adjust the First Order World Gravity Net. The computer program developed for the Canadian Net will be used in this project with additional routines for statistical analysis of the results contributed by the 1381st GSS. The Canadian and American data have now been converted to a common format and preliminary editing runs have been carried out on Canadian government computing facilities. The final adjustment of the net has been tentatively scheduled for September, 1968.

During 1967, all gravity data collected by the Division up to December, 1966, were compiled to produce a new Gravity Map of Canada (in four sheets) at a scale of 1:2,500,000. The map passed the colour proof stage and was scheduled for printing in May, 1968. The map will also be available at a scale of 1:5,000,000.

As in previous years, a full program of field measurements was carried out. Investigations were made as follows:

(1) A regional gravity survey was made in northern Alberta and adjacent areas of British Columbia and the Northwest Territories, covering an area of some 225,000 square miles.

(2) The gravity survey of British Columbia and the adjacent coastal waters was continued. Stations on land (284) and under water (316) were observed on Queen Charlotte Islands, Vancouver Island and on the mainland as well as in Hecate Strait and Queen Charlotte Sound. The results of these surveys have been corrected for terrain with computer programs developed in the Division.

(3) Gravity surveys were again extended over the Arctic Islands during 1967. Measurements were made on Devon and Ellesmere Islands, and over the Arctic Ocean in the vicinity of Prince Patrick Island.

(4) The underwater gravity survey of the Gulf of St. Lawrence was completed apart from a small part of the Strait of Belle Isle.

(5) More detailed local surveys were made over granite batholiths in the Burleigh-Anstruther area of Ontario and over the Morin anorthosite body in Quebec.

(6) A highlight of the field program occurred in May 1967 when scientists of the Division led a joint Canada-USA scientific expedition to the North Pole. The party flew from Alert to a camp on the ice pack within 20 miles of the Pole and remained on the ice floe for eight days, during which they took gravity and hydrographic measurements for geodetic purposes and sun and star shots to determine the position of the ice camp. The navigational data were relayed by amateur radio to a computer in Minneapolis and the computed results returned to the party via the same route within two hours. In addition, a sonar device was dropped on the ocean floor to study in detail the movement of the Arctic ice pack and to investigate the possible use of such devices for local navigation. This sonar device will be used in various geophysical experiments proposed for the next three years.

Interpretational studies of the regional gravity anomalies in the following areas have been completed during the year or are nearing completion: Hudson Bay, northern Saskatchewan, northern Manitoba, Quebec, Newfoundland, Appalachia (a review), Somerset and Prince of Wales Islands. Studies of the following areas are in progress: Quebec, Anstruther area, Bear and Slave Geological Provinces, Gulf of St. Lawrence, Queen Elizabeth Islands, and the Ontario-Quebec Mining Belt.

The continuing search for possible ancient meteorite craters in Canada has led to the investigation of six craters by diamond drilling, 12 by gravity surveys, eight by magnetic and six by seismic methods. Recent work has been largely concerned with the Brent, Deep Bay, West Hawk Lake, Lac Couture, Pilot Lake, Nicholson Lake and La Malbaie craters with further analysis of data from the New Quebec, Clearwater Lake, Carswell and Manicouagan craters also in progress.

The earth-tide observatory is now in operation in an old asbestos mine north of Ottawa. The purposes of the studies are: (1) to extend the existing coverage of continuous, systematic observations of earth tides; (2) to investigate the reliability of microgravimetric instruments and the techniques of site selection and installation; (3) to investigate the utility of these measurements in regional studies of the earth's crust and mantle.

The first phase of a long-term program to determine possible vertical movements of the crust due to loading by water at the South Saskatchewan River Development Project dam site was begun in 1966 by the Division. About 45 observations were made in the vicinity of Elbow, Sask. In 1967 unclosed portions of the control network were closed and a primary network linking Saskatoon, Moose Jaw and Swift Current to each other and to Elbow near the dam was established. In a similar survey 75 stations were established at the W.A.C. Bennett Dam on the Peace River.

GEOMAGNETISM DIVISION, OTTAWA

In order to keep the magnetic charts of Canada up to date, the slow changes in the direction of the geomagnetic field are determined by making careful measurements every few years at each of 100 repeat stations, uniformly distributed over the country. During 1967, 21 repeat stations were occupied, in Quebec, Ontario, Newfoundland and the Maritimes.

Reduction of the absolute values from the 1965 three-component airborne magnetic survey was completed, and the results were distributed to world data centres and map-making agencies in several countries. The survey covered Greenland, Iceland, and the

four Scandinavian countries, and intervening ocean areas. The survey data have now been digitized at three-kilometer intervals, and interpretation of detailed results in terms of crustal structure has been started.

Time variations of the geomagnetic field were recorded continuously at nine magnetic observatories: at Alert, Mould Bay, Resolute Bay, and Baker Lake, all in the Northwest Territories; at Great Whale River, in northwestern Quebec; at Churchill, Man.; at Meanook, Alta.; at Victoria, B.C.; and at Agincourt near Toronto. Buildings were completed for two new magnetic observatories – at St. John's, Nfld. and Ottawa; they were to begin operation in April, 1968. The Ottawa observatory will replace the Agincourt observatory which must be abandoned because of increasing industrial interference.

Construction was completed of the new geomagnetic laboratories on a 200-acre site in the Green Belt, 10 miles east of the centre of Ottawa. The complex consists of a main building, containing instrument-development laboratories, darkrooms, offices, and a machine shop, and 15 small isolated buildings of non-magnetic construction. It includes the new Ottawa magnetic observatory, mentioned in the preceding paragraph. It provides improved facilities for research in rock magnetism and instrumentation, both for the Observatories Branch and for the Geological Survey of Canada, and will permit more effective training of personnel for observatory and field work.

Three field programs were carried out to investigate electric currents induced in the crust and upper mantle of the earth by natural geomagnetic variations, in southern and central British Columbia, on Ellesmere Island, and in south-western Quebec. Arrays of portable observatories recording magnetic variations and the corresponding earth currents were operated in a line for several weeks. After a few moderate magnetic disturbances were recorded, the portable stations were moved to new sites. Analysis and interpretation of the data is proceeding well, and some results are already in press.

Studies of the natural magnetization of sedimentary rocks from the Maritime Provinces were continued. Many valuable results were published covering most of the Upper Paleozoic – a period for which previously there had been very few North American paleomagnetic results. An important new technique of interpretation was developed for rocks which contain two superimposed magnetizations in different directions.

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 Arctic Ocean, and it provides facilities and support for approved university researches in the area.

In 1967 the field activities of the Polar Continental Shelf Project ranged from the North Pole to the Mackenzie River delta, with some associated activities in southwestern Yukon and the Canadian Rockies. The main base of Arctic field operations was at Mould Bay on Prince Patrick Island, with a secondary base at Alert on Ellesmere Island. About

105 persons were engaged in the field work, which involved three departments of the Canadian government, one provincial government, two agencies of the United States government, and six university or private research groups.

The Canadian Centennial flag was flown by the Project's field party in the vicinity of the North Pole, and, as an international gesture, the flags of all the nations participating in Expo '67 were fastened to a sonar marker that was dropped onto the ocean floor, 25 miles from the North Pole.

The major activities comprising the 1967 program of the Polar Continental Shelf Project were:

Aeromagnetic Surveys. Measurements of the total magnetic field as recorded from a height of 1,000 feet above the surface were made over the continental shelf and continental slope, southern Prince Patrick Island, Fitzwilliam Strait, Crozier Channel, Eglinton Island, and M'Clure Strait. The surveys are part of the aeromagnetic survey of Canada undertaken by the Geological Survey of Canada. Approximately 15,000 line miles were flown, providing information for mapping an area of 27,000 square miles on a scale of 1:250,000.

Geodetic and Topographic Surveys, Position Determination and Control. Tests were made at Mould Bay of a new method of determining geodetic positions with improved accuracy, using computer analysis of astronomic observations. This method was then employed in the vicinity of the North Pole in conjunction with a local gravity survey and study of ice drift, to obtain information on the configuration of the geoid near the Earth's axis. A sonar transponder was placed on the ocean floor at Latitude 89°35′56″N Longitude 113°43′53″W to serve as a fixed reference for these and future studies.

The precise survey of a geodetic triangulation network between Ellesmere Island and northwestern Greenland was completed. It is intended that this network will be resurveyed in ten and twenty years' time to check on possible crustal movements in the area.

The Polar Continental Shelf Project played a part in organizing and supervising the repeated aerial photography and the ground survey of the surging Steele Glacier in the St. Elias Mountains of southwestern Yukon. The work included low-level oblique photography of the lower part of the glacier during the winter and spring, through the co-operation of the (then) Water Resources Branch, and repeated vertical aerial photography of the entire drainage basin during the summer, through the co-operation of the Surveys and Mapping Branch, with ground control provided through the co-operation of the Army Survey Establishment.

Marine Geology. Samples of bottom sediments were obtained offshore from channels between Prince Patrick Island and Melville Island, and in the inlets of western Melville Island. Collections were made of the material presently being delivered to the sea by the rivers of Melville Island. These activities are part of a continuing program to determine the age, source, and conditions of sedimentation on the floor of the seas surrounding the islands of the archipelago and covering the continental shelf and continental slope, and to provide evidence for changes of sea level and variations of climate in the geologically recent past.

Geomagnetism. A study was made of the geomagnetic character and behaviour of parts of north-central and eastern Ellesmere Island, where there are indications of crustal

peculiarities, such as enhanced electromagnetic conductivity, that may be connected with a major geological structure separating Ellesmere Island and Greenland.

Glacier Physics and Glaciology. Routine glaciological measurements were continued on the Meighen and Melville Island icecaps.

Further measurements were made of glacier temperatures and deformation in boreholes on Athabasca glacier, Alberta, as part of a continuing study of the mechanism of ice flow.

Gravity. The gravity investigations of the Polar Continental Shelf Project are carried out in co-operation with the Gravity Division of the Observatories Branch. The regional gravity survey was continued over the continental shelf and continental slope offshore from Prince Patrick Island, the Lincoln Sea and nearby parts of northern Robeson Channel, in a small area near the North Pole, and over northern Devon Island and southern Ellesmere Island.

Some gravity observations were made on surging Steele Glacier, and on nearby "Fox glacier" in the St. Elias Mountains, Yukon.

Heat Flow. Measurements of the flow of geothermal heat from the ocean floor were continued off Prince Patrick Island and in Crozier Channel.

Hydrographic Survey. The bathymetric survey of the continental shelf and slope, and of the straits and sounds between the western Queen Elizabeth Islands, was continued, with through-the-ice sounding on a grid spacing of 7 to 10 kilometres over about 35,000 square kilometres of the Arctic Ocean offshore from Prince Patrick Island. This work will be published at a scale of 1:500,000.

The hydrographic survey of northern Robeson Channel and Lincoln Sea, with soundings at intervals of about 4 kilometres, was completed to approximately Latitude 84° 00′N, Longitude 53° 00′W. This survey has covered approximately 32,000 square kilometres in an area of very heavy sea ice at the entrance to one of the major passages between the Arctic and Atlantic Oceans. The soundings were carried out by helicopter.

Oceanography. Field support and equipment were provided for an oceanographic reconnaissance of the Lincoln Sea. This work was undertaken by the Marine Sciences Centre of McGill University as part of the study of the "North Water" phenomenon of northern Baffin Bay.

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 season of significant sea-ice activity. Information was collected on the nature, break-up, amount, distribution, dispersal, and formation of the sea ice and of certain tabular icebergs or "ice islands."

Distinctive markers, in easily recognizable patterns, were set up on a number of tabular icebergs or "ice islands" in the Arctic Ocean off M'Clure Strait and in the Lincoln Sea to aid in identification and tracking by radar and visual means. The movement of these bodies is being followed through observations of Canadian and U.S. patrol and observation agencies, and is providing evidence of the rate and patterns of ice drift.

During the occupation of the geophysical and hydrographic camp on the Arctic Ocean ice, 200 kilometres offshore from Prince Patrick Island, a continuous record of the

drift of the ice pack was kept by means of the Decca Lambda survey equipment. Meteorological observations were also recorded. This is the first time that it has been possible to obtain detailed information on the movement of the ice, and its relation to the weather, in the unrestricted ocean for an extended period.

Seismic Studies. A seismic refraction traverse across the continental shelf and continental slope was run from Houghton Head on southwestern Prince Patrick Island, extending about 350 kilometres out to sea. The information obtained should add to our knowledge of the crustal and geological structure of the west edge of the Sverdrup sedimentary basin, the continental shelf, and the border of the Arctic Ocean basin.

Other Activities. Support was provided to a project of the Province of Quebec and the University of Alaska, in which muskoxen were obtained on Ellesmere Island for establishment of a breeding herd near Fort Chimo on Ungava Bay.

Assistance was given to a party from the Department of National Defence making an archeological and geomorphological reconnaissance along the north coast of Ellesmere Island.

Specimens of fossil vertebrates were collected for the Natural History Branch of the National Museum of Canada.

Some assistance was provided for university and private investigations in physiography, acarology, ornithology, geology, and history.

MINERAL DEVELOPMENT GROUP

Mineral Resources Division

The Mineral Resources Division conducts fundamental and applied resource-engineering-economic research and field investigations into non-renewable resource problems, policies and programs, on a regional, national and international basis. The work covers all aspects of the mineral industry from resources through exploration, development, production, processing, transportation, and consumption. On the basis of this work, the Division prepares economic forecasts and appraisals of the Canadian mineral economy, publishes resource-engineering-economic reports, and advises government departments and agencies on non-renewable resource policy matters.

Since July 1966, the Resource Administration Division has been a part of the Mineral Resources Division and has had the responsibility of administering and managing the federal interests in mineral resources off Canada's west and east seacoasts and in Hudson Bay, as well as those federally-owned mineral rights in the provinces that become available for disposition. As part of its responsibilities, this group helps to ensure that other interested governmental agencies are aware of proposed offshore exploration and that operators are in turn aware of any special requirements of these agencies. The group is also involved in a wide range of policy considerations of national and international import associated with matters relating to offshore resources.

ADVISORY AND CONSULTING SERVICES

The Mineral Resources Division provided other government departments with analyses and advice on mineral developments so that assessments could be made of the need for public services such as roads, airstrips, docks, housing, manpower training, etc. in specified areas. A subsidiary but important aspect of this activity is the provision of information and advice on mineral economic matters to consultants and company representatives, through office interviews and/or correspondence. Representative of the type of advisory service provided were the following:

Regional Studies in Eastern Canada. A detailed report *Mineral Resource Development, Province of New Brunswick* was prepared during the year at the request of the Atlantic Development Board. This report was similar to one completed in 1966 on the Province of Newfoundland and Labrador, and made available by the Atlantic Development Board to the Royal Commission on the Economic Prospects of Newfoundland and Labrador. The New Brunswick report reviews in depth the province's mineral industry. It contains an appraisal of the possible course of future mineral developments including production, capital investment and employment trends, and what direction assistance by the provincial and federal governments might take to speed that development. A similar study in Nova Scotia was commenced at the request of the Atlantic Development Board and is expected to be completed during the summer of 1968.

Northern Development. The Division acts in an advisory capacity to the Department of Indian Affairs and Northern Development and, in this connection, a special study was

completed for an interdepartmental committee concerning Canadian access requirements to tidewater on the Pacific Ocean. The study included a detailed examination of the existing mining industry, a regional mineral-potential appraisal, transportation requirements, a water-resource analysis, and an examination of the physical aspects of access to tidewater. During the year, a major study was made for the Department of Indian Affairs and Northern Development on the Baffinland iron-ore project on Baffin Island. In connection with this project, members of the Division also made an analysis of market conditions for iron ore. Petroleum-exploration opportunities in the Arctic were also reviewed during the year, in relation to industry's current expansion plans.

St. Lawrence Seaway Study. Officers of the Division prepared for the Department of Transport a detailed study *Iron Ore Requirements and Sources of Supply in the Great Lakes Area of Canada and the United States to 1980.* The study took into account the expected growth of the steel-producing areas in the Great Lakes area; available sources of supply of iron ore and their economic competitiveness; and the captive nature of sources of iron ore available to the area. Transportation costs, production costs and Seaway tolls were also reviewed, along with technological changes that are affecting the demand for iron ore.

Kennedy Round of GATT Negotiations. The Kennedy Round of trade negotiations under the General Agreement on Tariffs and Trade (GATT) ended June 30, 1967. Canada received tariff concessions from other countries and gave concessions in return.

The Department was represented by a senior officer on the Canadian Tariffs and Trade Committee, set up in 1964 to prepare for the negotiations, and also on the negotiating team at Geneva. The Mineral Resources Division provided the necessary support services, assisted in the evaluation of briefs from industry, and in the study of intra-governmental proposals in the field of minerals, metals and related semi-fabricated products. The Division also prepared assessments of mineral-industry needs and problems and made recommendations on the mineral content of the Canadian offer.

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 twenty-one applications for three-year tax exemptions, one application for the special oil-pipeline depreciation allowance, and three applications for research grants under the Industrial Research and Development Incentive Act.

A small number of studies were made during the year relative to the report of the Royal Commission on Taxation and the implications of the commission's recommendations for the Canadian mineral industry. Some of the most important and far-reaching recommendations of the commission relate to the taxation of mineral enterprises.

Nickel. An officer of the Division is a member of an interdepartmental committee formed to assist in the allocation of nickel to Canadian consumers. During the current nickel shortage, Canadian consumers have been limited to the amount of their 1966 purchases from domestic suppliers. This system threatened to cause hardships for certain consumers, and the committee is reviewing requests for increased quotas and may make recommendations that justified needs be satisfied by the three domestic producers.

The Maritime Coal Industry. The Division has helped to develop a new policy for the Nova Scotia and New Brunswick coal industries.

As a result of certain federal-provincial agreements, the Cape Breton Development Corporation was formally established on October 1 and charged with the rationalization of coal mining in the Sydney-Glace Bay area of Cape Breton Island as well as the simultaneous encouragement and development of new industry on that island. Formation of the new corporation proceeded throughout the second half of the year, along with essential work on the acquisition of the Dominion Steel and Coal Corporation coal mines. With coal-mine employees numbering 6,500, federal coal subsidies for Nova Scotia at $31 million per year, the major operator intending to withdraw from coal mining, intensified competition from other fuels, and a limited life expectancy for the mines, the Cape Breton coal problem had reached crisis proportions and aroused national concern. The program developed for Cape Breton Island marks the commencement of a new and interesting approach to the problems of a declining mining community.

Simultaneous discussions with the Province of New Brunswick, where the Minto coal field was faced with a situation similar to that of the Sydney coal field, led to the conclusion on March 26, 1968, of an agreement between Canada and New Brunswick on a new policy for New Brunswick coal. Under this agreement, New Brunswick will seek to rationalize mining and stimulate industrial development. The concept is similar to that for the Nova Scotia industry.

Frontier Package Television. Officers of the Division assisted the Canadian Broadcasting Corporation in its choice of communities which should receive priority in the installation of facilities to handle packaged television programs on a regular schedule. This service is designed to assist in the attraction and retention of workers in isolated locations.

INTERNATIONAL ACTIVITIES

An officer of the Division continued to represent the Department on the Canadian delegation to the International Lead and Zinc Study Group, and attended the group's 11th session, held in Geneva in October 1967.

The Division continued to review international trade in tin and Canada's position as a tin consumer under the Third International Tin Agreement. Division staff also compiled extensive statistics on the Canadian iron and steel industry for the OECD Special Committee for Iron and Steel. A representative of the Division attended three meetings of the committee in Paris. The Division also supplied data to two other OECD groups – the Special Committee for Non-Ferrous Metals, and the Nuclear Energy Agency. The latter consisted of reports, prepared in collaboration with Eldorado Mining and Refining Limited, on Canadian uranium reserves and potential productive capacity.

Statistics were also supplied to the Iron and Steel Committee of the United Nations Economic Commission for Europe. A representative of the Division attended committee meetings in Geneva. The Division continued its contributions to the study on the world supply and demand for tungsten, conducted by the United Nations Tungsten Committee, and an officer of the Division attended a meeting on this subject. Another officer took part in a trade mission to Eastern Europe exploring the possibilities for exporting Canadian minerals and metals to "Iron Curtain" nations.

PUBLICATIONS

The Division published reports in the *Mineral Information Bulletin* series on copper and iron ore, along with its regular preliminary annual review of the Canadian mineral industry. Also completed were nine *Operators Lists,* the 1965 *Canadian Minerals Yearbook* and the seventeenth edition of the popular Map 900A *Principal Mineral Areas of Canada.* Work proceeded on reports on berylium, zinc, manganese, natural gas, and fertilizers and on a gas-pipeline map. Several papers were prepared and delivered at national and international conferences or for publication in technical journals. The Division has a continuing program of educational mineral filmstrips. During the period, work continued under the direction of commodity officers on the two filmstrips, iron and steel and aluminum, designed for use in high schools. Both filmstrips will be in kit form with supporting information and samples. The Division's photographic library and mineral-resource records centre continued to be strengthened.

A major report on the Canadian and world uranium industry, which had been in preparation for a number of years, was published during the year; it is entitled *The Uranium Industry, Its History, Technology and Prospects.* At a period when the Canadian uranium industry is preparing itself to meet the needs of an expanding commercial market for uranium in the field of nuclear power, the report provides a timely review of the industry, its technology, and opportunities for the future.

The sixth edition of the *Digest of the Mineral Laws of Canada* was published during the year. The *Digest* is a summary of the Acts and Regulations in effect in Canada in 1965 and 1966 with respect to disposition of rights, conservation rules, fees, mineral taxation and royalties, and bounties and subsidies concerning minerals.

Work was completed on a comprehensive resource report on nickel. The report emphasizes the resource-economic aspects of the nickel industry and will complement the International Nickel Company of Canada Limited book *The Winning of Nickel* – an in-depth study of the technical aspects of the industry. It includes 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. It is expected that the report will be available for distribution in the fall of 1968.

FOREIGN AID TRAINING

The Division, on behalf of the External Aid Office, arranged 25 technical training programs for foreign trainees and provided consultation on 11 additional applications. These programs were sponsored mostly by the Colombo Plan and took place in the Department of Energy, Mines and Resources as well as in private industry. Thirty trainees completed training programs during the fiscal-year period ending March 31, 1968. At the end of the period six trainees were on study courses and seven planned programs were awaiting arrival of candidates. In addition to these postgraduate training programs, a number of foreign undergraduate students attending Canadian universities were helped to find summer employment and surveying instruction. The Division also participated in arrangements to send mineral consultants abroad to advise certain developing countries on mineral policies and projects.

MINERAL OCCURRENCE INDEX

The Division maintains an index of Canadian mineral occurrences available for the use of anyone interested in mining and mineral exploration in Canada. The index consists of comprehensive summaries of available information on some 10,000 mineral occurrences, with provision for revisions and additions as required. These summaries, each on individual cards, are arranged in conformity with areas of the National Topographic System in a manner which enables information on any occurrence or area to be readily located.

In May 1967 an agreement for the exchange of mineral occurrence information was reached with the Department of Mines and Petroleum Resources, British Columbia, complementing agreements ratified in 1961 with the Nova Scotia Department of Mines, and in January 1967 with the Ontario Department of Mines.

The indexing of Canadian mineral occurrences was begun before 1900 and was carried on intermittently for a number of years. During the past ten years indexing has been continuous.

ROADS TO RESOURCES

The Roads to Resources Program is a national program 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 Mineral Resources Division in October 1966.

Federal payments to March 31, 1968, were approximately $73.3 million. The balance, some $1.7 million, has been committed for the completion of the program in 1969-70.

Province	*Number of Roads*	*Mileage Completed*	*Federal Contributions to March 31, 1968*	*Termination Date*	*Status*
Newfoundland	10	270.78	6,403,577	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	7,441,956	March 31/69	–
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	7,468,100	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

ADMINISTRATION OF MINERAL RIGHTS

Canada Oil and Gas Permits. Offshore Canada Oil and Gas Permits are valid for six years with six renewals of one year each. A permit must be converted to oil and gas leases before commercial production can be undertaken. There are no leases in the offshore areas as yet.

A total of 295 Canada Oil and Gas Permits covering 19 million acres were issued in offshore areas during the past year, as follows:

East coast	–	253 permits	–	17,110,323 acres
West coast	–	18 permits	–	822,674 acres
Hudson Bay	–	24 permits	–	1,378,372 acres

This brought the number of offshore Canada Oil and Gas Permits (except the Arctic coast) to 2,976, covering 220.5 million acres, as follows:

East coast	–	1,904 permits	–	151,322,138 acres
West coast	–	246 permits	–	15,174,486 acres
Hudson Bay	–	826 permits	–	54,021,908 acres

On March 31, 1968, the Division held approximately $15 million in the form of guaranty deposits made by permittees against the work requirements of their holdings. The total revenues received during the fiscal year 1967-68 on behalf of offshore permits, including permit fees, transfer fees, forfeitures, maps and exploratory licences, amounted to $101,451.89, most of which was derived from permit fees.

Mineral Claims. Offshore mineral claims are issued for mineral rights other than oil and gas rights. Each mineral claim covers an area not greater than 1,500 feet square (approximately 52 acres). A total of 105 offshore mineral claims were recorded during the past year off the east coast. This brought the total number of mineral claims to 351, distributed as follows: east coast, 161; west coast, 105; Hudson Bay, 65. Total revenues received from the issuance of mineral claims and prospecting licences during the fiscal year 1967-68 amounted to $943.97.

Federal Lands in the Provinces. During the past year, 86 oil and gas leases were issued for lands in this category; of these 13 were in Alberta,41 in Saskatchewan, 31 in Manitoba, and 1 in Ontario. This brought the total number of federal oil and gas leases in the provinces to 286 as follows: 111 in Alberta; 103 in Saskatchewan; 58 in Manitoba; 5 in Ontario. In addition, there are 5 gas leases and 4 oil leases in Alberta. There are also 3 leases for minerals other than oil and gas – 2 in Ontario and 1 in Saskatchewan. On March 31, 1968, the following numbers of oil and gas leases were productive: 37 in Alberta; 19 in Saskatchewan; 6 in Manitoba; 1 in Ontario. The total revenues received during the fiscal year 1967-68 on behalf of oil and gas leases, including royalties, lease-sale bonuses, rentals, extension fees, lease fees and assignment fees, amounted to $282,499.61, most of which was derived from royalties.

THE EMERGENCY GOLD MINING ASSISTANCE ACT

The application of the Act was extended on December 21, 1967, for three years to the end of 1970 without change in the formula for computing the amount of assistance payable.

The Act was introduced in 1948 to provide the operators of marginal gold mines with financial assistance in meeting rising costs of production. The assistance has extended the operating life of many gold mines and has thereby allowed the communities dependent upon them to adjust gradually to diminishing economic support.

An amendment to the Act in 1963 contained a restriction limiting eligibility for assistance in the case of lode gold mines commencing production after June 30, 1965, to

those providing direct economic support to an existing mining community. A gold mine is deemed to provide such support if more than 50 per cent of the persons employed at the mine reside in the established mining communities listed in a schedule to the Act.

The administration of the Act is carried out in the Mineral Resources Division under the direction of the Assistant Deputy Minister (Mineral Development). Gold mines receiving assistance are visited by inspection engineers from the Division who determine the proper classification. The Audit Services Branch, Office of the Comptroller of the Treasury, examines interim applications and carries out the final audit of each applicant's books of account.

The amount of assistance payable to an operator is computed under the current formula whereby only gold mines with an average production cost of $26.50 or more are 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 39 lode gold mines and 18 placer gold mines in receipt of assistance during 1967. Four gold mines had average costs of production less than $26.50 an ounce.

Lode gold mines usually apply for assistance payments on a quarterly basis, while a single annual payment is generally made to operators of placer gold mines. In 1967, 180 separate applications were examined by the Audit Services Branch, approved by this Department and transmitted to the Chief Treasury Officer for payment.

The amounts paid to gold-mine operators to March 31, 1968, for the years 1948 to 1967 inclusive totalled $246,360,675.18 on a production of 55,369,122 fine ounces of gold produced and sold in accordance with the requirements of the Act.

The amount of assistance paid with respect to each calendar year since the Act was introduced is as follows:

1948 – $10,546,315.84 or 3.33 per ounce produced
1949 – 12,571,456.90 or 3.48 per ounce produced
1950 – 8,993,490.51 or 2.55 per ounce produced
1951 – 10,728,503.71 or 3.30 per ounce produced
1952 – 10,845,978.62 or 3.75 per ounce produced
1953 – 14,680,110.42 or 4.62 per ounce produced
1954 – 16,259,179.23 or 4.29 per ounce produced
1955 – 8,885,478.73 or 2.97 per ounce produced
1956 – 8,667,235.38 or 3.46 per ounce produced
1957 – 9,679,753.32 or 3.55 per ounce produced
1958 – 11,420,463.70 or 4.29 per ounce produced
1959 – 12,001,753.43 or 4.91 per ounce produced
1960 – 12,362,517.59 or 5.02 per ounce produced
1961 – 12,666,658.77 or 5.30 per ounce produced
1962 – 14,355,013.49 or 6.16 per ounce produced
1963 – 14,319,757.65 or 5.51 per ounce produced
1964 – 15,419,600.95 or 5.83 per ounce produced
1965 – 15,309,941.32 or 6.30 per ounce produced
1966 – 14,620,449.55 or 6.86 per ounce produced
1967 – 12,027,016.07 not available

Explosives Division

Since its inception in 1920, the Explosives Division has been responsible for the administration of the Explosives Act, a statute enacted in the interest of public safety to control the manufacture, authorization, storage, sale, importation and transportation by road of explosives.

All licences, permits and certificates for manufacture, storage, transportation by road and importation are issued from the Division's main office in Ottawa. The following were issued in 1966-67 and 1967-68.

	1967-68	*1966-67*
Factory Licences	42	34
Magazine Licences (storage for sale)	410	383
Temporary Magazine Licences (storage for private use)	1,290	1,219
Registered Premises (storage of small quantities for sale)	76	79
Explosives Transportation Permits	314	404
Explosives Importation Permits	643	642
Ammonium-Nitrate and Fuel-Oil (ANFO) Permissions	23	19

Inspectors of the Division inspect all storage facilities and vehicles used for the transportation of explosives. In addition factories are checked regularly, and proposed sites examined for approval. Accidents involving explosives are investigated and reports submitted. New explosives and equipment are evaluated and assistance is given to federal and provincial government agencies, explosives manufacturers, construction and transportation agencies in matters concerning explosives.

The following inspections were carried out during the year:

Factories	52
Storage magazines	2,294
Transportation vehicles	238
Fireworks and ANFO	65
Unlicensed premises	210

There were two amendments to the Explosives Regulations during the year. One restricted the size of firecrackers that may be imported into Canada to 11/2 by 1/4 inches, thus incorporating into the Regulations a Directive Letter from the Minister that was issued in 1962 and has been in effect since that time. The other permitted transportation of explosives in quantities greater than 10,000 pounds over approved "isolated" highways. This was introduced to assist industry in reducing costs of explosives for use in the construction and mining developments in remote areas.

The number of "on-site" manufacturing installations for explosives of the blasting-agent type increased considerably, and there is every indication that this trend will continue.

Production of explosives in licensed factories remained approximately the same as last year – just under 300 million pounds, plus an estimated quantity of on-site mixed ANFO of 50 million pounds.

The Division continued a safety campaign by distributing literature to licencees, provincial boards, safety organizations and to the general public on request. Over 20,000 pamphlets were distributed during the year and a revised sales-record form was adopted for use by explosives distributors and dealers.

The 1967-68 period was marred by two fatal accidents, both in the manufacture of fireworks.

In the first accident it is believed that an explosion occurred while the operator was adding composition to the hopper of a machine pelleting fireworks stars. As a result of this accident, the company was advised that future operations of this nature may only be performed where the operator has the protection of a remote-control process.

In the second accident, a supervisor and an operator were starting up a new quick-match process when the supervisor saw a flash. He alerted the operator who escaped without difficulty, but for some reason the supervisor was delayed and failed to escape from the burning building.

There were 46 prosecutions for violations of the Explosives Act and Regulations; approximately half of these were violations of the regulations governing the transportation of explosives by road.

The Division maintains offices at three locations -- Ottawa, Halifax and Vancouver.

A separate report giving more details is published by the Division.

WATER GROUP

Marine Sciences Branch

The Marine Sciences Branch of the Department of Energy, Mines and Resources carries out federal research and surveys to assure safe navigation and to support development of natural resources in Canada's inshore and coastal waters.

The Branch is organized along regional lines with offices in Dartmouth, Nova Scotia, in Victoria, British Columbia, and in Ottawa. The headquarters is situated in the Department of Energy, Mines and Resources complex in Ottawa.

The Branch is responsible for the production and distribution of all Canadian navigational charts and tidal information. Its surveys of geological and geophysical characteristics of the ocean floor provide basic information for mineral exploration. Its studies of oceanographic phenomena are directed to support fisheries, transportation, coastal engineering and defence.

In 1967 the Branch fleet totalled twelve ships supported by 75 sounding launches and 95 smaller craft.

The modernization of the fleet continued with the commissioning of three new vessels, the *Parizeau, Vector* and *Dawson,* for continental-shelf studies. They have replaced the *Ehkoli, Parry* and *Cartier* which were retired from service. In addition, three charter vessels were employed during the year to meet the continued high demands for oceanic research and to support pollution studies in the Great Lakes.

Continued emphasis has been placed on the design and construction of specialized vehicles for research. The first of these vessels, the CSS *Limnos,* built for pollution investigations, will be in service in 1968 on the Great Lakes. Designs and modelling of a catamaran-type vessel are well under way in expectation of adding another special research vessel to the Great Lakes operations.

Design studies have also been completed for a fast (25 knot) 80-foot cutter for the Great Lakes for high-speed synoptic surveys. This craft will be powered with gas-turbine engines and will be specially fitted out with laboratories and all-weather capabilities.

Plans for expansion of facilities at the Bedford Institute are progressing, and it is expected that the end of 1968 will see the completion of the extension of the laboratory wing to provide a 50-per-cent increase in lab accommodation and the provision of a breakwater and floats for mooring of smaller craft.

Although the overall work of the Branch is designed to insure coordination and integration of the efforts of its two specialties of hydrography and oceanography, it is instructive to report its accomplishments under these two main headings.

HYDROGRAPHY

In 1967, the Canadian Hydrographic Service began a systematic program of field revisory surveys directed at the maintenance of the 900 Canadian navigation charts. During the year, 59 charts were revised, and material is now being prepared for an extensive revision program for 1968 in both the Central and Atlantic Regions.

The demand for charts by Canadian and American pleasure-craft operators cruising to Expo '67 raised the 1967 chart distribution totals to an all-time high of 285,000 charts.

During the year, the Canadian Hydrographic Service published 193 navigation charts. This total included 27 new charts, 52 new editions, 57 corrected reprints, 15 reprints, 2 supplementary prints and 30 special charts. In addition, 54 *Catalogue Index* pages, 9

Information Bulletins and 7 *Pilot Index* maps were published. New editions of the *Great Lakes Pilot,* Volume 1, and the *Pilot of Arctic Canada,* Volume 3, were published. Eight *Supplements* to existing *Pilot* editions also were issued.

It is interesting to note that for the first time meters were used to portray soundings and depth contours in Canadian charts: two bathymetric charts of the Arctic ocean, two charts of the continental shelf off Nova Scotia and southern Newfoundland, and four charts of the waters off the Labrador Coast. The latter are being derived from charts compiled by the Federal Republic of Germany.

The Canadian Hydrographic Service is putting substantial effort into the application of automated techniques in hydrographic surveying and chart production. The work is being carried out by work groups in Ottawa, Saskatoon, Dartmouth, and a work group in Victoria will join the project in 1968. At the same time increased effort is being made in the training of new hydrographic survey staff. A record class of 23 began instruction in Ottawa this year.

Pacific Region. The hydrographic surveys in the Pacific Region ranged along the entire coast and into the Western Arctic during 1967, with the work being done by the field parties on the *Wm. J. Stewart, Marabell* and *Richardson.* Tidal, current and scientific investigations were carried out from the *Parry* and *Parizeau.* The *Ehkoli* was also operated in support of scientific studies.

CSS *Wm. J. Stewart* completed the survey of the approaches to Burrard Inlet and made a reconnaissance for Mini-Fix station sites in the Strait of Georgia for 1968 surveys. The control for the re-survey of Prince Rupert Harbour was completed and the general charting program in the Chatham Sound area, using both conventional and Mini-Fix survey equipment, was continued.

CSS *Marabell* completed surveys of the approaches to Nanaimo Harbour, the popular small-craft harbour of Prideaux Haven and the harbour and dock area of Gold River on Muchalat Inlet. A survey of Portland Inlet and approaches and a survey of Meyers Passage for the Royal Canadian Navy was also completed. In addition, surveys of Seymour and Belize Inlets and of Departure Bay north of Nanaimo were started.

After spending the winter in Victoria undergoing her quadrennial refit, CSS *Richardson* revised 25 charts around Vancouver Island before returning to the Western Arctic. While rounding Cape Barrow, she was trapped in the Arctic pack ice until freed by USCGS *Northwind* and CCGS *Camsell.*

Central Region. The most significant activities of the Region were concentrated in obtaining field information for the production of nautical charts. A major hydrographic survey using advanced survey techniques was completed in the Arctic Archipelago and support was provided to field activities in Great Lakes research conducted from the Canada Centre for Inland Waters at Burlington, Ontario. Important developments in semi-automated methods of processing field data were field tested.

Because the majority of field operations within the Region are conducted by shore-based surveys, the emphasis on mobility and flexibility was continued. Throughout the survey season hydrographic operations were supported by one helicopter which moved between the various field parties as required.

Small-boat charting along the Trent-Severn Waterway, commenced in 1965, was continued. In an endeavour to expedite the charting of this significant small-craft route, two parties were assigned to the project and successfully completed the sections Bobcaygeon to Stoney Lake and Bay of Quinte, Murray Canal.

An excellent start was made on the systematic survey of Lake of the Woods, required for the production of a new series of charts which will be of considerable importance to all users of the lake, and particularly to the pleasure-boat operators. Data were obtained for the production of the first chart depicting Kenora and approaches.

In the entrance to Georgian Bay a major survey was completed using electronic position-fixing equipment and high-speed sounding launches. A sub-unit of this establishment commenced a detailed survey of the main pleasure-boat routes between Port Severn and Parry Sound on the eastern side of Georgian Bay.

A new survey party was established and commenced charting of the complex Upper Ottawa River. It is anticipated that new charts in this area will not only encourage tourism but will also expedite engineering studies. Field surveys were completed from Chats Falls to Bryson during the 1967 season.

Studies directed towards the automation of field-data processing were continued. Sounding records can now be successfully digitized in the office using semi-automatic techniques and field data plotted centrally using departmental computer facilities.

Atlantic Region. The hydrographic survey of the Grand Banks was continued during 1967, with geophysical coverage throughout the survey. Decca Lambda was used to position the ship, as in previous years, but during much of the survey, the *Kapuskasing* surveyed along parallel lines to the *Baffin,* in an evaluation of the potential of multi-ship survey operations. Considerable interest has already been expressed by commercial organizations in the results from the survey.

Off Newfoundland's northeast coast, CSS *Acadia* continued the survey of Sir Charles Hamilton Sound after surveying Petit-de-Grat Harbour on Cape Breton Island, the site of a large fish-processing plant.

A team of hydrographers sailed to the Eastern Arctic on CCGS *Sir John A. Macdonald,* transferring later to CCGS *d'Iberville.* A survey of the entrance to Resolute Bay was completed and an extensive reconnaissance of the fiords on the northeast coast of Baffin Island was undertaken.

The magnitude of the surveying task which still lies ahead has been realized for many years. The hydrographic-development group established to devise and implement methods for improving the speed and accuracy of surveys was very active during the year in obtaining and evaluating equipment to be used in the automation of many facets of hydrography. Electronic-positioning equipment was tested aboard CSS *Baffin* and CSS *Hudson* during the summer, and the work on semi-automatic chart scalers progressed favourably. The Gerber Plotting Table was made operational and a series of programs was devised for its operation. Orders were placed for two satellite navigation receivers to be delivered during 1968, and evaluation will be made during a cruise of investigations of the Mid-Atlantic Ridge.

OCEANOGRAPHY

Under this broad classification is included the wide range of marine investigations which primarily are not intended to insure safety of navigation. These include geophysical and geological investigations of the deep structure of the continental shelves and of the floors of the open ocean. The importance of these studies is being emphasized by a growing interest in the potential mineral resources of the extensive shelves under Canadian jurisdiction, and by increasing international concern over the control and disposition of mineral resources on the deep ocean floor.

Oceanographic research in the Branch includes comprehensive studies on waves of all periods from short wind waves to those of astronomical tides and longer. These studies involve theoretical, observational and experimental approaches, and findings will apply to harbour and break-water design, to navigation, and to tidal-power problems, among others. There are also basic studies on the mechanics of air-sea interaction, a better understanding of which will apply not only to wave prediction, but to improve weather forecasting.

Studies in oceanic and coastal circulation are carried out to better understand the means of transport of water properties and the dynamics of mixing processes in the oceans. They have particular application to fisheries, to defence, and to the assessment and prediction of pollution, both locally and over large areas. The increasing possibility of large-scale oil pollution has demanded accelerated studies of such aspects as the distribution of naturally occurring chemical elements in the sea and those radioactive elements recently introduced.

The Branch publishes the results of its oceanographic research in scientific journals and is developing a series of charts to display its information on bottom characteristics. The following paragraphs should serve to illustrate the variety of activities and accomplishments over the past year.

The Branch provides a centralized data centre for oceanography in Canada through the facilities of the Canadian Oceanographic Data Centre in Ottawa. It is supported by environmental and systems specialists engaged on climatological analyses and retrieval of data to meet the needs of industry and research in Canada and abroad. The Centre has steadily increased the scope of its holdings and the sophistication of its processing system over the past year.

Theoretical hydrodynamical and tidal studies continue to be a major activity in Ottawa, with application to areas of particular Canadian interest and development, namely the Bay of Fundy, St. Lawrence River and Gulf.

The two regional centres which undertake oceanographic research are those on the Pacific and Atlantic coasts. In the development of an eventually well-rounded program, attention has been focussed first on building up an adequate activity on the Atlantic coast. Up to the present the extension of the activities of the Branch on the Pacific Coast has been limited.

Pacific Region. The Branch has undertaken an investigation of the tides and currents in the Strait of Georgia as a part of a cooperative program with the Fisheries Research Board. This investigation is intended to meet the needs of fisheries, navigation and harbour developments, and pollution abatement.

Support is being provided to the Ocean Weathership program. This investigation of the fluctuations in oceanic properties at Ocean Station "Papa" off the west coast represents the longest and most detailed continued study of ocean time variation anywhere in the world, and is of wide international interest.

Atlantic Region. Basic research at the Atlantic Oceanographic Laboratory, Bedford Institute, has now been firmly established on a sound and generally comprehensive range of activities. The year saw some expansion in research which provides more immediate and practical returns, such as the study of swell in Halifax Harbour for the National Harbours Board. It is expected that future growth will emphasize applied investigations.

Variability in the ocean is being investigated with growing vigour; one result of such studies will be a firmer appreciation of the reliance which can be placed on synoptic

oceanographic measurements. The collection of time series of observations, which form the basic data for studies in variability, cannot be made economically in the traditional manner using research ships. Moored buoys with recording oceanographic instruments are likely to be extensively used in such research, and also in research with short-term applied objectives. A project using such techniques has been in progress throughout the year, and a great deal has been learned of the value of such methods, as well as of the inherent problems and difficulties associated with them.

The comprehensive coverage of the North Atlantic in high latitudes in the winter which was undertaken in the past two years by the cruises to the Labrador Sea and Irminger Sea has produced a unique collection of data. Although not yet completely worked up, it promises to throw a significant new light on the formation of deep water and on the deep circulation in the whole of the North Atlantic Ocean.

In marine geophysics, the major effort this year was devoted to continuation of the gravity and magnetic survey of the Grand Banks and off shelf to Flemish Cap, working jointly with the hydrographers in their recharting of the Banks; within an area of 33,100 square miles, 16,500 line miles of geophysical data were obtained, a significant contribution. The marine geologists carried out their main field work along the Scotian Shelf, Grand Banks, Labrador Shelf and the associated continental slopes.

The close and satisfying working relationships between the Bedford Institute and other marine research organizations continued to develop during the past year. CSS *Hudson's* cruise to Expo '67, where she was on display for a week demonstrating the methods and potential of oceanography to some 20,000 visitors, was undertaken jointly with Dalhousie Institute of Oceanography; a subsequent *Hudson* cruise was also operated jointly between the Bedford Institute and Dalhousie, whilst visiting scientists were accommodated on many other cruises during the year.

Policy and Planning Branch

The Policy and Planning Branch's functions include advice on national and regional policies for water and related resources; co-ordination of federal and federal-provincial government policies and activities; basic and applied research, mainly on the socio-economic, institutional and jurisdictional aspects of resources; comprehensive basin and regional planning; and administration of certain acts and regulations.

The Branch consists of three divisions and an administration. The newest of the Department's branches, it is still developing and hiring staff. During 1967-68 it undertook a number of studies and projects and made plans to initiate several more as soon as personnel and other resources permit.

The Branch library, attached to the administration, integrated the entire collection of the former Geographical Branch library with that of the Policy and Planning Branch and other collections of the Inland Waters Branch. It thus acquired one of the major collections in Canada on geography and water resources. It also examined and discussed in seminars the development of automated systems for the collection, storage, dissemination and retrieval of non-numerical information.

POLICY ADVISORY, CO-ORDINATION AND ADMINISTRATIVE DIVISION

This Division conducts and co-ordinates studies leading to recommendations on water management and development by federal and federal-provincial agencies. It also negotiates and administers federal-provincial agreements for research, planning and development of water resources as well as annual grants in aid of water-resource research in Canadian universities.

During 1967-68 the Division reviewed federal water policies and programs. It helped prepare new legislation covering federal and federal-provincial activities in the water-resource field. There were many consultations with federal and provincial officials.

Particular attention was given to water pollution. On the basis of the guidelines announced by the Pollution and Our Environment Conference as well as other studies, the Branch developed several proposals for federal and federal-provincial measures to combat pollution. These included research, better intergovernmental co-ordination, the creation of a task force on water quality, comprehensive basin and regional planning, pilot projects, financial assistance for pollution control, and measures to improve training and education of water-resource personnel. After approval by the federal government, the proposals were submitted to the provinces.

Co-ordination within the federal government is in the hands of the newly established Interdepartmental Committee on Water Programs and its sub-groups. The committee replaced the Advisory Committee on Water-Use Policy, created in 1955. Division personnel serve as research workers, secretaries and in other capacities.

The Division maintains liaison between federal agencies and the Canadian Council of Resource Ministers. The latter is composed of eleven ministers – one from each province and one from the federal government. The Minister of Energy, Mines and Resources was president of the council during 1967-68. The council is advised and assisted by a co-ordination committee, headed by an official of the Department. Interdepartmental liaison to ensure a unified federal approach to the work of the council is provided through the Interdepartmental Committee on Resources, which deals with all natural resources. Among the many projects undertaken for the council were the preparation of reports and the arrangement of a workshop seminar on water resources. The seminar, scheduled for the fall of 1968, will provide the ministers and their aides with an opportunity for studying and discussing basic issues in water policy and planning.

In response to the need for more trained personnel in water resources, a National Advisory Committee on Water Resources Research was established in 1967. 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 co-ordinate such research; and to review and make recommendations on applications for grants in aid of water research dispensed by the government. In 1967-68, these grants amounted to $192,167. The committee's secretariat is provided by the Branch.

PLANNING DIVISION

This Division undertakes and co-ordinates water-resource studies either on its own or in co-operation with other agencies. Such studies include the economic, legal, social and financial aspects of regional and national water policies and projects.

Divisional staff continued to provide technical advice and assistance for the water studies undertaken by the Atlantic Development Board. These studies are being directed by a supervisory committee made up of officials from several federal agencies and the four Atlantic provinces. The head of the Branch's Atlantic Regional Unit is the secretary of the committee.

In the central region, the Branch participates in such agencies as the Co-ordinating Committee on Northern Ontario Water Resource Studies. Another joint committee with Ontario is trying to develop standards for common water-resources planning and development.

In the Prairies, Branch officials took part in the negotiations on the Saskatchewan-Nelson Basin Study, which was initiated in 1967. Discussions were also held with officials of Manitoba, Saskatchewan, and Alberta on other subjects. A joint committee was established with Alberta to design and undertake economic studies of water resources in the South Saskatchewan Basin.

In the Pacific region, the Branch helped to negotiate the Fraser River Agreement, concluded in 1968. In December 1967 the Branch, through the University of Victoria, financed a two-day seminar in Vancouver on the methodology of forecasting water demand. Participants came from public and private agencies.

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 staff of the Centre was increased in November 1967 by the transfer of the Economic Geography Division from the former Geographical Branch. Much of the effort during the year was concentrated on planning and staff organization.

Several studies were started on environmental problems, notably the implications of the guidelines proclaimed by the Pollution and our Environment Conference. The Branch represents the Department on the Alberta Advisory Committee on Pollution Control. This committee, which advises provincial authorities on the control of air, soil, and water pollution, illustrates the kind of consultation and communication recommended by the aforementioned conference.

Research into the application of air photographs to watershed planning is continuing. Attention is directed especially to determining what areas may be susceptible to flooding. A paper prepared on this subject aroused wide interest.

A survey and analysis of urban structure in the Atlantic provinces was conducted for the Atlantic Development Board. The study evaluates various aspects of urban potential such as type of establishment, employment structure, socio-economic characteristics, business methods and attitudes, population movements and consumer patterns. The results have been published. Another study in progress examines the socio-economic factors in the problems of regional development in Newfoundland.

Field work for the regional economic studies of the Prairie provinces was undertaken with the co-operation of other government departments and outside agencies. Particular emphasis was placed on transportation. The project was later transferred to the Economics Branch of the Department of Agriculture.

Inland Waters Branch

The Inland Waters Branch was created on April 1, 1967, to carry out primary continuing federal research and investigation into the inland water resources of Canada. Its creation, which resulted from the integration of the Water Research and Water Resources Branches, was prompted by the need for co-ordinating all inland water survey and research work within one branch.

From the Water Research Branch came the Great Lakes and Water Quality Divisions, which retained their names in the changeover, and the Hydrology Division which formed the nucleus for the new and larger Hydrologic Sciences Division. From the Water Resources Branch came the Canadian Hydrometric Survey which was renamed the Water Survey of Canada, and the Planning, Great Lakes and Research Divisions which combined to form the New Engineering Division. The Tides and Water Levels Section which had formed part of the Water Research Branch was attached to the Water Survey of Canada in 1967; however, responsibility for this section will revert to the Marine Sciences Branch at the close of the current fiscal year.

The Branch is responsible for the provision of all possible technical information concerning inland water resources; the conduct of research into the behaviour of water as a material; the comprehensive examination of existing pollution conditions in lakes, rivers and streams, with particular reference to the causes of, effects of and possible abatement measures for such pollution; the engineering investigation of river systems or portions thereof; participation in the planning and negotiations involved in water development and program appraisal being conducted by groups representing several agencies – federal, provincial, United States or other; co-ordination of these varied approaches to the understanding and solution of water problems, encouragement and support of research and investigatory activities in the freshwater field undertaken by universities or other appropriate agencies.

This work provides the Government of Canada with information essential to the development and application of an effective national water policy. The preservation and renewal in perpetuity of water resources are essential to a nation's well-being, and indeed are basic to its survival.

Subsequent sections outline briefly the activities of the Inland Waters Branch. A significant effort was made in establishing the Canada Centre for Inland Waters, located on the shores of Lake Ontario at Burlington. It will eventually become a major interdisciplinary water-studies centre large enough to allow biologists, engineers, chemists, physicists, geologists, economists, sociologists and other specialists to work together on water problems.

A start on the Centre was made in 1967 with the establishment of a 25,000-square-foot trailer complex comprising offices and research facilities. The Department of Energy, Mines and Resources has the major function of co-ordinating the Centre in collaboration with the Fisheries Research Board and the Department of National Health and Welfare. University professors and students will carry out research at the Centre to bring the academic research view to bear on these important problems and to help train water specialists. Industry will be involved in co-operative research projects and in undertaking, by contract, portions of the overall research. An advisory committee consisting of representatives from government agencies, industry and universities will participate in the planning of the work carried out at the Centre.

WATER SURVEY OF CANADA

The Water Survey of Canada conducts a systematic survey of streamflow, water levels and water-borne sediment throughout Canada. In addition it carries out snow and glacier surveys and water-power surveys, the latter mainly in areas of federal jurisdiction. On rivers subject to dangerous floods, frequent observations of stage are obtained and a flood-warning service is provided during danger periods; on many rivers, a study of river conditions in the upper reaches together with current meteorological data makes possible day-by-day computation of probable flood stages in the lower reaches. Although these activities are designed to meet the requirements of the federal government, an increasing portion of the total effect is aimed at satisfying requests from 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 27 field offices extending from St. John's, Newfoundland, to Whitehorse, Yukon Territory.

With such widespread operations the Water Survey has been assigned the additional task of expanding its survey network to include the collection of data on water quality, groundwater, snow, ice and tides.

During the year under review, some 250 stations were added to the gauging network, bringing to approximately 2,200 the total number of streamflow and water-level stations. Sediment data are gathered at 77 of these stations, an increase of 22 stations during the year.

An intensive program of sediment surveys on the lower Fraser River was continued to provide a sound basis for the maintenance and improvement of the navigation channels in that river. A similar program is under way on the South Saskatchewan River to determine the effect of sediment deposition behind the Gardiner Dam and the amount of erosion downstream of the dam caused by the release of water which, being relatively sediment-free, will have an affinity for sediment.

Approximately 35,000 station-years of record, representing all historical streamflow data to 1966, were key-punched and converted to magnetic tape for rapid retrieval. These data will be available as print-outs or on magnetic tape for computer processing early in 1969. Also, special equipment has been obtained and the development of a system for the automation of streamflow computations should be realized in 1969.

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 inter-provincial water problems. These responsibilities include major streamflow-measurement programs in the interconnecting channels of the Great Lakes, and on the St. Lawrence and Nelson rivers.

Tides and Water Levels. The objectives of the Tides and Water Levels Section are to supply the maritime, engineering and scientific communities and the general public with authoritative information and up-to-date accurate data and to provide vertical control for all hydrographic surveys. To fulfill this function, the Section maintains a continuous record of tides and water levels in Canada's coastal waters and the navigable waterways of the St. Lawrence River and Great Lakes system. From these records, water- and tide-level tabulations are prepared and distributed on a weekly, monthly and annual basis. In addition, tidal predictions are prepared and published annually for the use of Canadian seafarers.

To keep abreast of the increasing demand for data, many improvements to recording and data-acquisition systems were made, especially in the Arctic, sub-Arctic and off-shore areas. Several meetings with the United States Environmental Science Services Administration, United States Lake Survey, Department of Transport, National Research Council and others were held during the year to discuss common problems.

Permanent-gauge construction along the West Coast and the Western Arctic was deferred because of tidal and current surveys requested for the Straits of Georgia and Juan de Fuca. In the Great Lakes-St. Lawrence River system, and along the Atlantic Coast and Eastern Arctic, extension of gauging facilities was successfully completed. A major tidal-measurement program on the St. Lawrence River was completed on schedule and the data are being analyzed.

The network of automatic announcing and telemetry gauges was expanded, and it is now possible to obtain instantaneous water-level information at specific locations between Lake Superior and Trois-Rivières.

Considerable work was carried out for the Atlantic Tidal Power Programming Board and the co-operative effort with the Scripps Institute of Oceanography in preparing long-term hourly time series of mean sea-level data for Victoria, British Columbia, and Saint John, New Brunswick, was completed.

HYDROLOGIC SCIENCES DIVISION

The objectives of the Hydrologic Sciences Division are:

1. To develop new concepts in the evaluation of Canada's water resources, leading to improved methods of management and utilization.
2. To take part in international water-balance studies such as the International Hydrological Decade and the International Field Year on the Great Lakes.
3. To enter into joint research with universities, provincial authorities and other government departments and agencies in order to increase the understanding of the basic processes that govern each phase of the hydrologic cycle; particular emphasis is placed on relating new knowledge to Canadian situations and applications.

The Hydrologic Sciences Division has been divided into four operational Subdivisions – Glaciology, Groundwater, Hydrophysics and Water Science. Hydrophysics was in its formative stage in 1967; Water Science was being staffed during the year.

In addition to the four subdivisions, the Division provides administrative services to the Secretariat, Canadian National Committee, and International Hydrological Decade.

Glaciology. Glaciological research is conducted in the field and in the laboratory. Field investigations include studies of the mass, water and energy balance on selected glaciers as a means of gaining a greater understanding of the role of snow and ice in the hydrologic cycle. Investigations emphasize the relationship between climate and glacier variations and are aimed at ways of predicting glacier variations and meltwater yields. Glacier basins studied include the chain of five glaciers across the Cordillera in southern Alberta and British Columbia, and the Decade Glacier on Baffin Island. Similar studies were also initiated on the Berendon Glacier in northern British Columbia in order to fill a large gap in the north-south chain of glaciers along the west coast of the Americas. Movement studies were made on all glaciers and detailed studies of the application of terrestrial photogrammetry to glacier mass-balance studies were made on temperate and cold glaciers.

Personnel worked for short periods with the Defence Research Board on glacier surveys on the Per Ardua and the Gilman glaciers on Ellesmere Island and with the

Icefield Ranges Research Project on measurements of the meltwater from the "Fox" Glacier, Yukon.

An inventory of the perennial snow and ice in Canada is one of the major projects being undertaken for the International Hydrological Decade. Two pilot studies were completed, one in the Cordillera and one in Arctic Canada as the first step in this inventory. Both studies formed integral parts of the inventory manual which will be used by all countries participating in the Decade program.

Final compilation of the remaining six maps showing distribution of glaciers in Canada was completed. The Division worked with the Surveys and Mapping Branch on the compilation of detailed topographic maps depicting four of the International Hydrological Decade glacier basins and on the preparation of similar maps for the Steele Glacier.

Groundwater. The last few years have seen a marked increase in the demand in Canada for information on groundwater. Not only is there a need for a reasonably accurate estimate of the magnitude of this resource, but also a need for vastly expanded research to increase our knowledge of the behaviour of groundwater.

Until recently, most research in Canada was basic, aimed at a greater understanding of the deep groundwater flow at depths of 100 to 1,000 feet. However, a greater effort is being directed towards expanding the facilities for pure and applied research. Instruments have been designed which more accurately measure rainfall, evaporation from the ground, infiltration of water into the ground and the natural flow of groundwater.

During 1967, experimental plots for groundwater hydrology were established in all parts of Canada and the immediate results are proving invaluable. They have revealed the pattern of groundwater flows in the prairie regions; they have shown that sloughs form a useful function in a groundwater system; they have shown where to look for drinking water, why lakes are saline or fresh and how much seepage occurs under dams. In Ontario, greater insight has been gained into the flow of groundwater into lakes and rivers. Flood forecasting in British Columbia has been improved, research on saltwater intrusions into freshwater locations in coastal areas of Prince Edward Island and New Brunswick has been advanced, and mine pollution of rivers in New Brunswick evaluated. Studies of miscroscopic animal remains in prairie sloughs aim at establishing whether sloughs are permanent or temporary – knowledge that will be of immense value in better management of prairie wetland.

Hydrophysics. Winter studies of the water balance of a typical Arctic basin, frozen-ground resistivity and frost heave in mud boils have been undertaken in the Mackenzie Delta, Northwest Territories.

Discharge, snow pack, ice thickness and lake temperature have been measured in the Boot Creek Basin, south of Inuvik, and are being compared with similar measurements obtained at Gaynor's Lake, south of the Boot Creek Watershed.

Co-operative projects with the University of British Columbia are under way to determine the heat budget of a typical Delta lake and the cryostatic pressures in mud boils during freeze-back. Problems encountered in making the measurements have pointed up the requirement for development of instrumentation suitable for use during Arctic field observations.

Members of this Division contribute to the development of remote-sensing techniques, with special reference to evaluation of national water resources. Other

participants are the Geological Survey of Canada, the National Research Council and the Defence Research Board. An infrared scanner, purchased during the year, is now undergoing modification to provide improved imagery.

International Hydrological Decade. The secretariat's duties are guided by the 26-member Canadian National Committee, which co-ordinates the country-wide scientific investigation and assessment of water resources under the 1965-74 schedule for the International Hydrological Decade.

The committee includes executive personnel from federal and provincial water-resource agencies and scientists from seven Canadian universities. The chairman of the committee represents Canada internationally during the country's second 2-year term on the International Co-ordinating Council. Day-to-day administration of the national program is carried out by the Secretariat, which has been established within the Inland Waters Branch.

Ninety-seven countries and some 20 international organizations from around the world are engaged in the Decade program. The Canadian share consists of 185 research projects on all aspects of the hydrologic cycle, including detailed investigation of 45 watersheds, 34 of which are representative basins, and 11 experimental. In addition, another 14 basins are being considered for 'benchmark' studies.

GREAT LAKES DIVISION

The Division was organized during 1966 to carry out comprehensive research on the physical, chemical and geological processes acting in or affecting the Great Lakes, especially water circulation, composition and temperature, the distribution and assimilation of pollutants, the processes at the air-water interface and the relationship between the water and the shore and bottom materials.

Such knowledge will greatly increase the Department's ability to provide data and advice in support of the International Joint Commission reference on pollution in the lower Great Lakes, as well as to the Ontario agencies concerned with pollution abatement, to industries and others.

The year 1967 saw the firm establishment of the Great Lakes Division and a major start made on the development of the Canada Centre for Inland Waters (C.C.I.W.) at Burlington, Ontario. By the end of the year, the Centre was housed in a 25,000-square-foot trailer complex, and was staffed by the Great Lakes Division and units of the Water Quality Division and the Fisheries Research Board.

On December 9, the launching of C.S.S. *Limnos,* the first major research vessel for the Canada Centre, took place at the Port Weller shipyards. This 147-foot 650-ton vessel began scientific service early in 1968.

Much of the Division's time was taken up with the technical reports for Lakes Ontario and Erie required by the International Joint Commission pollution reference. However, some important elements of a longer-range program were developed.

Two major vessels were chartered and operated by Marine Sciences Branch on behalf of the Great Lakes Division in 1967. The two ships were the M.V. *Theron,* a 199-foot 850-ton vessel which operated mainly in Lake Ontario, and the M.V. *Brandal,* a 137-foot 350-ton vessel which worked mainly in Lake Erie.

Chemical Limnology. The Great Lakes and the Water Quality Divisions of the Inland Waters Branch collaborated with Department of National Health and Welfare in 21 cruises

on Lake Ontario, and 15 cruises on Lake Erie. A total of 285 samples from both lakes were analyzed by the Water Quality Division for some 30 different properties. An additional 1,000 samples from Lake Erie were analyzed on board ship for eleven properties. Department of National Health and Welfare personnel also undertook bacteriological analyses of samples from the two lakes.

A continuing series of monitoring cruises is planned to assess the change with time of the concentrations of inorganic solutes in the Great Lakes. These cruises will become less frequent as our knowledge increases.

Physical Limnology. The purpose of physical limnology is to discover the basic physical characteristics of the Great Lakes waters and to seek out and explain the distribution and variation of physical properties. For example, a number of moorings with current meters and other instrumentation have been established to provide information on the general circulation patterns and temperatures within the open lakes. Periodic flights over western Lake Ontario to undertake measurements with a thermal scanner, and airborne radiation thermometer, aerial cameras and radiometers are scheduled for surveys of lake surface phenomena and radiation balance; co-ordinated with the airborne survey is a motor launch equipped with an irradiance meter and equipment for measuring temperature profiles. Analysis of water-level data from three gauging stations was initiated to study the free surface modes and determine the periods of oscillation in western Lake Ontario.

Limnogeology. In 1967, chemical studies were undertaken to identify the organic materials present in the bottom sediments of Lakes Ontario and Erie. A geological study to differentiate and classify offshore sediments and to determine their sedimentary sequence in the post-glacial sediment column is also under way. This study is to determine present areas and rates of subaqueous erosion and accumulation, and the effect of crustal movement upon water levels and basin sedimentation during the past 10,000 years. A similar program is under way in the nearshore zone (0 - 10 fathoms).

ENGINEERING DIVISION

The Division serves as the engineering arm of the Departments's Water Group. It provides technical advice on water-resources development and control and carries out hydrologic, hydraulic and water-resources investigations.

Members of the Division participate in some 30 international, federal-provincial or inter-departmental engineering boards and committees. For example, a special staff in Vancouver provides technical support to the Canadian officers of the Columbia River Treaty Permanent Engineering Board and assists in the administering of conservation projects in British Columbia by assessing and reviewing contracts for new projects and inspecting the progress of existing projects. The Division also provides technical advice to the Department of External Affairs in connection with an international tribunal's investigation of the causes of high water on Lake Ontario in 1952.

Great Lakes. The Division provides engineering advice on the regulation and control of the waters of the Great Lakes-St. Lawrence Basin. Because of the international nature of this important drainage system, the Division is called upon to provide technical advice to and carry out investigations for the International Joint Commission, often working in close co-operation with counterparts in the United States.

From an office in Cornwall, members of the Division oversee the regulation of Lake Ontario and the St. Lawrence River. They also participated in a continuing study of the feasibility of further regulation of the Great Lakes, a major undertaking under the aegis of the International Joint Commission. Studies also were undertaken on behalf of other international boards with responsibilities in the Great Lakes-St. Lawrence Basin, including the St. Lawrence River Board of Control, Lake Superior Board of Control, Niagara Board of Control and the Co-ordinating Committee on Great Lakes Basin Hydraulic and Hydrologic Data.

An important contribution is being made on behalf of the American Falls International Board, appointed by the International Joint Commission to investigate and recommend what measures would be feasible and desirable to remove the rock debris collected at the base of Niagara Falls and to prevent or retard future erosion.

Water Projects. 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 were concentrated on the conservation and flood control of the Upper Thames Valley Conservation Authority and the Metropolitan Toronto Conservation Authority in Ontario, and on projects in North and West Vancouver, British Columbia. Similar service was provided in connection with the Greater Winnipeg Floodway which was virtually completed during the year.

A new development was the establishment of a joint Canada-Ontario task force to develop engineering and economic guide lines, criteria and standards for use in future river-basin developments in Ontario.

Engineering Hydrology. During the year, the Division investigated the causes of the recent high water on Lake Winnipeg, computed the average run-off for Canada as a whole and for the principal drainage basins, and studied flood frequency in Southern Ontario and in the Maritime Provinces. Calculations of the quantities of water capable of being handled by specific spillways were made for a number of potential water-project sites in northern Ontario, and flood characteristics of streams draining the eastern slopes of the Rocky Mountains were under study.

The Division provided technical advice to the Atlantic Development Board in connection with the Board's study of water resources in the Atlantic Provinces.

River-Basin Studies. Considerable progress was made on a study of the potential and the economic development of several river basins in northern Ontario. A full-time staff completed its second year on the study, formulating alternative development schemes, locating storage and diversion sites and designing and costing the required control structures. Reports are under preparation to show the water yield, the cost and the physical benefit for various alternative development possibilities.

In the Atlantic Provinces, a study of the Bay of Fundy tidal power is being conducted under an agreement between the Governments of Canada, New Brunswick and Nova Scotia. The first phase of the study involving the selection of alternative power sites has been completed and the second phase has been initiated. The Chief of the Engineering Division serves as chairman of the Engineering and Management Committee which is undertaking the technical and economic studies for the Atlantic Tidal Power Programming Board.

On the Prairies, the Government of Canada and the three Prairie Provinces initiated a study of the water resources of the Saskatchewan-Nelson River Basin including the additional supply that would become available through diversion or storage. The Division Chief is alternate to the chairman and a senior engineer of the Division is secretary of the board guiding the study, which is being carried out by a study director and staff located in Regina.

WATER QUALITY DIVISION

The Water Quality Division's main objective is the study of water and waste-water chemistry, water-treatment procedures and pollution abatement to promote the effective utilization of Canadian water resources. Its present activities include basin and regional water-quality studies, such as the operation of monitoring networks, research on sampling and analytical methods, and field and laboratory investigations and research on treatment processes for improving water quality. The Division also studies the prevention of corrosion from waters and waste waters, and the Division's laboratories provide analytical support to others undertaking research into and investigations of water problems.

The water-quality network, one of the Division's commitments to the International Hydrological Decade, was expanded during the year from 140 to 180 sampling stations on about 125 Canadian rivers. This network is being further expanded for analytical coverage at key points to provide additional information on pollution parameters and thus serve to some extent as a surveillance network. In addition, the Division extended its co-operation with provincial and federal agencies and universities on I.H.D. studies in research and experimental basins, increasing the number of studies from four to ten in various areas of Canada.

The Division extended its monitoring for toxic pollutants at base-metal mines in New Brunswick, daily sampling being established on several receiving streams. Monitoring was also initiated at one operating mine in the Northwest Territories. Research is under way on pollution from mining wastes, on better processes for treatment of acid waters, on ponding and neutralization techniques, and on the transport of sulphide-containing wastes by receiving waters and the role of bacteria, air, etc. in the production of acid waters.

The Division assisted consultants engaged by the Atlantic Development Board and the New Brunswick Water Authority on resources studies in the Atlantic Provinces, providing information on water quality and on pollution of waters by mining.

In western Canada, the Division continued its long-term survey of the quality of international waters, particularly those of the Pembina, Souris and Red River systems. To assist the Eastern Slopes (Alberta) Watershed program, surveys were continued on the quality of the headwaters of the Saskatchewan River system and the monitoring of receiving streams near Alberta coal mines. A number of smaller short-term surveys were carried out to assist various researchers, e.g., surveys on water quality in the Waterton National Park for the Department of National Health and Welfare and in the Crowsnest area for the Department of Lands and Forests, Province of Alberta. Studies of the Columbia River at the International boundary were made and a suitable location for continuous monitoring of this river selected.

Studies of the relationship between corrosion and water quality continued and research on the relationship between water quality and pitting corrosion of copper pipe was initiated.

Research on methodology was intensified, with major emphasis on the automation of methods for sulphate and for low concentrations of nitrogen and phosphorus and to the identification of organic pollutants by chromatographic and other techniques. Modest research on natural organic matter in waters is under way.

The Division continued to assist the Departments of National Defence and Public Works on boiler-water treatment and to provide technical assistance to provincial and other public and private agencies on water quality and treatment.

The Division set up a small laboratory at the Canada Centre for Inland Waters at Burlington to carry out analyses and related work both on shore and aboard ship in support of research on the Great Lakes. Staff and equipment at this laboratory have been increased to provide analytical support for two research vessels during the coming year.

Work continued on data-processing systems to provide computer storage, retrieval, and print-out of analytical data. A desk computer is now in operation for rapid processing of analytical results in the laboratory. Every effort is being made to make the system compatible with data and publications of other divisions and with data obtained from other agencies, particularly provincial agencies.

The Division maintained its liaison with national and international organizations and co-operated with Committee D19 of the American Society for Testing and Materials and with the U.S. Department of Health, Education and Welfare (Public Health Service) on research connected with methods of analysis.

The Division will be moving from Ottawa to the Canada Centre for Inland Waters at Burlington within about three years. Much of the initial planning for laboratories and pilot-plant facilities at the Canada Centre has been completed, but these facilities must be available before a number of major applied and engineering research projects on pollution abatement can proceed.

ENERGY DEVELOPMENT GROUP

The Energy Development Group examines Canada's total energy sources and requirements, with the Assistant Deputy Minister serving as senior adviser on overall energy plans and policies. This total energy concept is imperative at this time when there are many changes taking place in the energy area; the shifting from a predominantly hydro-electric supply to a thermal-electric and nuclear base; the development of new sources of oil and gas and extensive exploration in the far north and on our continental shelf; the reactivation of our uranium industry to meet the growing world demand for nuclear energy; and the development of large markets to permit the economic development of our vast western coal reserves. These conditions cannot be considered in isolation if the maximum benefits are to be developed for Canadians. Co-ordinated development policies and research programs must be established and fostered, and this is the task now facing the Department of Energy, Mines and Resources.

An Assistant Deputy Minister (Energy Development) was appointed on July 1, 1967, and began to organize the Energy Group. Senior advisers will be selected to head branches concerned primarily with electrical energy, oil and gas, and solid fuels (uranium and coal). In addition to the new advisory staff required for these branches, two transfers of existing energy-oriented units are proposed. An internal departmental transfer of the Resource Administration Division which, among other duties, has the responsibility for offshore oil and gas resources, has been approved; and absorption of the staff and functions of the Dominion Coal Board is contemplated following approval of legislation to dissolve that board.

ELECTRIC ENERGY

Atlantic Provinces Power Development Act. This Act is presently administered by the Northern Canada Power Commission which, in this responsibility alone, reports to the Minister of Energy, Mines and Resources. In addition to a general review of all APPDA matters for the Minister, the Energy Group participated in the following:

(a) An interdepartmental review of a submission by Maritime utilities seeking financing under the Act for thermal-electric power development as well as transmission facilities.
(b) A joint study by the Newfoundland Power Commission and the federal government to establish the relative economics of alternative means of satisfying Newfoundland's future power needs.

Atlantic Tidal Power Study (Bay of Fundy). The Group maintained a general review of progress during the year on this federal-provincial endeavour and participated in studies concerning the matching of power generation to market conditions in the United States and Canada. The Group is represented on the Engineering and Management Committee which is carrying out the study.

Saint John River Treaty. While this draft treaty for joint U.S.-Canada development of the Saint John River remained relatively dormant during the year, liaison was continued with United States, New Brunswick and Quebec officials.

Nelson River Development. An informal liaison was maintained with Manitoba Hydro and Atomic Energy of Canada Limited to follow the progress on the federal-provincial Nelson River Agreement. The Review Committee called for by the agreement will be established in the coming year. The committee is to provide annual reports to the two governments on the progress being achieved on the transmission facilities being constructed by AECL and the power-generating facilities which are the responsibility of Manitoba.

Columbia River Development. The Assistant Deputy Minister 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 board submitted its last annual report to the Canadian and United States Governments in December of 1967.

Numerous studies relating to construction and operation of the Canadian Treaty projects of Arrow, Duncan and Mica were reviewed or carried out by the board staff (Canadian section) in Vancouver, B.C.

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.

Trans-Canada Grid Study. The Group prepared the final report of the Federal-Provincial Working Committee on Long-Distance Transmission. This study was initiated in 1962 at the request of a ministerial committee representing the federal and nine provincial governments. The report of the working committee has been distributed to all participating governments and is ready for tabling in Parliament.

The working committee continued to follow closely the development of transmission facilities in Canada and discussed with utilities transmission developments which could improve the chances for the inter-provincial or international flow of electrical energy.

Research. The advent of long-distance high-voltage direct-current transmission in Canada for the Nelson River development has prompted interest in the development of solid-state equipment for the conversion of alternating to direct current for transmission and back to alternating current for distribution. A survey of possible direct-current applications in Canada over the next 13 years was made to assess the domestic market for such equipment. Research has been discussed with Canadian industry and the Department of Industry and the possible test-sites were selected.

OIL AND GAS

A continuing review of domestic and international oil and gas developments and market trends was carried on; however, the group's activities in this field of energy were restricted pending staff recruitment. The Group participated in appraisals of the Panarctic exploration program for the Arctic Islands in which the federal government participates; and the Point Tupper, Nova Scotia, refinery which is being established with federal

assistance as a means of encouraging the development and diversification of the economy on Cape Breton Island. The large Point Tupper refinery is looked upon as a cornerstone for petrochemical and related industries, and it will have the benefit of a deep-water port capable of handling the super-tankers of the future.

(Jurisdiction over offshore exploration on the Atlantic and Pacific coasts and in Hudson Bay is exercised by the Resource Administration Division. During the period covered by this report, that division operated within the Mineral Resources Division of the Mineral Development Group, and its activities will be found covered under that heading. In future, reports on the Resource Administration Division will be found under the heading of Energy Development, to which Group it is being transferred.)

COAL AND URANIUM

The Group participated in interdepartmental work concerned with the rationalization of the Cape Breton coal industry. The establishment of the Cape Breton Development Corporation, a Crown corporation, to administer the coal mines and encourage the development of a more diversified economy on Cape Breton Island, marks a new approach to the solution of problems caused by changes in the pattern of energy production and consumption.

Arrangements were made with the New Brunswick government for a new form of assistance to the Minto coal field that will make coal production more efficient and thus reverse the gradual loss of markets.

With greatly increased activity in the uranium industry, attention is being directed towards Canada's uranium prospects. Canada is one of the leading sources of uranium in the world and is expected to play an important role in meeting the world's requirements for this new source of energy. In anticipation of greatly increased exploration, the Group joined the Atomic Energy Control Board and provincial departments of mines in planning regulations governing exploration for uranium in Canada.