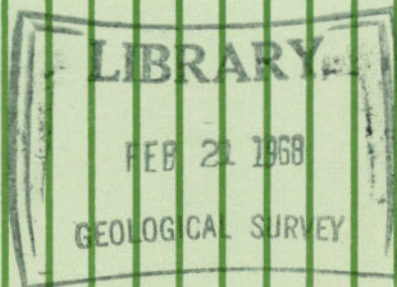


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Department of ENERGY, MINES and RESOURCES  
Ottawa, Canada  
annual report 1966-67

## CONTENTS

1	INTRODUCTION
3	MINES AND GEOSCIENCES GROUP
4	Surveys and Mapping Branch
8	Geological Survey of Canada
11	Mines Branch
17	Observatories Branch
20	Geographical Branch
22	Polar Continental Shelf Project
25	MINERAL DEVELOPMENT GROUP
26	Mineral Resources Division
29	Explosives Division
31	WATER GROUP
32	Marine Sciences Branch
35	Policy and Planning Branch
36	Inland Waters Branch consisting of
36	Water Resources Branch and
38	Water Research Branch

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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. To better fulfill this task, the Department (previously known as the Department of Mines and Technical Surveys) was considerably broadened and reorganized by Act of Parliament (Government Organization Act, 1966, 14-15 Elizabeth II, Chapter 25), which came into force on October 1, 1966.

Most significant among the changes were (1) the acquisition from the former Department of Northern Affairs and National Resources of water resources inventory and planning, and the administration of mineral exploration in certain areas under federal jurisdiction, including Hudson Bay and the continental shelves off the Atlantic and Pacific coasts; and (2) the newly-created function of studying, recommending and co-ordinating federal policies related to energy development. The staff of the Department now numbers around 4,000.

Taking account of its new responsibilities, the Department underwent considerable internal reorganization. Its operative agencies were distributed among four large units or "groups": Mines and Geosciences, Water, Mineral Development, and Energy Development. Each of these groups is in the charge of an assistant deputy minister reporting to the deputy minister.

The Mines and Geosciences Group retained most of the older branches -- Surveys and Mapping Branch, Geological Survey of Canada, Mines Branch, Observatories Branch, Polar Continental Shelf Project, and Geographical Branch -- and is consequently considerably larger, in personnel, than the three other groups combined. The Water Group contains the Marine Sciences Branch, plus two new branches -- Inland Waters, and Policy and Planning. The latter two branches were still in a process of formation and consolidation during the period under review, and the Inland Waters Branch is covered under its two former organizational headings, Water Resources and Water Research. The Mineral Development Group contains the Mineral Resources Division and the Explosives Division, both units having been taken over from the old Department.

The Energy Development Group contains no pre-existing units, and was not yet in operation during the period covered here. It will, therefore, not be covered under a separate heading in this report. An Assistant Deputy Minister (Energy Development) was appointed in June 1967, and recruitment of professional staff was expected to begin in 1968. The Group's function will be to collect information and to make recommendations to the Minister on energy matters and energy policy, in co-operation with the several Crown companies and agencies in the energy field. It will also examine the various forms and sources of energy -- coal, oil, gas, hydro-electric and

nuclear -- and work towards effective co-ordination and implementation of energy policies. Examples of such federal efforts in the field of electricity are the participation, with the provinces of Nova Scotia and New Brunswick, in the study of the tidal power potential of the Bay of Fundy; the federal-provincial agreement on the Nelson River power development whereby the federal government will build a 600-mile transmission line costing \$170 million and lease it to Manitoba Hydro; participation in the control bodies for the proper implementation of the Columbia River Treaty; and the study of the proposed trans-Canada transmission grid.

The functions of the other three groups need not be described here, since their work is dealt with comprehensively under the various branch headings which follow. Several new developments, however, may be noted.

The Canada Centre for Inland Waters was under construction at Burlington, Ontario, whose special field of study will be the Great Lakes, with emphasis on pollution abatement. The Department's water-quality laboratory for the Maritime Provinces was moved from its temporary quarters at Dartmouth, N.S., to its permanent establishment at Moncton, N.B. The Bedford Institute of Oceanography at Dartmouth announced plans for a \$2.5 million expansion that will practically double its capacities over the next five years. The new Institute of Sedimentary and Petroleum Geology at Calgary, constructed at a cost of \$2.5 million, with a planned staff strength of 100, began its work. A new geomagnetic laboratory for the Observatories Branch was under construction in Ottawa; the total cost was to be \$1,250,000. A new spectograph was built for the 72-inch telescope in Victoria, B.C., and was expected to double the instrument's efficiency. Three new survey-and-research ships were under construction and six high-speed launches were purchased for the Marine Sciences Branch. The Department also co-ordinated federal preparation for the important National Conference on Pollution and Our Environment which was held in Montreal in November 1966 and produced numerous guidelines on the abatement of water, air and soil pollution.

By far the largest part of the Department's work is not of the type that causes headlines or can be summed up in a sentence. It is rather the steady accumulation by patient and dedicated effort of bits of scientific and technical information. This information, analyzed, combined and published in many ways, provides a progressive and ever-broadening base for the resource development of Canada.

One detail about this report itself deserves mention. While previous annual reports of the Department covered calendar years, future reports will cover fiscal years, i.e., from 1 April to 31 March. To provide for this transition, the present report covers the period 1 January, 1966, to 31 March, 1967.



**MINES AND GEOSCIENCES GROUP**

## Surveys and Mapping Branch

Demands on the services provided by the Surveys and Mapping Branch continued to expand in all its activities. There was a substantial increase in map production, and the new series of the federal electoral maps was completed. Receipts from the sale of maps and charts increased by 12 per cent, producing a revenue of over \$380,000. Orders and sales by the National Air Photo Library accounted for a revenue of \$260,000. A Branch regional office was opened in Fredericton, New Brunswick.

The Geodetic Survey had 20 parties in the field extending and strengthening the national survey framework. Close co-operation has been maintained with the United States Coast and Geodetic Survey on the Satellite Triangulation Program. Investigation in long-range studies on crustal movement is continuing. The Topographical Survey again employed its airborne electronic positioning equipment, called aerodist, in its resource mapping north of the prairies. An increased workload for this division has been occasioned by the Mapping and Charting Establishment of the Department of National Defence phasing out of domestic mapping. The Legal Surveys and Aeronautical Charts Division staffed 17 field parties on legal surveys of public lands. The northern boundaries of Manitoba and Saskatchewan were completed as well as the northern portions of the boundary between the two provinces; legislation concerning these demarcation lines was presented to and ratified by Parliament. Two new series of aeronautical charts were produced in addition to the heavy commitment for both civilian and military agencies.

The Interdepartmental Committee on Air Surveys produced aerial photography to meet the demands of 11 federal departments and agencies. Experimental work on colour photography continued.

The Branch continued to provide technical advice to the External Aid Office in connection with air-survey projects in certain developing countries. Senior Branch officials represented Canada at a number of international meetings including the International Geodetic Conference, Directing Council of the Pan-American Institute of Geography and History, International Society for Photogrammetry and the Fifth United Nations Regional Cartographic Conference for Asia and the Far East in Canberra, Australia.

The annual meeting of federal and provincial survey directors was held in Victoria, B. C. The National Advisory Committee on Control Surveys and Mapping sponsored a map-users' conference and in co-operation with the Canadian Institute of Surveying sponsored a symposium on Survey Education. The Interdepartmental Committee on Air Surveys sponsored an air-photo interpretation symposium in Ottawa which was attended by over 200 experts in that field.

### GEODETIC SURVEY

Twenty field parties extended or strengthened horizontal and vertical control to provide a national framework for mapping, charting, and major engineering projects. In addition, the Geodetic Survey participated in the Satellite Triangulation program in co-operation with the United States Coast and Geodetic Survey, and continued work on several investigational projects.

The extension and strengthening of the network of first-order horizontal control was carried on in the Northwest Territories and eight provinces. In the Northwest Territories and northern Manitoba a triangulation arc was extended westward along the 60th parallel from the Hudson Bay coast to a point 40 miles east of the Manitoba-Saskatchewan boundary. In British Columbia small triangulation networks were established in the Hudson Hope and Campbell River areas. At Campbell River a strong network was established, connecting Vancouver Island to the mainland; this network will provide a basis for a long-term investigation into suspected horizontal crustal movement in this area. A number of lines were measured

by geodimeter and tellurometer to provide scale control in existing networks between Campbell River and Vancouver. In Alberta first-order control for municipal surveys was established in the Greater Edmonton area. The Geodetic Survey co-operated with the Topographical Survey in the establishment of a first-order aerodist network which extends eastward from existing triangulation, north and east of Edmonton, across Saskatchewan to Lynn Lake, Manitoba. In Saskatchewan the Medicine Hat-North Battleford arc was completed. In northern Manitoba an arc of triangulation and first-order traverse was extended south from the 60th parallel to Churchill and Cape Churchill.

In Ontario and Quebec a large network was established to provide first-order control for municipal surveys throughout the Ottawa area. Control for municipal surveys was also established at North Bay and throughout the Niagara Peninsula. The triangulation arc in northern Quebec was extended west and south from Sugluk to the vicinity of Port Harrison. In Newfoundland satellite triangulation stations at St. John's and Goose Bay were connected to existing networks.

The Canada-United States Satellite Triangulation Program continued at Lynn Lake (Manitoba), Cambridge Bay and Frobisher Bay (Northwest Territories), Timmins (Ontario), Halifax (Nova Scotia), St. John's (Newfoundland), and Goose Bay (Labrador). All operations were terminated in June.

First-order levelling operations were carried out in four provinces and the Northwest Territories. In the Northwest Territories a line was run from Yellowknife to Enterprise. In British Columbia a line from Vancouver to Kamloops was re-levelled together with three branch lines to Iona Island, to Ladner and along Steveston Jetty. In Alberta, municipal control was established in Edmonton and Calgary. In Ontario, municipal control was established in part of the National Capital Commission area including Ottawa, and a portion of an old line along the Welland Canal was re-levelled. In Quebec the line along the railway from Hervey Junction to Senneville was re-levelled together with the line from the Lake St. John area to La Passe Dangereuse and Lac Rouvray. The results of the re-levelling verify the crustal uplift associated with the Lake St. John area. An inspection party checked some 800 bench marks in the area south of Montreal and Quebec. Precise astronomical latitude and longitude was determined at 45 triangulation stations to be used for investigational work at 15 points in British Columbia, 12 in Alberta, 3 in Manitoba, 6 in Ontario and 9 in Quebec.

The elevation and position of a Goddard Space Centre Satellite Camera at Laurentian University, Sudbury, Ontario were determined.

In the laboratory, development and improvement of electronic and radio equipment continued. All divisional electronic and radio equipment is maintained by the laboratory. New electronic-computer programs, to analyze our data and to process the aerodist field results, have been developed.

During the past 15 months the Geodetic Survey continued its interest in international geodetic organizations. Staff members attended several meetings and seminars in Canada and the United States.

### TOPOGRAPHICAL SURVEY

The Topographical Survey has maintained a high level of map production and in the fifteen months covered by this report has cleared for reproduction 30 maps at the 1:25,000 scale, 403 at 1:50,000 and 73 at 1:250,000, for a total coverage of 352,500 square miles.

Early in 1966 the Mapping and Charting Establishment (previously the Army Survey Establishment) of National Defence declared its

intention of discontinuing domestic mapping, except for strictly military needs, and in succeeding months turned over to Topographical Survey almost its entire 1:50,000 mapping program including about 150 sheets of completed compilations. It is however carrying to completion the 1:25,000 and 1:250,000 mapping that had already reached compilation stage.

The Topographical Survey has therefore been obliged to revise its field and compilation scheduling to accommodate the priority elements of the former two parallel programs. In future, this Division will be responsible for the production of new mapping at the 1:25,000 and 1:50,000 scales and the maintenance of all mapping at the three scales: 1:25,000, 1:50,000, and 1:250,000.

The Mapping and Charting Establishment has for many years accepted and under agreement has published the 1:50,000 mapping produced by the British Columbia Department of Lands, Forests and Water Resources. This work will also be taken over by the Topographical Survey.

Complete map coverage of Canada in 1967 at the 1:250,000 scale appears probable. There will be a continuing program of revision after the series of 925 maps is complete.

About 7,250 maps at the 1:50,000 scale are now available for distribution, representing 33 per cent of the land area of Canada. Another 500 maps at the 1:25,000 scale cover the major cities. Distribution of advance information prints of new mapping amounted to 1,000 prints per month.

Field work engaged 36 field officers and six office personnel in a wide variety of surveys and map inspection across Canada.

An air-supported party secured control for 1:50,000 mapping of 13,000 square miles required by the Geological Survey in northern British Columbia and in southwestern Yukon.

Several field parties obtained control for 1:25,000 mapping at Halifax, Moncton, Sept Iles, Simcoe, and Leamington and for special airport plots at Gander, Newfoundland, and at North Bay, Sudbury, and Timmins, Ontario.

More cities are requesting co-ordinate control surveys and monumentation for municipal use. This year the Division assigned seven field officers to this type of work who undertook surveys in co-operation with municipal engineers in St. John's, Corner Brook, Halifax, Dartmouth, Sydney, Ottawa, Orillia, the city complex west of Toronto, and in Regina, Calgary and Edmonton. This work was extended to provide control surveys for new express highways and the twinning of the Welland Canal in southern Ontario. Reconnaissance was carried out in Vancouver in preparation for a co-ordinate survey of that city in 1967.

Three field parties carried out spirit levelling surveys for engineering and mapping purposes. In the winter of 1966, one party established levels along the Churchill River (Newfoundland) for 200 miles from tidewater to Churchill Falls; another party, under the same officer, in 1967 extended levels for 355 miles in Ungava between Schefferville and Lac Bienville. The third party continued the joint federal-provincial levelling program in Saskatchewan and established second-order levels in the industrially developing areas around Quill Lakes and Yorkton.

Five field officers were assigned to surveys for revision and/or field completion of 1:25,000 and 1:50,000 mapping in Nova Scotia, New Brunswick, Quebec and Ontario; some members of the office staff of the inspection subsection were also engaged in these projects on a rotational basis.

Assistance to other organizations included determination of positions for 50 radio aids to navigation across Canada for the Department of Transport, and surveys for the Polar Shelf Project in the Arctic Islands.

Much progress was made in the processing, evaluation and cataloguing of survey data by computer. New ground had to be broken in digitizing aerodist data for computer processing. The resulting files and catalogues are available to, and being widely used by, other survey and engineering organizations.

With completion of the 1:250,000 mapping in sight, emphasis in compilation returned to the 1:50,000 scale. Production has not shown an increase over the previous year but reorganization of staff, replacement of obsolete equipment and training are expected to show early returns. Map revision work consisted of recompilation of about 70 sheets in the Eastern Townships of Quebec, around Ottawa, and southwest of Calgary.

The demand for special plots at larger than mapping scales continued to increase. In this reporting period, there were 41 special projects varying from a few days' work to major mapping tasks for many branches of this department, for the departments of Indian Affairs and Northern Development, Public Works and Transport and for Atomic Energy of Canada, Defence Research Board, National Capital Commission and the Arctic Institute of North America. Of particular interest were the mosaics and special plots, produced from several sets of aerial photography, of the surging Steele Glacier in the Yukon. In addition, technical advice and assistance was extended to many agencies in preparing specifications for map compilation by contract.

The Topographical Survey continued to inspect the aerial photography carried out by contract for the federal government, advised on specifications and recommended payment for acceptable work.

The Technical Assistance Unit continued to monitor the surveys and mapping carried out by the External Aid Office under the Colombo Plan, Special Commonwealth African Assistance Plan and the Canada-Commonwealth Caribbean Assistance Program. Countries now involved are Trinidad, Guyana, Nigeria and Tanzania.

The Research and Development Unit provided electronic computer programs for control plotting and manuscript drawing, adjustments for aerotriangulation control extensions, adaptation of existing and new equipment parameters into the adjustment program, the adjustment of common points along aerotriangulation block edges, and adjustments of special test projects. In addition, the unit assessed photogrammetric block adjustment of foreign-aid mapping, accuracy assessment of plotting equipment, and problems encountered in the processing systems of different computers.

Several possible approaches to automated mapping systems were investigated and these studies will intensify throughout the coming year.

The photographic laboratory of the unit was established late in 1966. Experimental work was directed toward map revision, map substitutes and map supplements.

#### LEGAL SURVEYS AND AERONAUTICAL CHARTS

Legal surveys in Indian Reserves, national parks and territorial lands were undertaken as usual. Of particular note were subdivision surveys at several settlements in the Northwest Territories. All work connected with the north boundaries of Manitoba and Saskatchewan, and the northern part of the boundary between Manitoba and Saskatchewan was completed. Legislation establishing these boundaries as surveyed by the respective boundary commissions was presented to and ratified by Parliament. New types of aeronautical charts continued to be required to support new developments in electronic aids to navigation and to assist aviators and air-traffic controllers.

Five interprovincial and territorial boundary commissions were active in the 15-month period from January 1, 1966. In addition to the work mentioned above, the report for the north boundary of



British Columbia was completed and preparation for legislation to ratify this boundary was initiated. The report of the inspection and restoration of the north boundary of Alberta was completed. The surveys to demarcate the unsurveyed portions of the Manitoba-Saskatchewan boundary were completed, and preparations were begun to resurvey the southerly 240 miles of this boundary.

Seventeen field parties carried out legal surveys in the public lands of Canada. In addition, contracts were arranged with 11 survey firms in private practice for government surveys, and technical instructions were issued for 308 legal surveys on Crown Canada lands for private and provincial agencies. Surveys were undertaken in 60 Indian Reserves, the largest project being the survey of the boundaries of a 63,000-acre new reserve for the Lac La Ronge band of Indians in northern Saskatchewan. The program of establishing local co-ordinate control networks for legal surveys was continued. One network was established at Banff townsite and two others in the Yukon Territory -- one at Hunker Creek, and another at Vangorda Creek, where 14,000 claims had been staked following the discovery of rich mineral deposits. In the Northwest Territories a new townsite at Wrigley and an addition to Inuvik were surveyed. Subdivisions for administrative staff and Eskimo settlement were carried out in the Arctic at Cambridge Bay, Gjoa Haven, Spence Bay, Igloodik, Hall Beach and Broughton Island.

Significant advances were made in aeronautical charting. Two new series of charts were produced -- one to inform aviators of standard instrument departure procedures and the other to provide information for traffic controllers at busy airports. A plotting chart at the scale of 1:6,000,000 was also produced to provide aviators with a suitable chart extending from the west coast of Canada to the coast of Europe. To facilitate military jet air operations, the high-altitude instrument approach procedures charts were published in bound book form rather than loose leaf as formerly, and were issued every 35 days.

Survey documents entered in the Canada Lands Surveys Records consisted of 556 plans and 200 field books. About 35,300 document extracts, publications and astronomical field tables were dispatched, and information on 398 airline distances was provided for official purposes.

The Board of Examiners met eight times. Of the forty-eight candidates examined in February 1966, nine qualified for the certificate of preliminary examination and six for commissions as Dominion Land Surveyors. Of the thirty-eight candidates examined in February 1967, eight were successful in their preliminary examinations, five qualified for Dominion Land Surveyor commissions and one completed the first part of the final examination to qualify as a Dominion Topographical Surveyor.

#### INTERNATIONAL BOUNDARY COMMISSION

The International Boundary Commission continued the annual maintenance required for the effective definition and marking of the 5,525 miles of boundary that divides Canada and the United States. Various parts of the line were inspected and three Canadian field parties, as well as parties from the United States, carried out maintenance on widely scattered sections.

The Commissioners for Canada and the United States made joint inspections along the line and inspected the work of field parties on the boundary between New Brunswick and Maine, Quebec and Maine, and Manitoba and North Dakota.

A Canadian field party working on the New Brunswick-Maine boundary inspected 166 monuments and relocated 1 monument at a highway crossing. In addition, herbicides were applied to maintain a cleared vista on 44 miles of boundary. The same party measured 109 lines with geodimeter on 37 miles of the Quebec-Vermont boundary, and inspected 115 monuments on that section.

A second Canadian party recleared 23 miles of the height-of-land boundary between Quebec and Maine, treating it with herbicide. On this section 553 boundary monuments were inspected, two of these were repaired and 12 monuments were replaced. In addition, this party established 6 new triangulation stations and measured 11 lines with geodimeter on the Detroit River, a continuation of a resurvey undertaken the previous year. Positions of buoys marking the boundary through western Lake Erie were also checked.

A third Canadian party made resurveys on the 49th parallel for the re-establishment of ornamental monuments at border road crossings from Manitoba westward to central British Columbia. Precise distance measurements were made with geodimeter to assist a United States party of the Commission in North Dakota. In all 17 new monuments and marks were installed and 18 lines measured.

An aerial application of herbicides was made on a 20-mile section of the boundary south of Trail, B. C., to maintain the cleared boundary vista.

During the 1966 field season, Canadian parties recleared 23 miles of boundary vista, treated 87 miles of boundary by chemicals (of which 20 miles were by aerial application) measured 138 lines with geodimeter, inspected 834 monuments (of which 3 were repaired), and re-established 30 boundary monuments.

#### MAP COMPILATION AND REPRODUCTION

Map and chart production for the last 15 months was slightly higher than for the previous 15-month period.

Maps received from the Topographical Survey for reproduction numbered 511. These included 32 at 1:25,000 scale; 395 at 1:50,000; and 84 at 1:250,000.

Maps received from the Mapping and Charting Establishment for plating and printing numbered 140. These included 29 at 1:25,000 scale; 56 at the 1:50,000 scale; and 55 at the 1:250,000 scale.

Maps and charts printed numbered 5,534. Of the total, 2,996 were printed on the large offset presses and 2,538 on multilith.

In the spring of 1967, the status of the 1:50,000 series stood at 28.3 per cent published for 6,175 sheets of a potential 21,800. The status of the 1:250,000 series stood at 88.9 per cent published, or 821 of a potential 923.

The conversion of the eight-mile series to 1:500,000 was 85.4 per cent complete, with 188 maps.

#### NATIONAL AIR PHOTO LIBRARY AND MAP DISTRIBUTION

##### National Air Photo Library

During the period under review, 5,880 requisitions for photographic work, the highest annual total in the Library's history, were prepared for processing. These requisitions covered 537,829 reprints from federal government air-survey negatives (contact prints, enlargements, multiplex diapositives, mosaics, lantern slides, etc.).

The Library received 60,803 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.

The sixth edition of the Air Photo Coverage Map of Canada (1965) was made available for distribution in April 1966. Copies are supplied, free of charge, on request. In addition, four supplementary sheets were compiled to show, in the same manner as the national coverage, the available photography held by those provinces which had not stored their negatives with the N.A.P.L. It is intended that this supplement to the national coverage will be compiled and issued annually.

A brochure, presenting a brief outline of the history of the Library, and containing information regarding requests and photographic material, first published by the Queen's Printer in December 1962, required a fourth printing. Approximately 30,000 copies of this brochure have now been distributed to the public, either by mail or through various government agencies.

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.

The National Air Photo Library will maintain a branch office in the new Geological Survey of Canada building in Calgary and distribute air photos covering the four western provinces, Northwest Territories, Yukon, and the Arctic Islands.

The Library has undertaken to store present and future negatives of the Newfoundland Forest Inventory, and to distribute prints.

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

#### Map Distribution

During the past 15 months, the distribution of civilian and military maps was combined in a single Map Distribution Office. This involved considerable reorganization and expansion.

The number of maps distributed rose from 1,236,219 in 1965 to 1,485,906 in 1966, and total revenue increased from \$258,757 to \$301,262.

The stationing of Canadian troops in many parts of the world has necessitated a steady expansion of the section for foreign maps and charts. The section now has 12,572 maps and charts, an increase of 1,398 from the preceding year. It is the only depot for foreign maps and charts in Canada.

Since August, 1966, large map orders for federal and provincial government departments are no longer sent free of charge, but are sold with a 70-per-cent discount.

## Geological Survey of Canada

The Geological Survey conducts investigations designed to add to the understanding of the geology of Canada and to contribute to advances in earth sciences. Its functions include preparing an inventory of the potential mineral resources of Canada; providing industry and government with the data needed for the discovery and exploitation of the nation's mineral deposits; providing data essential for proper planning and development of various resources; research that will contribute to an understanding of the formation of rocks and mineral deposits thus enabling geologists to assist even more effectively in prospecting for mineral deposits; developing instruments and methods as aids to both geological and mineral-deposit investigations; and assisting in field and laboratory training in the geological sciences and in the supporting techniques to meet the requirements of both science and the nation for trained personnel.

In 1966 the Survey provided support for 20 doctorate-theses projects through summer employment. A total of 72 graduate assistants were employed in the field and 41 in the office; 114 student assistants worked with various field parties and 54 were assigned to office positions.

The Geological Survey conducts a broad category of investigations of a regional nature in the Canadian Shield, in the Appalachian and Cordilleran geosynclinal belts, in the sedimentary basins of the Arctic Archipelago and the Interior Plains, and in the unconsolidated Quaternary deposits. In addition, activities directed toward the investigation of specific topics are undertaken, commonly as a result of the interest generated by the broader regional studies.

During the period covered by this report the Survey sent out 102 full-time field parties and 36 short-term parties. Twenty parties were active in reconnaissance studies, the remainder in more detailed mapping or in the investigation of specific topics. Although no major airborne reconnaissance projects were carried out, helicopters and light fixed-wing aircraft were used by many parties. Operation Selwyn, using a helicopter, continued reconnaissance mapping in eastern Yukon and adjacent areas; helicopter support was also provided to parties in central British Columbia and District of Mackenzie.

On a more detailed and topical scale the Geological Survey activities covered a wide range. Many of these projects were based on information derived from previous reconnaissance studies. More than 80 field parties were engaged in studies of this nature; the subjects studied ranged from ultramafic rocks in Yukon Territory to Cambrian biostratigraphy in the Canadian Cordillera; from relatively recent volcanic rocks in northern British Columbia to the uranium content of Saskatchewan lignites; from organic growths in carbonate tongues to the Manicouagan circular structure in Quebec. Laboratory studies ranged from the development of new geophysical instruments such as an ultra-low-frequency resistivity-probing device for Pleistocene and aquifer mapping or the adaptation of the rubidium-vapour airborne magnetometer for use as a practical and economical survey instrument, to mineralogical studies of nine new minerals and refinement of Rb/Sr age-determination techniques. Chemical analyses of 2,244 samples were completed, 1,959 spectrographic determinations were made and a total of 81,603 analyses were made on rocks, minerals and ores.

To stimulate and support geological research in Canadian universities, grants by the Geological Survey were initiated in 1951. During the period covered by this report 85 grants totalling \$150,000 were awarded to 20 universities.

The results of the Survey's scientific work are published in the form of memoirs, bulletins, papers and geological maps. During the fifteen-month period covered by this report 6 memoirs, 22 bulletins, 52 papers, 20 geological maps (apart from those used to illustrate the preceding reports) and 1 miscellaneous report were issued.

About 390,000 copies of maps and reports were distributed, 8,218 sets of mineral and rock chips were sold, and 70 special collections representing Canada's mineral industry were prepared for display in Canadian embassies throughout the world.

The Geological Survey library, the most extensive of its kind in Canada, had a circulation of 61,174 items during the report period.

In addition to the headquarters in Ottawa, the Survey maintains offices in Calgary, Whitehorse, Yellowknife and Vancouver. The Calgary offices were moved in March to the Survey's new Institute of Sedimentary and Petroleum Geology building, officially opened in September 1967.

Several staff members are among the scientists from the United States and six other countries who have been selected as principal investigators by the U.S. National Aeronautics and Space Administration to conduct experiments on the first samples from the moon's surface to be brought back by United States astronauts.

### GEOPHYSICS

The 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 instruments and methods in, among other fields, electromagnetic, resistivity and magnetotelluric surveys; magnetic methods; rock magnetism; seismic methods; and remote sensing.

Field activities of the Division during the period covered by this report included (1) telluric and magnetotelluric studies in Manitoba, Ontario, Quebec, and New Brunswick; (2) evaluation of *in-situ* susceptibility meter and related studies at Bancroft, Ontario; (3) collection of samples for palaeomagnetic study in Yukon Territory and District of Mackenzie; (4) seismic studies in British Columbia and Saskatchewan; (5) research into the use of seismic waves in the study of groundwater problems in southeast Saskatchewan and Manitoba; (6) a feasibility study for using seismic techniques to determine the thickness of strata overlying uranium pay-zones, Elliot Lake, Ontario; (7) determination of thickness and attitude of sediments overlying basement rocks in various parts of coastal Newfoundland and Nova Scotia; (8) a broad reconnaissance in the Elliot Lake area, Ontario, for radioactive minerals using the ground gamma-ray spectrometer; and (9) as assessment of the geological potential of coloured air photographs, using a geologically known area--Carleton Place, Ontario.

Members of the Division continued to participate in the management of the federal-provincial aeromagnetic survey program. Three 3-year contracts were drawn up and let for certain areas in Quebec, Saskatchewan and British Columbia. There are now nine different areas under contract for aeromagnetic surveys in various provinces and territories in the country. Geophysics personnel checked 411 one-mile aeromagnetic map compilations and 36 four-mile composite maps resulting from the program.

In the laboratories staff geophysicists undertook the development and/or construction of several types of electronic equipment, including a lightweight magnetometer suitable for installation in a light twin-engined aircraft and a field susceptibility meter. In the palaeomagnetic laboratory, work included the measurement and testing of the palaeomagnetism of dykes from Val d'Or-Noranda, Sudbury, and southern Nova Scotia. A study of the palaeomagnetism of the Manicouagan area was completed and an investigation on the magnetic properties of sulphides is in progress.

### PETROLOGICAL SCIENCES

The Petrological Sciences Division is responsible for research, development and services in the fields of isotope geology, analytical

chemistry, mineralogy, petrology, and data processing to complement and support the work of the Geological Survey.

The Division measures the age of rocks, minerals and carbonaceous materials, using methods based on the radioactive decay of naturally occurring nuclides. It also investigates stable isotopic variations in nature and conducts fundamental research using enriched stable and radioactive isotopes in laboratory and field studies, a research designed to yield information regarding the magnitude of isotopic fractionation to be expected in biochemical and geological environments.

The age-determination program was continued, and 186 K/Ar age determinations, 13 Rb/Sr isochron studies, and 265 radiocarbon age determinations were made. The first two techniques are used to date rocks and minerals, usually of great age, and the resultant dates are used to unravel tectonic history and to identify periods of intrusion and metamorphism in the Appalachian, Precambrian Shield, Inuitian and Cordilleran regions. Radiocarbon methods give reliable dates only if the material tested is less than 54,000 years old. Most radiocarbon samples processed by the Division were selected to provide data for current research in Quaternary chronology, to shed light on crustal movements as evidenced by shore-level changes, and to provide information on the rates of geological processes, such as sedimentation. Some archeological material is being dated, and one sample of wood from a carved figure of historical interest was dated for the National Gallery of Canada.

During the period covered by this report the major emphasis in isotope geology has been on the refinement of Rb/Sr age-determination techniques. The Geological Survey has recently assumed responsibility for the development of a national system of recording for all Canadian isotopic age data as a service to the public, to earth scientists, and to the mineral industry. The format to be used has been developed and distributed to interested laboratory workers for discussion.

Stable-isotope studies continued on a reduced scale owing to the heavy requirements of the age-determination program; 136 sulphur-isotope determinations were made for staff members.

Chemical and instrumental analyses of rocks, minerals and related terrestrial and extraterrestrial materials were continued in order to meet the demand for more varied and sensitive analytical data. A total of 69,836 individual determinations were made. The number of samples submitted for rapid analysis was about 400 more than that submitted the previous year, but there was a considerable decrease in the total number of samples submitted for spectrographic analysis. The backlog carried in the fiscal year 1967-68 is much smaller than that carried in 1966. Research development included the development of a non-fusion general method for silicate rocks, studies directed toward a reliable determination of fluorine in silicates, the development of a new spectrophotometric method for the determination of palladium, and an evaluation of a titrimetric method for the determination of silica as a possible alternative method for routine use.

Mineralogical studies made by the Division cover the physical and chemical properties of minerals using X-ray, electron-beam and other techniques. The Survey's mineralogists provide mineralogical data to staff geologists for use in solving geologic problems, compile and publish data on Canadian mineral localities, catalogue the National Mineral Collection, collect bulk rock and mineral samples in order to assemble collections for public sale, and identify rock and mineral samples as a public service.

The number of mineral and rock collections distributed was 8,218, and staff members prepared two tons of rock chips for construction of a mosaic map of Canada for display at Expo '67. More than 1,600 samples of rocks and minerals were examined for members of the public, and the reorganization of the systematic Reference Series to Dana's new system was completed.

Petrological studies carried out by the Division are designed to investigate the theories and problems of petrology and to elucidate petrologic problems of economic or regional significance encountered by other Survey geologists. A major study of granites in Canada continued. At present it is directed toward the elucidation of problems of plutonism and migmatization in a well-defined mountain belt in southern British Columbia. As part of a study of ultramafic rocks in Canada the petrologic study of the Muskox Intrusion in the Northwest Territories was continued. Laboratory investigation of Canadian meteorites was continued by members of the staff as were studies in the fields of data processing and geomathematical research.

#### ECONOMIC GEOLOGY

The studies carried out by this Division are directed primarily to those aspects of geology that have a direct commercial application, i.e. the study of mineral deposits, geochemistry, engineering geology and Pleistocene geology. Since the last annual report was prepared the Groundwater Section, with the exception of the Engineering Geology Unit, was transferred to the Water Research Branch.

The most significant accomplishment of the year in the geology of mineral deposits was the first publication applying concepts of genesis of uranium deposits to our knowledge of the geology of Canada and so providing a direct assessment of those areas in Canada where the more important types of uranium deposits should be sought.

Five field projects were directed towards the study of mineral deposits, three examined nickel, iron and tin deposits throughout Canada, two others concentrated their efforts in the District of Mackenzie and the Sault Ste. Marie-Chibougamau regions studying many different types of deposits and attempting to relate them to the overall geology.

The evaluation of dam sites in Yukon Territory and a geological assessment of the new routes of the Welland Canal System were carried out by the Engineering Geology Unit.

Studies concerned with the development and testing of methods that can be used to delineate anomalously high concentrations of metals on both reconnaissance and detailed scales were carried out as part of the geochemical research program. The immediate acceptance by industry of methods devised for locating silver-bearing veins in the Cobalt area of Ontario and the staking rush that followed release of geochemical surveys in the Bathurst area, New Brunswick, are evidence of the success of this program.

Pleistocene geology is concerned with the study of unconsolidated deposits, mainly of glacial origin, which cover large parts of the country and on which most of Canada's cities are built and her crops and forests grow. The work carried out by the Geological Survey comprises areal studies and topical projects designed to solve specific problems. The results of the areal studies are used extensively by agencies concerned with forestry, agriculture, land inventory, groundwater and engineering. Several projects were undertaken to meet the specific requirements of one or more of these agencies.

Eighteen projects were carried out during the 1966 field season. The surficial geology of parts of southern Yukon Territory and the Mackenzie Delta region was studied. The valleys of the Peace, Findlay and Parsnip Rivers in British Columbia were examined in advance of hydro-electric development and a similar study was carried out in the Columbia and Kootenay Valleys. Palynological studies were made on the Prairies. Areal studies were made in Iosegun map-area, Alberta; Ganoque, Ontario; Stratford-Conestogo, Ontario; southeastern Quebec and Summerside, Prince Edward Island. The uplift of the Hudson Bay and Lake Huron Basins was studied and the surficial deposits of the Kirkland Lake region were examined as part of a program designed to assist in mineral exploration.

## REGIONAL GEOLOGY

The Regional Geology Division has as its prime objective the systematic investigation of orogenically disturbed regions, such studies being directed towards the recognition of fundamental geological models, known or new, and their implications in regard to mineral explorations. Studies are carried out in three of the four orogenically disturbed regions of Canada -- the Cordilleran Region on the west, the extensive Precambrian Shield of central and northern Canada, and the Appalachian Region of the east.

Eleven field parties carried out studies in the Cordilleran Region; seventeen on the Canadian Shield; and six in the Appalachian Region.

In the Cordilleran Region activities were mainly directed toward completion of the reconnaissance phase of regional investigations, although other more detailed and more specialized projects such as volcanological, structural, stratigraphic and metamorphic studies were also conducted. One party completed the reconnaissance of Sekwi Mountain, Nahanni, Frances Lake, Watson Lake and Jennings River map-areas, in Yukon Territory, District of Mackenzie and northern British Columbia. A reconnaissance study of about half of McBride map-area, British Columbia, was completed. Other investigations in British Columbia concerned central Vancouver Island, the metamorphic terrain along Canoe River valley, a program of volcanological work in association with the Observatories Branch in the vicinity of Mount Edziza, the Atlin Horst in the northern part of the province and the Mesozoic stratigraphy of the Skeena River region. Three graduate students undertook these projects as part of the Cordilleran Structural Project, and one graduate continued a structural and petrographic study of the Grand Forks Group rocks.

Although no major helicopter-supported reconnaissance projects were carried out on the Canadian Shield, aircraft were used extensively by most of the 17 field parties, both for transportation and as traversing tools. One helicopter was shared by several parties in the Western Shield and was moved north and south to take advantage of changing ice and weather conditions. Most projects involved areas and problems of significance to geological theory and/or of importance in mineral exploration in northern Canada. One party continued the study of the structure and petrology of gneisses south of the East Arm of Great Slave Lake, and a graduate student began a thesis project on the stratigraphy, sedimentology and tectonics of the Proterozoic rocks in the same general area. As part of a broad study of volcanic piles in the Canadian Shield one geologist studied the volcanic rocks of the Coppermine River Group. The reconnaissance study of the gold-bearing Point Lake-Contwoyto Lake area was completed, as was the mapping of Wholdaia Lake map-area and a study of the internal constitution of the Dubawnt Group. A study of a critical strip across the northern end of the Ennadai-Rankin orogenic belt was started. Ten field parties carried out studies in that part of the Shield lying east of the Manitoba-Ontario boundary.

The field phase of a study on the age, petrology and tectonic importance of the diabase dyke swarms of the Shield was completed. A graduate student completed the field work on his thesis study in the Hastings area of Ontario, another student commenced a structural and metamorphic petrological study of the Naskaupi and older fold belts in Labrador and a third student began a study designed to define the volcanic-sedimentary stratigraphy of the Kirkland Lake area and to relate this to the known mineral occurrences. The latter project was directed by a staff member who also started a study of Archaean volcanic belts. A study of the Grenville metamorphic front north of Lake Huron was continued, as was a detailed study of the sedimentary sequences in the volcanic-sedimentary belt between Sioux Lookout and Savant Lake, northwestern Ontario. A geological reconnaissance was made of the Northwest River area of Labrador, and preliminary studies were carried out in connection with Operation Tornat, planned to begin in 1967.

In the Appalachian Region six projects were carried out in central New Brunswick, a detailed study of the stratigraphy and structure of the Ordovician and Silurian strata was begun in the McKendrick Lake area. In southern New Brunswick a detailed study of the stratigraphy, structure, and mineral deposits of the St. Stephen-Pleasant Mountain area was completed, an area containing tin, molybdenum and nickel deposits. In northern Nova Scotia, detailed studies of Lower Palaeozoic rocks continued in the Cobequid Mountains and were completed with re-examination of key areas in the Antigonish Highlands. Regional investigations of Ordovician and Silurian volcanic and sedimentary rocks in Red Indian Lake area, central Newfoundland, which includes the Buchans lead-zinc-copper mine, was completed and work in Burgeo area to the south was begun. The results of recent studies by mining-company and university geologists on the Burlington Peninsula, northern Newfoundland, were investigated and a detailed structural analysis of a key part of the area was begun by a post-doctoral fellow. The study of the Lower Palaeozoic klippe rocks at the north end of Great Northern Peninsula was continued.

## FUELS AND STRATIGRAPHY

This Division is concerned primarily with the unmetamorphosed, stratified, largely marine fossiliferous rocks, in which oil, natural gas and coal--the fossil fuels--are most commonly found. Thus the principal objective of the Division is to determine the succession, lithology, structure, age and correlation of the sedimentary bed-rock formations in Canada; to chart and otherwise illustrate the surface and subsurface distribution of these rocks in space and time; to carry on research in structural geology, stratigraphy, sedimentology, palaeontology, and to study the petrologic and organic constitution of coal seams. A permanent repository for well cores and cuttings is maintained, and these materials are made available to visiting geologists for study.

Nine field parties carried out stratigraphic investigations in Canada's sedimentary basins. A reconnaissance investigation by several staff members of the regional geology of about 12,000 square miles of the southern Rocky Mountains was completed, as was the mapping of the Palaeozoic rocks of southern Ontario. Tectonic and structural studies were carried out in various parts of the Foothills area, and mapping of areas of the southern Alberta Plains was continued.

On the Arctic Islands, Operation Grant Land, begun in 1965, was completed. This project involved four staff members and included studies in stratigraphy and structural geology.

The investigation of the various forms assumed by living animals in the past is of great importance as fossils form an important criterion for determining the regional and intercontinental equivalence of stratified rocks. To further this aim, palaeontologists of the Division prepared 203 reports on 3,008 lots of fossils. Loans and exchanges of material were made to individuals and institutions in Canada and elsewhere. In Canada and five other countries, 52 experts on particular groups of fossils are engaged in studies on Geological Survey material that result in reports to field officers and/or publications on Canadian fossils. Forty-five geologists from universities, oil companies and abroad made use of the Survey's fossil collections or consulted with staff members during the period covered by this report.

Investigations of Canadian coals and associated clastic sediments were continued. Petrological studies were carried out to obtain information valuable for coal geology, coal mining and coal utilization, particularly as applied to research on coking coals. Palynological (spore) investigations designed to assist in determining the stratigraphy of the coalfields and regions with Permian and Carboniferous rock were continued.

A field and laboratory study was made of the Pictou coalfield at the request of the Nova Scotia Department of Mines. The uranium possibilities in the Saskatchewan lignite exposures were investigated and visits were made to North and South Dakota where commercial quantities of uranium ore are extracted from lignite.

## 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 fifteen-month period 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 and Mining Practice, Mineral Sciences, Extraction Metallurgy, Mineral Processing, and Mining Research.

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 "trouble-shooting" for government departments and private industry. The degassing of molten iron and steel, and methods for measuring oxygen content of molten steel are samples of its foundry research. Research on fuels concerns especially the refining of heavy, low-grade crude oils and better uses of Canadian coals. In mining safety, attention is directed to such problems as the operation of electrical equipment in explosive atmospheres.

Mineral-sciences experts study the composition and properties of useful minerals. The complicated sulphides occupy much attention, as do multi-oxide systems of such elements as niobium, tantalum, iron, aluminum and manganese. Research is also being conducted on the fabrication of piezoelectric and magnetic ceramics and the elaboration of mineral standards. Extraction metallurgy is concerned with hydrometallurgical and pyrometallurgical methods for processing ores. Also studied are the causes and cures of corrosion, hydrogen embrittlement of metals during electroplating, and analytic procedures. Research in mineral processing covers the flotation, jigging, and filtration of metallic minerals, the processing of industrial minerals such as clays and shales, preparation of concrete, building stone, asbestos, and other materials. In the mining-research laboratories, rock mechanics, drilling and blasting, the application of computers to mining operations, and the testing of explosives under the Canadian Explosives Act occupy most of the work.

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

### PHYSICAL METALLURGY DIVISION

The work of the Division in support of Canada's metal and mining industries encompassed both fundamental and applied research as well as short-term investigations to resolve problems of immediate urgency. The Division continued to meet requests from industry and from other government departments for consultation and advice on metallurgical problems, especially the Departments of National Defence, Transport, Agriculture and Public Works, as well as such agencies as the National Energy Board, National Research Council, Atomic Energy of Canada and Eldorado. Industrial concerns ranging from primary metal producers through manufacturers and consumers down to small foundries and shops are represented among those calling upon the assistance of the Division.

In the international field, senior staff members participated in numerous organizations, particularly in support of Canada's defence commitments at home and abroad, as well as the development of international standards and specifications. Visits to the laboratories by distinguished scientists from abroad attest to the interest in work being done and permit discussions on new developments within the Division and elsewhere.

Investigations of damaged or otherwise unsatisfactory metal components continued to be an important part of the Division's service. This work, primarily directed to determination of the cause of each problem, generally leads to recommendations for prevention

or remedy where possible. During the period covered, such metallurgical investigations and assistance covered military equipment, aircraft components, ship's propellers, gas-transmission pipe, steel rails for heavy-duty iron-ore traffic, mining equipment and miscellaneous industrial metal products. Components of crashed or damaged aircraft necessitated thorough metallurgical investigation to determine whether they contributed to the accident. Many foundries encounter problems with castings associated with moulding sands, and an important service is rendered by testing and examining such sand, with appropriate recommendations. The failure of heavily stressed parts due to fatigue requires expert analysis of the mechanical and metallurgical factors involved.

Among the more unusual and interesting items investigated were an ancient ship's anchor recovered from the bed of the St. Lawrence, which was confirmed metallurgically to be of puddled iron characteristic of the 1600-1840 period, and a survey marker dating back to 1882 which had suffered abuse. With short supply of silver and prospects for a higher price, its displacement in the common coinage of the country is expected soon, and assistance was rendered to the Royal Canadian Mint to develop nickel coins that would not run afoul of vending-machine slug-rejector mechanisms. Assistance was given to the Canadian Wildlife Service in a search for non-toxic bird shot to prevent lead poisoning among water fowl swallowing the pellets.

Advice was given to a manufacturer of safes on incorporating cast-in-place refractory materials, and a company was assisted in a metallurgical problem concerning a lead-tin alloy for producing organ pipes.

An important function of the Division is the certification of industrial radiographers on behalf of the Canadian Government Specifications Board. This activity has grown considerably in recent years, and in the period covered, 29 senior radiographers and 84 junior radiographers received certification. The number of candidates may be expected to increase, since certification of radiographers is required by the R. C. A. F. for aircraft materials and the Atomic Energy Control Board has specified that only certified personnel may conduct radiography using radioisotopes.

Research, for which the laboratories of the Division are both well equipped and staffed, embraced a wide range of important work in ferrous and non-ferrous metals. The importance of iron and steel in the economy of the country is recognized by a large proportionate effort with these metals. Extensive research is being conducted on new melting and refining processes. In particular, degassing methods, mechanisms of solidification and alloy development are being studied.

A method for directly measuring oxygen content of molten steel is under development. Its attractions are expedience and economy, both important for better production control and quality of product. The wider use of ultra-strong steels, which is desirable to improve performance through better strength/weight ratio, has required extensive study of those sudden catastrophic failures amenable to metallurgical control. This work is particularly relevant to the development of hydrofoils and advanced aircraft components.

In its search for new and better ways of using non-ferrous metals, the Division experimented with a new use for gold in preventing hydrogen embrittlement of highly stressed steel components. Similarly, work on improvements in zinc-galvanized coatings is directed to increased use of zinc and better protection for composite assemblies made from several different steels. Work has been conducted for many years on development of new high-strength magnesium-zirconium alloys, and this has now been extended with promising results to similar alloys containing silver.

Dispersion strengthening of zirconium by the direct addition of

refractory compounds during inert-atmosphere arc melting is under investigation, with intriguing early results, and a study has been initiated on the possibility of fibre-reinforcement or dispersion-strengthening of magnesium by magnesium oxide. Division personnel are also working on a process for producing better bismuth-telluride thermoelectric material. This would expand the use of this type of material in solid-state electronics, such as refrigeration devices having no moving parts.

In addition to the more obviously practical aspects of physical-metallurgy research described above, a considerable effort is being made in metal physics. This work is directed to the elucidation of phenomena of the metal state, particularly the atomic arrangement and structure of metals and alloys. The mechanisms of creep and cohesive failure and the manifestation of fatigue damage are important topics of study, as are those of solidification and diffusion. Continued ion bombardment of metal crystal surfaces has provided further confirmation of this technique for the rapid and convenient determination of crystallographic orientation. The work is being extended to studies of metal crystals and their behaviour in corrosion resistance and catalysis.

#### FUELS AND MINING PRACTICE DIVISION

The conversion of Canada's mineral fuel resources into products that will meet the diverse needs of modern industry is one of the major roles of the Fuels and Mining Practice Division. Consequently, this Division is deeply concerned with all the numerous aspects of chemical process engineering required to transform coal, as well as low-grade petroleum and natural bitumen, into products acceptable to industry.

The approach adopted by the division for the refining of residual oil and bitumen was to select the most direct route for the conversion of these substances into jet fuel with a minimum of waste. For this purpose a combined liquid-and-vapour-phase pilot plant was constructed and operated during the year. The result of operating this pilot plant has shown that a suitable catalyst can be made in Western Canada for the large-scale industrial refining of this class of oil, and further, that this catalyst has an activity which is equal to that of the standard catalyst used for this process in Europe.

The difficulties of operating the pilot plant in a stable manner have been overcome, and it is expected that a steady improvement will be made during the current year.

The catalytic-cracking program which involves the construction of a fluid-bed pilot-plant unit capable of operating at pressures up to 1,000 pounds per square inch was continued. The feed system has been put into operation, and the catalyst recirculation will be tested shortly. When completed, this pilot plant will be used to refine the intermediate products from the hydrogenation program of this division.

Catalysis plays an extremely important role in the refining of low-grade crude oils. The search for improved catalysts was continued during the year using the automated testing facilities previously constructed. The results to date suggest the importance of diluting the bitumen with a middle oil of good hydrogen transfer characteristics, and of sufficiently high boiling point to avoid the formation of hydrocarbon gases.

As concerns mineral-matter removal from heavy oils, it was shown that hydrocracking in the absence of a catalyst or diluent was an advantageous preliminary step. It remains to be shown that it is more economical than a pure visbreaking operation. However, it is already evident that hydrocracking has great merit from the point of view of conservation, and consequently further research in this area is proposed.

During the past year some new trends have developed. The combustion section of this centre has been separately designated as

the Canadian Combustion Research Laboratory. The research of the laboratory formerly concerned the combustion of Canadian coals and particularly such questions as the fouling of superheater tubes when burning the Venezuelan crude oils. By contrast, the emphasis during the past year has been on developing methods of reducing atmospheric pollution at the combustion source. The progress has been most encouraging. A magnesia-alumina additive to fuel oil has been developed that is very helpful in the elimination of acid-smut pollution. This additive is already gaining rapid industrial acceptance in the United States.

One of the most important problems of the maritime coal industry relates to the reduction of the sulphur content of the coal so that it may hold its market in the local steel industry as a source of coke. It is well known that half of the sulphur content of coking coal is associated with the mineral pyrite. However, due to particle-size limitations for the conventional coking process, little effort has been made to remove the pyrite by new means available in conventional coal-cleaning plants. Because of the great difficulties confronting the Cape Breton coal industry, studies were undertaken, with the support of the Dominion Coal Board, to determine the maximum elimination of sulphur that may be achieved by physical separation with different sizes of coal lumps. It has been shown that the size reduction need not be too extensive to arrive at sulphur levels acceptable to the steel industry, and, in addition, it was demonstrated that low sulphur contents of about 0.6% could be achieved by fine grinding (-200 mesh). Research is now in progress to study the agglomeration and dewatering of fine coal to prepare agglomerates that will be acceptable for coke manufacture in conventional ovens.

The removal of the mineral matter from coal plays an extremely important role in holding the present markets for coal and in developing new markets in Japan. The same principles that apply to the beneficiation of coal also apply to the beneficiation of many of Canada's low-grade ores. Because of the importance of improving mineral separations to the whole Canadian mineral economy, the Western Regional Laboratory has concentrated on the design of cyclone separators for separating minerals and purifying water. Considerable progress was made during the year on the improvement of the materials of construction of the "Slugging Cyclone." Special emphasis has been placed on this program to enable closed-circuit operations to be introduced in coal-washing and mineral-dressing plants, thus preventing water pollution at the source.

The safety of personnel and property is of great concern in underground mining, and also in many industrial activities involving explosive or inflammable materials. The section of the Fuels and Mining Practice Division dealing with this aspect of public safety has recently been separately designated as the Canadian Explosive Atmospheres Laboratory. In addition to its research, this laboratory also checks on and certifies the safety of mining equipment. How this work has grown may be deduced from the eightfold increase in fees in the last ten-year period, and there is no sign that the trend is levelling off. It has been difficult to increase the staff at a rate sufficient to give adequate attention to research. Nevertheless, the Canadian Explosive Atmospheres Laboratory published a report on hydrogen explosions relating to electrical apparatus. This was presented in 1966 at the first international meeting to be held in Canada of an International Electrotechnical Commission Technical Committee. The report was used as a basis for discussing international recommendations for the construction of electrical apparatus for use in explosive atmospheres of hydrogen in air.

In recent years, more equipment has appeared which is not in special explosion-proof enclosures. This category includes instrumentation, control circuits, and communication systems. Often such equipment operates at low electrical-energy levels and may be certified as "Intrinsically Safe" if it cannot produce sparks capable of igniting explosive atmospheres. Considerable research has been conducted in the laboratory concerning the energy available and the energy which can be released from iron-cored inductance coils which are often used in communication and remote-control circuits.

## MINERAL SCIENCES

The research of the Division has been concerned with eight major programs.

The most extensive of these is the multi-disciplinary study of sulphide minerals. This study has given special emphasis to the many economically important sulphide minerals occurring in Canadian orebodies. The structures of sulphides and related minerals are being studied intensively in an effort to determine the reasons for the wide variations in composition and structure, to systematize the classification of sulphide minerals, and to develop a greater insight into the relationship between crystal structure and chemical and physical properties.

In order to provide basic data for the structural study, a laboratory has been equipped with the most up-to-date types of apparatus for X-ray diffraction, including an automated four-circle goniometer, controlled by an on-line digital computer.

Phase-equilibrium studies are being conducted in some of the more important sulphide systems. This is done by synthesizing sulphide minerals under carefully controlled conditions of temperature, vapour pressure and composition, and relating the resulting assemblages to the conditions of formation.

In addition, as part of the sulphide program, a crystal-growing project has been initiated, the objective of which is to prepare large single crystals of various sulphide minerals. A study of the growth of sphalerite (ZnS) using a chemical vapour transport method has been made, resulting in the growth of some crystals up to 5 millimetres long. Some exploratory work on the effects of the addition of foreign elements to the synthetic crystals has been carried out. The program will be extended to cover other methods of crystal growth.

The work on the phase-equilibrium study of multi-oxide systems of mineralogical and metallurgical significance that has long been one of the lines of major research effort in this Division continued throughout the year. In continuation of the series of studies involving niobium and tantalum pentoxide that has been made in recent years, studies of the systems  $\text{CaO-Nb}_2\text{O}_5\text{-TiO}_2$  and  $\text{CaO-Ta}_2\text{O}_5\text{-SiO}_2$  have been initiated and are leading to some interesting results. Studies of the Ti-O system, initiated several years ago but later discontinued due to pressure of other work, have been reinstated and brought to a successful termination. Studies in the complex refractory oxide systems  $\text{CaO-Al}_2\text{O}_3\text{-Fe}_2\text{O}_3\text{-SiO}_2$  and  $\text{MgO-Al}_2\text{O}_3\text{-SiO}_2$  have also been continued during the period under review.

Work has continued in the devising of new analytical methods and in the study of the physical and chemical properties of numerous complexes on which analytical procedures might be based. Using ligand or crystal field theory to interpret the absorption spectra of transition metal ions in solutions, in crystalline complexes and in certain minerals, it was found possible to gain information on the valence state of the metal ion and on the geometry and constitution of its co-ordination sphere. Several studies of this kind were conducted in the review period. The near-ultraviolet to near-infrared spectra of various copper, nickel and cobalt complexes, formed mainly in acetone solutions, have been correlated with their structures. Many of these complexes had not previously been isolated or their nature elucidated.

The absorption spectra of silicate minerals such as biotite, xanthophyllite, tourmaline, kyanite and cordierite have been studied, and valuable information on the oxidation state and siting of the various cations has been obtained. From such studies, it is often possible to explain certain optical properties of the minerals, such as colour and pleochroism.

The Division has participated on an increasing scale in standards work in collaboration with national and international standards organizations. The first testing and evaluation of methods for the

determination of manganese, silica and phosphorus in iron ores and of chromium oxide in chrome ores was completed for the American Society for Testing and Materials (ASTM). Testing and evaluating methods for determining silica and fluorine in fluorspar, sulphur in iron ores and the manganese-dioxide content of manganese ores are in progress. The Division assisted in the standardization by the National Bureau of Standards of Sibley Iron Ore. Participation continued in the work of the Chemical Analysis Group of the Advisory Group for Aeronautical Research and Development (AGARD) of NATO. During the past year the copper, nickel and iron content of molybdenum metal was determined by wet chemical methods, and proposed polarographic techniques for traces of tin in tantalum metal were evaluated. Instrumental techniques such as the use of atomic absorption spectra for the determination of the lime and magnesia contents of iron ores are being investigated as part of the Canadian contribution to the International Standards Organization (ISO). In addition to these, the Division has assisted the Canadian Association for Applied Spectroscopy in the determination of trace elements in copper metal to be certified as spectrographic standard.

The Divisional program on the study of piezoelectric and magnetic ceramics, largely sponsored by the Defence Research Board and the Department of Industry, has been continued throughout the year with the further investigation of factors affecting the fabrication and sintering behaviour of such materials and of the effect of chemical changes on the electrical and magnetic properties of the resultant materials. In the study of the "hard" or permanent-magnet type of ferrites based upon lead/strontium/barium hexaferrite compositions, novel methods of preparation have been investigated. A press, designed to maintain a strong orienting magnetic field during the fabrication of the shapes, has been constructed and placed in operation. A phase study of the barium oxide/iron oxide and strontium oxide/iron oxide systems is under way to define the nature of the various possible compounds in these systems. A considerable amount of work has been done in conjunction with Canadian industry with a view to characterizing the oxides and assessing their suitability as potential raw materials for ferrite manufacture.

Investigations of Canadian ores, with particular reference to those mineralogical characteristics that affect recovery and beneficiation, are being undertaken. The most comprehensive of these involves a study of the silver-cobalt deposits of the Cobalt-Gowganda district of Ontario.

A program on the surface properties of minerals, particularly as they relate to their flotation behaviour, is under way. The measurement of the surface area of oxide minerals by the Kr. adsorption method is used. Studies of the solid-liquid interface behaviour of oxide minerals in various solutions have been made; a contact-angle apparatus has been constructed to study the hydrophobicity of mineral surfaces when treated with surface-active agents. An extended series of studies of the flotation of hematite in oleic-acid solutions and the interpretation of the behaviour in terms of surface structure is under way.

In a program designed to investigate the semi-conductor properties of minerals and related measurements, a study has been made of the temperature dependence of the ion drift of silver in single-crystal bismuth telluride at various current densities.

In addition to the above-mentioned research projects the Division conducts a large number of service investigations employing a variety of techniques such as wet chemical and instrumental analyses, X-ray and emission spectroscopy, X-ray diffraction, differential thermal and thermogravimetric analyses and neutron diffraction. Most recently, Mossbauer spectroscopy, also controlled by the "on-line" computer, has been added to the facilities available in the Division. 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.; some work of assistance to industry and universities is also conducted.



## EXTRACTION METALLURGY

In extraction metallurgy, applied research continued on the development of hydrometallurgical and pyrometallurgical processes, on electroplating technology, and on causes and prevention of metal corrosion. At the same time, fundamental studies were carried out on the kinetics and thermodynamics of metallurgically important chemical reactions. Liaison with the uranium-mining and the gold-mining industries continued through the activities of the Canadian Uranium Producers' Committee and the Association of the Canadian Gold Metallurgists.

Hydrometallurgical research concerned the treatment of uranium, gold, and base-metal ores. The leaching of uranium from Elliot Lake ores by bacterially produced acidic-ferric-sulphate solutions was investigated, both to test its applicability to the salvaging of residual uranium from mine and concentrator wastes, and also to examine its possibilities as a primary leaching process to supplant the conventional hot-acid leaching now in use.

Studies of improving hydrometallurgical processes by mathematical simulation techniques were undertaken. A laboratory investigation was made to determine the effects of temperature and acid on the extraction of uranium from an Elliot Lake ore, under conditions suitable for statistical analysis. From this investigation a second-order equation was developed which related the variables of temperature and of acid addition to uranium extraction, and which ultimately may be used to assess, by calculation, the efficiency of various possible leaching conditions. Similar mathematical simulation programs are being carried out on grinding circuits, continuing from an earlier investigation on the application of automatic control to grinding circuits. A laboratory study is also being made to determine the mathematical relationships in the cyanide process between process variables and gold extraction.

A process for the production of high-purity tungstic trioxide from a Canadian scheelite ore was brought to small-scale pilot-plant operation during the year. Tungsten recoveries were excellent and reagent consumptions were modest, and it appears that the process will be attractive economically not only in Canada but probably elsewhere.

The development of a hydrometallurgical process for the production of mixed oxides of controlled chemical composition and physical properties for the manufacture of lead-zirconium-titanium oxide ceramics was largely completed by the end of 1966. The most recent innovation was the introduction of fatty-acid flotation to separate the mixed lead-zirconium-titanium oxide precipitate from the wash solutions.

In an investigation into the causes and prevention of metal corrosion in industrial environments, samples of mild steel, high-strength steels, stainless steels, copper and zinc were exposed to sulphurous, hydrochloric, sulphuric and nitric acids. Not all these metals were attacked by sulphurous acid, but where sulphurous acid attack did take place, it proved to be very rapid in comparison with the attack by the other acids. It was also found that the rates of corrosion by all these acids could be expressed as mathematical functions of the normalities of the acids in contact with the metal.

In view of the seriousness of the corrosive effect of sulphurous acid on some metals particularly steels, inhibitors against its attack have been sought, and it has been found that ammonium oxalate and hexamine are particularly effective.

The study of the prevention of hydrogen embrittlement in high-strength steels during pickling and electroplating was continued. It was found that hydrogen embrittlement during pickling could be greatly reduced if an oxidizing agent such as ferric sulphate or nitric acid was incorporated in the pickling solution, or if the metal being pickled was made anodic during pickling. A potential of no more than 0.5 volt was found to be adequate.

Work on the prevention of hydrogen embrittlement during electroplating also continued. The earlier investigations on electroplating of zinc and cadmium were extended to include copper, which can now be plated onto a number of high-strength steels without producing embrittlement. Similar attempts with chromium have not been successful. It was found, however, that if high-strength steels were first plated with copper, chromium could then be electroplated over the copper, to produce a good chromium-plated surface without embrittlement in the basis metal.

In pyrometallurgy the development of the combined shaft furnace-electric furnace unit continued. This unit is designed to make possible the application of oil, natural gas, or electric power to the smelting process, so that the most economical combination can be used for any particular purpose or location. Improvements to the shaft furnace were made to ensure that better use was made of the off-gases from the electric smelting to preheat the incoming feed to the furnace. In a pilot run making high-carbon iron from metallized iron pellets, an energy input of 840 Kwh per net ton of pellets were achieved, of which 700 Kwh was supplied as electrical energy and the balance as thermal energy. Projections based on theoretical maximum throughput of the shaft furnace-electric furnace unit indicated an ultimate energy requirement of 725 Kwh per ton, half of which could be supplied as thermal energy in the shaft. Similar data were developed for the smelting of ilmenite ore to produce metallic iron and high-titanium slag.

The data for these preliminary pilot-plant runs have been used to design an improved version of the shaft furnace-electric furnace combination which will yield energy-consumption data for a variety of smelting operations. The design permits the furnace to be automated to a large degree, if this should prove desirable. This aspect of the project is being conducted in co-operation with the National Research Council.

Other pyrometallurgical research included investigation of the factors controlling the pelletizing of ores, such as the effects of individual ranges of feed-particle size on the unfired-pellet strength. In another program, sintering studies were carried out on minus-twenty-mesh chrome fines with the object of converting this product to usable material for the manufacture of certain refractories.

Basic research on chemical reactions of metallurgical importance included a study of the kinetics of the dissolution of the copper mineral covellite in acidic-ferric-sulphate solutions. This reaction, and similar reactions with other minerals, is of importance in the heap-leaching of copper ores, and of potential importance in the leaching of uranium ores by solutions of ferric sulphate generated by bacterial action.

Completed during the year was a thermodynamic study of the principal reactions resulting from the treatment of a complex sulphide concentrate containing iron, nickel, copper and cobalt with chlorine to produce sulphur in elemental form, iron in the ferric oxide form, and nickel, copper and cobalt as chlorides. The study indicated that a reaction temperature of about 400°C would be suitable, since at this temperature all the principal reactions would go in favourable directions to produce solid nickel, copper and cobalt chlorides and a mixed gas containing ferric chloride and sulphur. Appropriate conditions for separating ferric chloride from sulphur, and for converting ferric chloride to ferrous chloride were established, and finally the conditions necessary for the conversion of ferrous chloride to ferric oxide, with regeneration of chlorine, were defined. The growing demand for sulphur in elemental form, and the growing need to reduce the pollution of the atmosphere with sulphur dioxide, the product of conventional methods of sulphide-concentrate treatment, emphasize the potential importance of this study.

In the development and modification of analytical procedures, the X-ray fluorescence technique was improved by adoption of a computer program developed to cope with the matrix effects encountered in the analysis of certain complex compounds. In addition,

an investigation was initiated of using the relatively new technique of atomic absorption for the control of industrial leaching. A simple method was developed for determining very low levels of free and complex cyanides that will help the gold-milling industry to avoid the pollution of rivers and lakes by cyanides contained in cyanide mill effluents.

#### MINERAL PROCESSING

The Mineral Processing Division carries out basic and applied research in aid of the mining, ceramics or construction-materials industries.

Flotation, jigging (gravity-concentration) and filtration investigations were carried out within metallic-minerals research to improve processes for industrial use. The role of depressants in iron-ore flotation and the electrochemical properties of mineral surfaces were studied to provide essential understanding of the flotation process. A research project on jigging was extended to titanium and asbestos ores. New methods of evaluating filter performance were devised, and the publication of this work has attracted international interest.

Pilot-plant investigations were made on seven shipments including iron, chromite, silver, titanium, niobium and copper-nickel. Approximately 300 tons of niobium (pyrochlore) ore was treated in search of a better method of concentration than that now in use in Quebec.

Seventeen investigations were undertaken on samples of ferrous and associated metals, including iron ores from the Yukon Territory and Pakistan. There was a noticeable increase in titanium and tantalum projects. Twenty-eight investigations for the non-ferrous industry included a co-operative project with the silver industry to decrease the costs of silver refining in the area of Cobalt, Ontario, a research project to find a process for treatment of talcose molybdenum ore in Quebec, and projects to recover gold from the tailings of the Kirkland Lake area mines.

The industrial-minerals research covers processing of a wide variety of non-metallic minerals and rocks submitted by individuals and companies, new or improved methods of products, and the provision of information on processing methods and uses, markets and specifications of minerals and products.

The research on the development of piezoelectric ceramics was concerned mainly with the effects of variations in preparation and composition on the properties of lead zirconate-titanite. The study of the heat capacity of a wide variety of minerals and ceramic bodies was concluded. Projects on thermal conductivity, on the properties of clays and shales, and on methods of pressing and firing ceramic clay continued. Methods of processing magnesite and pyrophyllite to produce suitable refractory products were studied. Samples of clay from British Columbia to New Brunswick were evaluated.

The increasing demand for better construction materials has resulted in stricter specifications and the need for better methods of production and evaluation. Methods for improving the manufacture of lightweight aggregate and the evaluation of concrete were under investigation. The method developed for accelerating the curing of concrete specimens has been accepted by the ASTM for a test program. Further work was carried out on the ring-test method for measuring the tensile strength of concrete. The division continued to provide the Canadian Standards Association with an impartial service for its co-operative cement-testing program, and will collaborate in its cement-strength survey. It supplied technical advice to various hydro-electric power organizations on the quality of materials.

Close contact was maintained with suppliers or possible suppliers of dimension stone in an effort to encourage greater use of Canadian stone. Assistance was given to Expo '67 in procuring rocks for use in the Geological Court in the Canadian Pavilion.

In the industrial-minerals mill, research projects on the floatability of pure minerals, the recovery of weakly magnetic minerals and electronic sorting were continued. Further work was done on the processing of fluorite. Studies were carried out on the use of ultrasonics vibration grinding, and vibration-materials-handling equipment. Smaller investigations were carried out on samples of industrial minerals submitted by industry from a number of sources.

The asbestos-research project dealt mainly with the study of particle size, surface area and dielectric properties of fibre. A static method for measuring the length and diameter of fibre has been devised, and equipment has been assembled. The use of zeta potential measurement in the measurement of surface properties is under study. A suitable method of processing by-product synthetic gypsum is being sought. Samples of various industrial minerals from many sources have been evaluated to some degree, generally to provide specific information to the supplier.

Almost all studies carried out in the division require prior mineralogical evaluation. Investigations of the relationship between the mineralogy and ceramic properties of clays and shales and between the mineralogy and physical properties of aggregates and building stones are carried out continuously. A study of the making of polished sections resulted in a method for producing inexpensive high-quality sections that could be used in remote locations.

#### MINING RESEARCH LABORATORIES

On advice from the Canadian Advisory Committee on Rock Mechanics, the Mines Branch has been able to stimulate mining research in the universities through its grants-in-aid which, starting with \$10,000 in 1962, have grown to a total of \$250,000 for the six years. In addition, the Committee, which consists primarily of representatives of industry and of the universities, has been able to co-ordinate research in rock mechanics throughout the country and to improve communication between interested parties. During its brief period of existence both the production of graduate students by the mining departments at universities and the volume of research throughout the country in rock mechanics have greatly expanded.

While experimental work continues in the laboratory and in the field, greater use is being made of applied mathematics through computers to expand analytical and predictive capabilities. This approach has shown that the mathematics on which the programs are based are very similar to the mathematics that would simulate other systems such as mine ventilation, heat flow, mining costs taking into account interaction of variables, and specialized subjects like the design of hydraulic fill systems. Consequently, wider application of the research will be possible.

The Canadian mineral industry is currently excavating about 400 million tons of rock per year at a cost of more than \$1 billion. With the third-largest mining industry (excluding fuel) in the world, we have more rock problems and more requirements for rock research than most other countries. The major research is being conducted on problems where the potential payoff is estimated to be far in excess of the required costs.

The mines with which co-operative projects are being conducted produce commodities varying from salt and potash through coal and asbestos to base metals, gold and uranium, from British Columbia to Newfoundland. These studies are aimed at improving the design and operating methods of both underground and open-pit mining. As an example, one project concerned with improving the stability of deep open-pit excavations indicates a ratio of capitalized benefit/cost of more than 100 to 1.

The current cost of drilling and blasting in industry is around \$100 million per year. The blasting research in process is aimed at savings in these operations that will produce a benefit/cost ratio of approximately 20 to 1. In addition, as a result of a survey made by the Mining Association of Canada some two years ago, a new program of research has been started on the fundamentals of non-explosive rock breakage, which may lead to some novel methods of mining.

A modest amount of work is being done on mine environments through the study of the techniques of dust measurements. This work is being done in co-operation with the Quebec Metal Mines Accident Prevention Association and the Mine Accident Prevention Association of Ontario.

Besides being part of the working team on the above-mentioned blasting research, this laboratory under the Canadian Explosives Act during 1966 tested 11 new explosives, 17 types of ammunition,

128 new kinds of fireworks, and checked previously authorized explosives and blasting accessories. Similar work was done for the Post Office Department and the Board of Transport Commissioners. As Canadian representative on the Group of Experts on Unstable Substances of the OECD (Paris), this laboratory provided personnel for the working party investigating hazards of a number of explosives and "near" explosives and seeking to establish an international classification for such materials.

## Observatories Branch

The Observatories Branch is concerned with two major disciplines - astronomy and geophysics. There are three geophysics divisions: seismology, which operates 26 seismograph stations as well as an array for the detection and identification of nuclear explosions, and sends field parties to all parts of Canada; geomagnetism, which studies the existing and past magnetic fields in Canada through nine permanent observatories and a major laboratory, and which conducts field surveys in all parts of Canada; and gravity, which conducts field work in all parts of Canada.

It is proposed to construct a major observatory, with the 150-inch Queen Elizabeth II telescope as its principal telescope, on Mount Kobau in south-central British Columbia, and to establish an Institute of Astronomy on the campus of the University of British Columbia. These plans have entailed some reorganization of the Branch. The two previous astronomical divisions in Ottawa have been combined, and a small separate group has been set up for the design of the Queen Elizabeth II telescope.

### ASTRONOMY, OTTAWA

This Division comprises the former Divisions of Positional Astronomy and Stellar Physics. During the past 15 months the work of the Division has been directed along the following lines:

Positional Astronomy. Discussion of the final program of observations of the Meridian Circle telescope 1955-1960 was completed and published in the form of a star catalogue. The Mirror Transit Circle, which has replaced the Meridian Circle, was operated for 20 nights early in 1966, but has been out of commission all winter for repairs to electronic parts. Pivot errors were re-examined and the automatic measuring engine improved. A new observing program has commenced.

Time Service. The photographic zenith tube (PZT) was operated every clear night, securing a 12-month total of 200 plates containing 3,897 stars. Each star yields a value of astronomical time and latitude. The time determinations, when compared with an atomic time keeper, reveal random variations in earth rotation. Latitude variations provide evidence of polar wander. The results are studied and form a part of the quarterly Time and Latitude Bulletin. They are also supplied in weekly summaries to the Bureau International de l'Heure, Paris, and the International Polar Motion Service, Tokyo. The observatory caesium standard was co-ordinated with others on June 19, 1966, by the international flying-clock experiment by Hewlett Packard. CHU, operating continuously on the three frequencies 3330 kHz, 7335 kHz and 14670 kHz, was improved with a rubidium atomic standard. Time to the millionth of a second is maintained by the official custodian of time for Canada.

Solar Physics. A solar-flare program was continued for part of the year. Site-testing equipment was designed and used on Mount Kobau and at Ottawa, demonstrating the great superiority of the higher location for certain phases of solar research. V. Gaizauskas is spending the current academic year at Kitt Peak Observatory studying the design and operating characteristics of large solar telescopes.

Meteor Physics. Photographic study of meteors and the upper atmosphere was continued at the Alberta meteor observatories. Special preparations to observe the most spectacular display of Leonids in more than a century were foiled by clouds. Further diamond drilling at West Hawk Lake established the underground profile and provided an improved estimate of the size of this ancient meteorite crater. Staff members interviewed the public and made field searches and calculations to recover probable meteorite falls in Quebec, Ontario, and Alberta. A few small fragments of the Alberta fall were recovered and more recoveries were expected in the spring of 1967. Plans are well advanced for a prairie network of camera stations to aid meteorite recovery.

Public Relations. The scope of duties performed by this section has continued to increase, and the educational facilities have been broadened to cope with the demands. There has been a steady growth in the number of requests for popular material by mail and telephone. Additional assignments have been undertaken, assistance given to other agencies and specialized information prepared. The facilities of the Ottawa Observatory have been organized for the regular Saturday evening public visits and the mid-week educational tours. The growing popularity of astronomy has increased the demand for Observatory tours beyond the capacity of the present staff. Approximately 60 requests have had to be refused during the period September 1966 to March 1967. Even so, senior scientific staff members have been pressed into service in exceptional cases. Considerable time and effort has been spent in the preparation of new display material and models, in which bilingual legends have been introduced. One model, illustrating solar, meteor and radio astronomy has proven to be particularly useful since the level of interests of visitors ranges from elementary school students to university graduates and visiting scientists. The section co-operated with the Department in preparing and manning a display on careers in astronomy and geophysics for "Career Expo '66", held by the Ottawa Collegiate Board in May.

### DOMINION RADIO ASTROPHYSICAL OBSERVATORY, PENTICTON, B. C.

A complete survey of the radio emission from the sky at a frequency of 22 MHz is continuing. Most regions of the sky have been observed and work is progressing on the reduction of the data. Several regions have been mapped in detail, and accurate flux densities for several hundred radio sources have been measured. New apparatus is being built to enable the antenna beam to scan rapidly in declination.

Results from the 10 MHz studies have been encouraging and flux densities have been measured for over 150 sources. A new improved receiver system has been placed in operation which records eight beams simultaneously. An absolute measurement of the fluxes of Cygnus A and Cassiopeia A at 10 MHz has been made.

A survey of the continuum radiation in the vicinity of 1420 MHz, using the 25.6-metre paraboloid, is nearing completion. A number of new sources discovered at DRAO in this survey have subsequently been observed with the 46-metre paraboloid of the National Research Council, at 3200 MHz.

A 100-channel spectrometer designed principally for the study of neutral hydrogen emissions has recently been completed. A new receiving system is being built as a joint project with the Department of Physics at the University of British Columbia to search for undiscovered spectral lines in the 1-4 GHz range. The Observatory is collaborating with NRC, the University of Toronto and Queen's University, in a long-baseline-interferometer experiment designed to measure the angular diameters of quasars by observing these sources simultaneously at DRAO in British Columbia and the Algonquin Radio Observatory in Ontario.

The solar-patrol work at 3200 MHz, operated as a joint project with NRC, is continuing.

An entirely new field of investigation was initiated during the year to measure radio pulses originating in extensive air showers (cosmic rays). This has been undertaken as a joint project with the Department of Physics, University of Calgary, and uses a portion of the existing 22 MHz aerial array.

### DOMINION ASTROPHYSICAL OBSERVATORY, VICTORIA, B. C.

The basic programs of the Observatory's research continued as in past years. Much new instrumentation is under construction and

most of it is ready for testing. As a result it is expected that many of the current programs may be extended to fainter stars and new programs will be implemented.

The sudden death of the Director, Dr. R. M. Petrie, was a major blow to the Observatory and to its staff, but it is felt that his memory can best be honoured by continuing and extending the research programs he began. Work on the Queen Elizabeth II 150-inch optical telescope has continued almost without interruption because Dr. Petrie has provided an excellent theoretical foundation for the project.

During the year the spectrographs attached to the 72-inch and 48-inch telescopes were used on nearly every clear night; the 72-inch telescope was used on a few nights for direct photography and the 48-inch telescope was also used for photometry to measure the colours of stars. Observations were made on 139 nights at the 72-inch telescope and 137 nights at the 48-inch, with a total of 1,476 spectrograms being obtained. These plates are measured on special instruments, many of which have been made for the purpose in the Observatory shops. The results are analyzed to give information concerning the radial motions of the stars, and hence the structure of our Milky Way, the distances of the stars, the structure of their atmospheres, their chemical composition and the evolution of stars and galaxies.

Several investigations and results obtained during the past year should be mentioned. A new value for the period of rotation of our galaxy has been determined and will soon be published. From investigations of double stars, for which a new catalogue is being prepared, it is found that about one third of all "binary" systems are at least triple, and one quarter of "triple" systems are quadruple; this result is important in discussions of the formation of stars. The correlation of rotation with helium content in the hot stars seems to indicate that helium may separate from the more abundant hydrogen in slowly rotating stars. In studies of giant cool stars which are eclipsed by smaller hot stars, evidence for clouds or prominences has been found; the lifetimes of these clouds may be a week or more. Several new and possible members of a rare group of stars with abnormal carbon abundances have been found.

Work on new instrumentation for the telescopes was a major feature of the year. A new spectrograph for the 72-inch telescope which will increase its efficiency by a factor of two was built and is ready for testing. A new large mosaic of optical gratings was prepared and is also being tested. An image-intensifier tube, which amplifies starlight electronically, thus gaining a factor of ten over photographic methods, was lent by the Carnegie Institution of Washington and is ready for testing. A new method was devised for using the starlight which is usually wasted when it enters the spectrograph.

More than 25,000 persons visited the Observatory and 5,000 attended public observation periods, including special tours by youth and educational groups. Staff members gave 28 lectures to local organization, including 14 at the University of Victoria. Astronomical information was supplied to representatives of the press, radio, and other groups as requested.

#### THE QUEEN ELIZABETH II TELESCOPE, MOUNT KOBANU, B. C.

A feasibility study which will provide detailed planning on the telescope as well as for other developments on Mount Kobanu has been prepared and was submitted at the close of the period under review. It provides an estimate of costs and recommends methods of procedure. A fork mounting has been found most suitable at our latitude and the study shows that its construction is quite feasible.

The fused silica mirror blank, being constructed in the United States, was making good progress and was expected to be available late in 1967. Construction has been delayed on the optical shop which will shape and polish it, but the necessary optical equipment has all been ordered. Our opticians have been working on large

mirrors in the United States to gain experience. The major work of preparing the mirror will begin without delay once the optical shop is ready.

#### SEISMOLOGY

New seismic observatories were brought into operation at Suffield, Alberta (in co-operation with the Defence Research Board), and Mica Creek, British Columbia, near the site of Mica Dam on the Columbia River. A local seismic station at Banff, Alberta, was closed down. The total number of seismic stations now operated by the Department is 23 first-order stations, complemented by 3 second-order local stations.

The strong-motion network in western Canada has been extended: six stations are fully equipped and some 22 locations have now been instrumented for detailed earthquake-zoning studies.

Considerable progress has been made in the preparation of a new earthquake-zoning map for Canada for National Building Code purposes in defining earthquake loads. The proposed new zoning is based on a theory which uses the catalogued knowledge of the locations, sizes and characteristics of all Canadian earthquakes determined by the Division. It is being evaluated on an experimental basis in co-ordination with the National Committee for Earthquake Engineering. A definitive revised quantitative map should be adopted nationally within two years. Meanwhile, the investigation of a unique sequence of more than 2,000 micro-earthquakes, which occurred in the Northwest Territories during 1965, is nearing completion. Seismic regionalization studies in eastern Canada have been extended. No major earthquakes occurred in Canada during the year.

The Division experienced another increase in requests for advice and quantitative earthquake-risk estimates for engineering, safety and insurance purposes, including information for a number of major critical government-proposed installations.

International co-operation in the study of earthquakes continued at a high level, and the availability of Canadian records and data for national and international research was enhanced by a number of major organizational changes.

A milestone was passed in the automatic processing by digital computer of seismic data from the medium-aperture seismic array at Yellowknife, N.W.T. Detection levels and location accuracies were determined and published, and plans made to increase this work with an "in-house" analogue-digital processor. The results were of great significance to the internationally discussed proposals for the enhanced exchange of seismological data for nuclear detection and national identification.

Fundamental research in the mechanism of earthquakes, in surface-wave dispersion, and in the character of seismic-body-wave signals continued. The Division developed digital library files of data for intensive automatic processing.

The reorganized crustal-seismic-refraction group was very active. A major experiment was completed in the Northwest Territories, serving the additional purpose of calibrating the Yellowknife array. This highly successful experiment was probably the largest one ever undertaken by any group with its own resources in the western world. In addition, an unreversed profile nearly 500 kilometres long was shot across British Columbia, and the results of much work in that province were published. Finally, a new technique for determining structure inside the earth to depths of a few hundred kilometres was developed and published.

The heat-flow section installed thermometer cables in two abandoned oil wells in the Northwest Territories. Three holes were drilled in northern British Columbia, in an experiment designed to search for anomalously high heat flow in a volcanic area. Instrumentation was developed for measurements in a group of deep holes

in the Sudbury area, in order to study the effect of the retreat of the ice of the last ice age.

A number of technical papers were read at scientific meetings, and many papers on seismology and the physics of the earth's interior were published.

#### GEOMAGNETISM

To keep track of the slow changes in the direction and intensity of the geomagnetic field, careful measurements are made every few years at some 100 repeat stations, uniformly distributed over Canada. During 1966, 21 repeat stations were occupied, mostly in the Yukon and Northwest Territories, with a few in Alaska, British Columbia, Alberta, and Newfoundland.

No airborne magnetic surveys were made in 1966, as the staff worked on the reduction and interpretation of data from the joint Canadian-Scandinavian three-component airborne survey carried out at the end of 1965. Preliminary results have been sent to the five Nordic countries participating in the project. New methods have been evolved, making use of the Department's computer, for detecting errors in the data, carrying out a potential analysis of the observed field, and presenting anomalies in graphical form.

Time variations of the geomagnetic field were recorded continuously at nine permanent 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, Manitoba; at Meanook, 100 miles north of Edmonton; at Victoria, B.C.; and at Agincourt, near Toronto. Surveys were conducted to choose the location of a new magnetic observatory in the vicinity of St. John's, Newfoundland.

A contract has been let for the construction of new geomagnetic laboratories on a 200-acre site, 10 miles east of central 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 will replace the present geomagnetic laboratory on the Prescott Highway, Ottawa, and the magnetic observatory at Agincourt which must be abandoned because of increasing industrial interference. It will also provide improved facilities for palaeomagnetic research, both for the Observatories Branch and the Geological Survey, and permit more efficient training of personnel.

During the summer of 1966, four temporary observatories, recording both magnetic and earth-current variations, were operated in a line extending from St. John's, Newfoundland, to the north end of Cape Breton Island. Later the stations were moved to give a line north from St. John's to Goose Bay. The purpose of this experiment is to study the electric currents induced in the earth's crust and upper mantle by natural geomagnetic disturbances. Theoretical models of various underground distributions of electrical conductivity are tested in an attempt to explain the observed magnetic and electric fields. Since electrical conductivity depends on the composition, structure, and temperature of the rocks, such experiments provide a method of discovering the properties of the crust at great depths. Analysis of the records indicates the presence of an induction anomaly of a type often found at the edge of continents. A similar investigation continued in southern British Columbia and Alberta, in co-operation with the University of British Columbia.

Studies continued of the natural magnetization of sedimentary rocks collected in the Maritimes and Quebec. By carefully controlled experiments in which the rock samples are subjected to high temperatures and artificial magnetic fields, it is often possible to recover the direction of the magnetic field which existed when the rocks were formed. In this way, the history of the geomagnetic field can be traced through geological time, and theories such as the hypothesis of continental drift can be tested.

#### GRAVITY

During 1966, emphasis continued to be placed on the measurement of the gravity field within Canada. The field program included observations to maintain gravity standards both in Canada and in other parts of the world as recommended by the International Union of Geodesy and Geophysics, and observations to map in detail the regional gravitational field in Canada. These field projects were carried out in many parts of Canada, and both automobile and aircraft were used for transportation. The highlights of the field program are as follows:

- (1) A regional gravity investigation of the Precambrian areas of the Northwest Territories was completed between latitudes  $61^{\circ}\text{N}$  and  $70^{\circ}\text{N}$  and longitudes  $100^{\circ}\text{W}$  and  $120^{\circ}\text{W}$ , and included a detailed investigation of the boundary between the Bear and Slave geological provinces.
- (2) As a preliminary to a major regional study in the Cordilleran region, 800 observations were made along three traverses in central British Columbia.
- (3) As part of the Polar Continental Shelf Project three gravity traverses were carried out over the continental shelf north of Prince Patrick Island, and regional surveys were conducted on the sea ice west of Melville Island, on Ellesmere Island, and on Baffin Island.
- (4) The Branch's program of underwater gravity measurements in the Gulf of St. Lawrence continued with regional measurements west of the island of Newfoundland.
- (5) The long-term program to determine fluctuations of elevation of the Penny Ice Cap on Baffin Island also continued. The gravity measurements first carried out in 1962 were repeated in 1966.

Excellent progress has been made with structural interpretation and in theoretical studies to evaluate and develop methods of quantitative analysis of gravity data. Approximately 20 scientific papers covering a wide range of topics were either completed or published in 1966. Included were papers on crustal structure in Hudson Bay, crustal structure in Newfoundland, the analysis of gravity measurements at sea, terrain corrections and automated methods of gravity interpretation.

The large volume of data resulting from the gravity surveys and the computations necessary to analyze and interpret the field observations have required extensive use of computers. In the interest of efficiency this Division began the development of a comprehensive data and program library which will be used on a large computer. Complicated operations involving the use of difficult programs and/or difficult sets of data will be initiated with the same ease as a single operation on a single set of data.

During 1966 the investigation of craters of possible meteorite origin continued. Diamond drilling was completed at West Hawk Lake, Manitoba, and Deep Bay, Saskatchewan. Laboratory investigations continued with detailed measurements, using optical and X-ray equipment, being carried out on quartz, feldspar and other minerals from twelve Canadian craters at which shock effects due to impact have been recognized.

Instrumental development included the establishment of an earth-tide laboratory 30 miles north of Ottawa and the virtual completion of the reconstruction of the Canadian pendulum apparatus. The earth-tide laboratory is equipped with two horizontal pendulums to measure crustal tilt and a gravimeter to record earth tides. The pendulum apparatus underwent a series of tests between Ottawa and Almonte, Ontario. Minor adjustments to the apparatus were being made at the year's end.

## Geographical Branch

### PHYSICAL GEOGRAPHY DIVISION

Baffin Island. This was the largest of all the Branch field parties. It investigated the geomorphological, glaciological and post-glacial characteristics of the whole central part of Baffin Island. Work was mainly concentrated on the Barnes Ice Cap and in the area between it and the northeast coast. Observations and measurements of mass balance and of movement continued on the Barnes Ice Cap and on Decade Glacier at the head of Inugsuik Fiord which is being studied as a contribution to the Hydrological Decade. Observations were also made for a study of moraines, both beneath the waters of one of the perimeter lakes of the Barnes Ice Cap. This is part of a study to determine the location and probable date and manner of the separation of the Baffin Island ice sheet into the proto-Barnes and proto-Penny ice caps. A landscape survey was made by aircraft and photographic coverage was taken to permit continued qualitative evaluation of the area. A reconnaissance was made of the outwash plains at the head of Ekalugad Fiord on the east coast, and the studies of glacial chronology of the isostatic rebound of the area were continued as far as Cape Hooper at the southern limits of Home Bay. Other studies included a palaeoecological examination of the sediments and fossil molluscs in a cliff section at Cape Christian; observations and measurements of till fabrics and pebble roundness; sedimentary aspects of present-day boulder fans; a detailed geological study at the head of McBeth Fiord; a continuation of last year's observations of movement of solifluction tongues and talus slopes, and a special helicopter-supported examination of mountain tops to determine the upper limit of continental glaciation.

To further the study of the glacial history of the whole eastern Canadian Arctic, a field trip was made to the Ottawa Islands in the late summer to observe the evidence of isostatic uplift in that area and to study the palaeontology of shell beds. The operation was conducted with support from three other branches of the Department and in association with two universities.

The Cypress Hills. Studies continued of the structural geomorphology of the area and of the soil-landform relationships on the summit surface and pediment slopes. Soil samples were collected for laboratory analysis and radiocarbon dating. Work also continued on the mapping and examination of prairie mounds. Preliminary work was carried out for long-term studies of the sequence of terraces along the major drainage lines of the area and their relation to valley-side debris as well as for the mapping and examination of soils and gravels in the area.

Data obtained from 12 Class A weather stations established by the survey, as well as data supplied by the Department of Agriculture, are being used to study the difference between the climate of the Cypress Hills and that of the surrounding prairies. Microclimatic studies are being made at selected areas as well as comparisons between the behaviour of dynamic phenomena such as the vertical flux of momentum, heat and water vapour within the forests of the Cypress Hills and on the adjacent prairies. The climatic effect of various local landforms is being studied from data obtained from aircraft equipped with various types of recording instruments.

Studies were begun on the historical geography of the general field area with a view to evaluating man's impact upon the recent evolution of the landscape.

The Mackenzie Delta. Further observations were made in the continuing study of the advance of permafrost under shallow or partially drained lakes and of other phenomena common to areas of frozen ground. Studies were made of the electrical resistivity in frozen ground and of the summer soil-moisture regime in hummocks and tussocks. Observations were made of the climatic transition evident from the head of the Mackenzie Delta to the coast at Garry Island, and data for the heat-budget studies being made at Hidden Lake and another small unnamed lake in the delta were recorded.

The dates and patterns of freeze-up and break-up along the Mackenzie Waterway were again noted.

Polar Continental Shelf Project. For the sixth season, participation of the Geographical Branch continued both in the glacial and periglacial studies and in research into the characteristics of sea ice in the area of the Queen Elizabeth Islands. The 1966 season was the longest (five months) and most rewarding of all those in which the Branch has shared in the sea-ice project.

In addition to the above projects, survey work was carried out with the aim of bringing the geographic data on Southampton Island up to date, and further data were collected on Mount Seymour, B. C., for the study of the processes and effect of snow creep.

Office studies in the Physical Geography Division concerned:

Prediction methods of estimating from heat-budget data the onset of ice in the Beauharnois-St. Lambert section of the St. Lawrence Seaway.

The relationship between ice-sheet thickness, marine limit and isostatic uplift on the Canadian mainland and the arctic islands exclusive of the Queen Elizabeth group.

Changes in pebble shape in different arctic environments.

The relationship between present and past glaciations using trend-surface techniques.

Work on the glossary of periglacial phenomena which had been in preparation for some time as a joint French-English project under Dr. Louis-Edmond Hamelin of l'Université Laval and Frank A. Cook of the Geographical Branch, had to be reassessed as a result of the death of Mr. Cook on March 25, 1966. A final editing of the already-completed English section was made and passed, together with the illustrations, to Dr. Hamelin who has assumed responsibility for publication of the project through the Centre d'Etudes Nordiques at l'Université Laval.

### REGIONAL AND ECONOMIC GEOGRAPHY DIVISIONS

Atlas of Canada. The Atlas of Canada is the major undertaking of the Division of Regional Geography. The atlas presently in compilation is part of a continuing atlas program. The new atlas will have contents comparable to the 1957 Atlas of Canada, but will be of smaller dimensions, with a two-paged spread measuring 20 x 15 inches. It will, therefore, be more portable than the 1957 atlas. It is planned that the first edition will be issued as loose-leaves in a specially designed box, but page layout is organized to facilitate binding of later editions. Publication in French and English is expected in 1968. Several special maps from the atlas covering population, territorial evolution, and lakes, rivers and glaciers, will be released for distribution in 1967. Distribution of the finished atlas will be by the Queen's Printer.

Prairie Provinces Regional Economic Studies. Field work for this project, undertaken with the co-operation of other government departments and outside agencies, has been completed. The information gathered covers many facets of Prairie activity and development, and maps and text evaluating these data are now being prepared.

Agricultural Development Possibilities in Southeast Renfrew County. This survey, begun in 1964, is a study of the possible development of good agricultural land in the county and an evaluation of the use, other than agricultural, which might be made of land unsuitable for farming. Field work has been completed, the statistical data are in the process of being analyzed and the final report is in preparation.

Present Land-Use Survey (a part of the Canada Land-Use Inventory being compiled by ARDA). The purpose of this survey is to provide maps from which a reliable estimate can be obtained for large-scale planning of the extent and location of land presently used in various categories such as urban, recreational, cultivation, forestry and grazing. The information is obtained from air photographs, supplemented by selected field checks and such relevant land-use surveys as have already been made by other agencies. Surveys and mapping have been completed for about 70 per cent of the Maritimes - exclusive of Newfoundland - and for about 50 per cent of Ontario. In Quebec, where the work is approaching 50 per cent completion, the surveys have been concentrated mainly in three areas: along the north shores of the St. Lawrence and Ottawa rivers, in the Eastern Townships and in the Gaspé Peninsula.

Three other ARDA projects are in progress in Nova Scotia:

Compilation of an inventory of the Nova Scotia shoreline for purposes of possible recreational development.

A survey of the potential tourist industry development in Guysborough County.

A survey to assist in planning a farm-consolidation program and community woodlot development in the nine eastern counties. This also includes a survey of the blueberry industry in Cumberland and Colchester Counties to assess its potential for acreage expansion.

Two Newfoundland projects were completed and the results published as ARDA Study 1043, "Forest Utilization, Great Northern Peninsula, Newfoundland", 1965, and ARDA Study 1043, "Fishery Utilization, St. Barbe Coast, Newfoundland", 1966.

The Survey of Urban Characteristics. This is an inventory of selected urban characteristics in 16 major Canadian cities for the Emergency Measures Organization, the results for each city being displayed on 32 maps at a scale of 1:25,000. Surveys and mapping were already completed for Vancouver in 1965, and survey work for Toronto is completed and 22 of the map sheets are printed. The survey work for Montreal, Ottawa and Windsor is completed and maps will be prepared as soon as possible. Survey work for Hamilton is in the final stages.

Survey of the Urban Structure of the Maritime Provinces. This study for the Atlantic Development Board was begun in the summer of 1966. It aims at evaluating the potential of maritime urban centres to absorb investment and at suggesting which centres are most in need of capital infusion. It considers the type of establishment and the employment structure of each community and examines its socio-economic characteristics, analyzing them by factor analysis for comparison with the economic well-being of other centres. Finally, it intends to determine, by means of field surveys, the business methods and attitudes, the population movement and

the extent and fluctuation of the trade areas of each town. The preliminary report for Newfoundland has been completed.

Atlantic Provinces Resources Map. Compilation has been completed on the map of economic, human and natural resources of the Maritimes which has been revised by the Geographical Branch for the Atlantic Provinces Economic Council. It is expected the map will be published - in both English and French versions - early in 1968.

Harbours. The analysis of the movement of commodities through the ports of Halifax and Saint John, begun during the winter of 1964-65, has been completed and the final comprehensive report delivered to the National Harbours Board.

#### TOPONYMY DIVISION

During 1966 the staff of this Division investigated nearly 20,000 geographical names and answered over 600 enquiries. Field investigations of geographical names of counties in eastern Ontario were completed in 1966 and studies made of the names in parts of Prince Edward Island and in the western part of Carleton County, Ontario.

Work was begun on the revision of the Gazetteer of Manitoba and is still continuing on the Gazetteer of Quebec. The Gazetteer of Newfoundland is almost completed, and the revised Gazetteer of British Columbia is now with the printer.

#### CANADIAN PERMANENT COMMITTEE ON GEOGRAPHICAL NAMES

This Committee deals with all questions of geographical nomenclature affecting Canada and is composed of federal and provincial representatives concerned with nomenclature. At the plenary session held in Victoria in September 1966, it was agreed that the pronunciation of geographical names should be a concern of the Committee, that a sub-committee on undersea-features nomenclature be established, and that steps be taken to initiate a punch-card system for geographical names.

#### NATIONAL ADVISORY COMMITTEE ON GEOGRAPHICAL RESEARCH

During 1966, the National Advisory Committee held two meetings, on February 4, 1966, and May 25, 1966. Working committees were set up to inform and advise the main group on matters relating to regional analysis, resource geography, remote sensing and the processing of statistical data. A grants sub-committee was appointed and guidelines were laid down to facilitate the advertising and awarding of research grants. Twenty-three grants, ranging in value from \$200 to \$2,000, and totalling \$25,000, were awarded in 1966.



## Polar Continental Shelf Project

The Polar Continental Shelf Project is a continuing investigation of the continental shelf fringing the Canadian Arctic Islands and mainland, 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 as the agency through which the researches and surveys of other branches of the Department of Energy, Mines and Resources, and of other government departments, are carried out in the Arctic Archipelago and in the Arctic Ocean; in part it carries out, with its own personnel, work that is unique within the Department; and it also provides facilities and support for approved university researches in the area.

The main base of 1966 field operations was at Mould Bay, on Prince Patrick Island, with a secondary base at Alert on Ellesmere Island. Up to ten temporary or mobile camps were established as the work required. Field investigations were carried on from early March until mid-October, and engaged about 90 persons, exclusive of contract aircraft engaged for short periods or of university parties to whom minor though important support was given. In addition to the work initiated and carried out by the Project itself, the activities of the Polar Continental Shelf Project contributed to the work of four branches of the Department (Geological Survey, Marine Sciences Branch, Observatories Branch, and Surveys and Mapping Branch) as well as that of eleven other departments and institutions.

As a supplement to the field activities, the Polar Continental Shelf Project continued its investigation and development of special equipment and techniques for research in polar regions. Further progress was made in meeting the problems of high-speed hydrographic surveying in Arctic waters, in electromagnetic wave propagation for position-fixing over sea ice, in the development of ocean-floor heat probes, and geomagnetic and magneto-telluric equipment.

The principal activities of the Polar Continental Shelf Project in 1966-67, by subject, were:

Aeromagnetic Surveys. Measurements of the total residual magnetic field as recorded from a height of 1,000 feet above the surface were made over the continental shelf and continental slope offshore from Brock and Prince Patrick islands, and over southern Prince Patrick Island, Fitzwilliam Strait, Crozier Channel and Eglinton Island. Poor weather and unsettled geomagnetic conditions combined with equipment difficulties to limit severely the amount of survey.

Geodetic Surveys. The precise survey of a geodetic control network between Ellesmere Island and northwestern Greenland continued. This survey, when completed, should determine the horizontal position of stations on Ellesmere Island, with respect to those on Greenland, with sufficient precision that subsequent surveys of similar accuracy, planned to be repeated after 10 and 20 years, will show whether there has been significant relative movement between the islands. This work is part of a long-term multi-disciplinary investigation of the crustal and structural relationships in the Nares Strait region.

Geology. Samples of sediments were taken from the sea floor on the continental shelf and continental slope offshore from northern Prince Patrick Island, in a program designed to provide information on the present and geologically recent conditions of sedimentation and the recent geological history of the area. A similar but more detailed study was continued in Hecla and Griper Bay, northern Melville Island, to investigate the present and past sedimentation and faunal record, and the conditions under which the present bottom-dwelling organisms are living, in a protected body of water under a continuous ice cover. Logistics support and field facilities were provided to parties of the Geological Survey of Canada and other institutions studying terrestrial geology.

Glacier Physics and Glaciology. The detailed investigations of the Meighen Icecap continued, with vertical temperature and deformation

profiles measured in the borehole that penetrates the icecap near its apparent thickest point, and with crystallographic and fabric studies on the ice cores collected in 1965 from the borehole. Routine glaciological measurements, by a survey of the previously established stake networks, were continued on the Meighen and Melville Island icecaps. A contract was let for low-altitude aerial photography of the Melville Island icecaps; ground survey control was run and photographic target markers were prepared, but owing to poor weather the snow cover did not disappear sufficiently from the icecap to permit photography.

Logistics support was provided for glaciological studies by McGill University on Axel Heiberg Island and by the Arctic Institute of North America on Devon Island.

Measurements were made of the surface displacement of boreholes in Athabasca Glacier, Alberta, continuing a series that was carried on annually from 1959 to 1963 inclusive, in connection with studies of the flow law in a temperate glacier; and instruments were installed in certain boreholes to measure the vertical temperature distribution in a glacier near its melting point, as a comparison with the "cold" Arctic glaciers.

A visit was made to Steele Glacier, Yukon, to observe the reported surge of the tongue of this large sub-Arctic glacier. Photography contracts were let within a few days and two sets of photographs, 28 days apart, of the rapidly changing glacier were obtained in August and September. The Project played a part in arranging for the subsequent study of this glacier, which has included periodic observations and oblique photography during the winter by the Water Resources Branch; the drawing up of maps by the Surveys and Mapping Branch; and a ground control survey by the Army Survey Establishment in 1967, as well as further aerial photography.

During a brief field trip to Antarctica, a member of the Project investigated the structure and behaviour of certain glaciers in the "dry valley" region of Victoria Land, took part in studies of snow accumulation problems as they affected the maintenance of research stations on the icecap, and contributed to surveys designed to measure the stress in a floating ice shelf.

Gravity Studies -- (See Observatories Branch.)

Hydrographic Survey. The bathymetric survey of the continental shelf and continental slope, and of the straits and sounds between the western Queen Elizabeth Islands, continued, with through-the-ice sounding from spot landings by helicopters on a grid spacing of 7 to 10 kilometres over about 35,000 square kilometres of the Arctic Ocean offshore from Prince Patrick Island. Decca Lambda position control, based on Prince Patrick and Brock islands and tied to the Shoran geodetic network, was used. This work is being compiled for publication on a scale of 1:500,000.

Periglacial Studies. A detailed two-year study was completed of the periglacial features of the Arctic coastal plain and adjacent parts of Prince Patrick Island. Pingo-like forms, sand dunes, raised and dissected deltas, slopes and scarps were investigated as to their structure, mineral and textural composition, and method of formation. This work was supported jointly by the Polar Continental Shelf Project and the Canada Council, and was carried out by a geomorphologist from the University of Liege, Belgium.

Radio-Wave Propagation Studies. A series of experiments was carried out, with the assistance of a party from the Defence Research Telecommunications Establishment, to determine radio-wave transmission properties over the Lincoln Sea and Robeson Channel ice at different frequencies and throughout the year with changing ice conditions. The results have shown significant effects of sea ice on radio transmission, which will have important and in some cases inhibiting consequences on electronic survey and navigation systems in polar regions.

Sea-Ice Studies. Systematic studies were made of all major waters of the Queen Elizabeth Islands and of the adjacent Arctic Ocean and Parry Channel, Beaufort Sea and Amundsen Gulf throughout the season of significant sea-ice activity. Information was collected on the composition, break-up, amount, distribution, dispersal and formation of the sea ice, and of the origin, movement, and disintegration of certain tabular icebergs or "ice islands". It has proved possible to follow the movement of the same ice throughout the season and from year to year, and to record its progressive and cyclical changes. Information is collected relating the behaviour of the sea ice to meteorological and oceanographic factors; this, it is hoped, will lead to a better understanding of the causes and controls of sea-ice development and movement and thus, in turn, to better forecasts of ice conditions.

Sub-Ice Acoustics. Logistics support and field facilities were provided for an investigation, undertaken by the Pacific Naval Laboratory of the Defence Research Board, of the transmission of sound under unbroken pack ice over deep water, offshore from Prince Patrick Island.

Topographic Surveys. Location surveys were completed for the establishment of the Decca Lambda survey and navigation chain to cover McClure Strait. Surveys were run to provide additional ground control for aerial photography, and to record glacier movement, in the icecap area of Melville Island. Glaciological surveys were carried out in the Meighen Icecap.



## MINERAL DEVELOPMENT GROUP

## Mineral Resources Division

The value of Canada's mineral production for 1966 surpassed the \$4 billion mark for the first time in the country's history. At \$4,003 million, it represents an increase of 7 per cent over the 1965 production value of \$3,744 million. Each of the three mineral-industry sectors set new highs in 1966, with metalics increasing to \$1,995 million from \$1,907 million, industrial minerals to \$843 million from \$760 million, and mineral fuels to \$1,165 million from \$1,076 million in 1965. Mineral exploration and development was extensive and widespread in all producing provinces and territories. Development of properties for production continued at high levels, assuring continued expansion and diversification of Canada's mineral industry in the years ahead. Minerals and mineral products continued to be one of the mainstays of Canada's export trade, and in 1966 crude and fabricated mineral materials accounted for over 30 per cent of total Canadian exports.

In the field of offshore exploration, more than \$20 million has been spent to date by the various companies concerned, and the tempo of offshore activity is increasing. Approximately \$8 million was spent during the past year.

The work of the Mineral Resources Division lies mainly in the field of resource-economics and is divided into two categories - operational and advisory. Mineral specialists of the Division conduct field and office investigations directed toward both basic and applied engineering-economic research on a wide range of mineral commodities and problems. The work covers all aspects of the mineral industry from resources through exploration, development, mining, beneficiation, smelting and refining, and transportation, to pricing and marketing. This basic research is essential for the preparation of reports for general distribution and for providing informed assessments and advice to government departments and agencies, industry and the public on mineral and related problems.

Federal responsibilities in the administration and management of non-renewable resources were reorganized at the beginning of 1966 in accordance with Order-in-Council P. C. 1965-2284, December 22, 1965. These responsibilities have been allocated between the Department of Indian Affairs and Northern Development and the Department of Energy, Mines and Resources, so that the former now handles mineral rights in the Yukon, Northwest Territories, offshore Arctic and Indian Reserves, and the latter the federal interests offshore from Canada's west and east seacoasts and in Hudson Bay, as well as the federally owned mineral rights in the provinces. The Resource Administration Division was formed in 1966 to handle the mineral-resource responsibilities thus transferred to the Department of Energy, Mines and Resources. The Mineral Resources Division now consists of the Research and Special Projects Section, Materials Section, Taxation and Legislation Section, and the Resource Administration Division.

General Advisory Activities. Research continued in many mineral matters of national and international concern for the preparation of government submissions. By means of basic-resource investigations and economic research, officers of the Division are able to advise the Department on a wide variety of mineral matters of national importance, including mineral taxation and legislation. Service rendered by the Division from January 1, 1966, to March 31, 1967, included continuing assistance to the Canadian Tariffs and Trade Committee representing Canada at Geneva in discussions relating to the General Agreement on Tariffs and Trade (GATT); advice on the implementation of Canadian export controls on copper; an estimate of Canadian tin consumption for 1966 for the meeting of the International Tin Council; a study on the effect of higher tolls on Canadian iron-ore passing through the St. Lawrence Seaway and Welland Canal to consumers in Canada and the United States; a brief in support of mine access roads; an appraisal of the past and present mineral-resource-development policy of Newfoundland and Labrador with recommendations for the future; and the commencement of a similar study on New Brunswick. Other studies included an economic evaluation of the Anvil lead-zinc property in the

Whitehorse Mining District of the Yukon Territory, taking into consideration various transportation and processing alternatives, overall operating costs and marketing expectations. An economic evaluation was also made of the benefits that might be expected from the opening up of the iron-ore deposits in the Mary River area of Baffin Island, having regard to various cost and marketing assumptions.

The 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 and buildings in specified areas. This work requires resource-economic appraisals of all pertinent factors from resource development through processing to marketing.

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 29 applications for three-year tax exemptions. One application for certification as operators of an industrial-mineral mine on a non-bedded deposit was processed.

During the second half of 1965, the Chief of the Division and a member of the Division's Research and Special Projects Section were seconded to work with J.R. Donald, Special Consultant on Coal to the Minister of Trade and Commerce, on the Cape Breton coal problem. This assignment was completed in the second quarter of 1966, but follow-up work continued throughout 1966 and early 1967 relative to Dr. Donald's report and its study by the Government.

Late in 1966, the Assistant Chief of the Division and a member of the Division's Research and Special Projects Section attended mineral-industry hearings as special minerals advisers of the Royal Commission on Economic Prospects of Newfoundland and Labrador. Hearings were held in St. John's, Wabush and Labrador City. Follow-up advisory work continued into the first quarter of 1967.

International Activities. Officers of the Division presented reports at meetings of several international organizations concerned with minerals and mineral trade. These included special mineral-industry committees of the Organization for Economic Co-operation and Development (OECD); the steel committee of the United Nations, Economic Commission for Europe (ECE); the International Lead and Zinc Study Group; the United Nations ad hoc Committee on Tungsten; and the International Tin Council.

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, 1967, were approximately \$71 million. The balance, some \$4 million, has been committed for the completion of the program in 1968-69.

Foreign Aid Training. The Division, on behalf of the External Aid Office, arranged 58 technical-training programs for foreign trainees and provided consultation on 13 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. Nineteen trainees completed training programs in the period January 1, 1966 to March 31, 1967. At the end of the period ten trainees were on study courses and 23 planned programs were awaiting arrival of candidates. In addition, 34 foreign students in attendance at Canadian universities under various technical-aid programs were given summer employment in the Department in fields related to their academic courses. The Division also participated in arrangements to send mineral consultants abroad to advise certain developing countries on mineral policies and projects.

Publications of the Division. Between January 1, 1966 and March 31, 1967, Division personnel completed Mineral Information Bulletins on iron ore, federal taxation and legislation, mercury, the OECD steel industry and preliminary reports on the mineral industry for 1965-66. Other publications completed were nine Operators Lists and the Canadian Minerals Yearbook 1964. Reports on uranium and the mining laws of Canada, as well as the Canadian Minerals Yearbook 1965 were being printed, while work proceeded on the preparation of reports on nickel, beryllium, zinc, copper, molybdenum, manganese, natural gas, fertilizers and stoping practices. Several papers were prepared and delivered at national and international conferences or submitted for publication in technical journals.

Information Activities. The Division has a continuing program of educational filmstrips. During the period, research and scripting was completed by the National Film Board under the direction of commodity officers on 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 enlarged.

Revision and reprinting of the booklet Entrance Awards for Mineral Industry Courses at Canadian Universities and Technical Institutes was completed. The 16th edition of the popular mineral map Principal Mineral Areas of Canada was also completed and received wide distribution.

Mineral Occurrence Index. The Division maintains an index of Canadian mineral occurrences which is available for the use of anyone interested in mining and exploration in Canada. The indexing of Canadian mineral occurrences was begun nearly 70 years ago, and was carried out intermittently until 1959. Since that time work has been continuous. The method of indexing has been changed to conform to the National Topographic System and the index has been reorganized to include a comprehensive summary of the information available on each occurrence with provision for revision and additions as required. At March 31, 1967, the Mineral Occurrence Index contained descriptions of almost 10,000 mineral showings and deposits.

Canada Oil and Gas Permits. Offshore Canada oil and gas permits are issued under the Canada Oil and Gas Land Regulations. They are valid for 6 years with 6 renewals of one year each, and are granted for a grid area or half a grid area. A grid area is delimited by lines of longitude 15 minutes apart and lines of latitude 10 minutes apart, and may range in size from approximately 95,000 acres at 42° 00'N latitude to approximately 60,000 acres at 62° 00'N latitude. The applicant must pay a fee of \$250 per permit, and deposits must be made at the beginning of each work period throughout the life of a permit to the full amount of the work requirements at that period. All such guaranty deposits are returned upon satisfactory performance of work, but they are subject to forfeiture to the amount that work requirements are not met. The total amount of work required during the 12-year life of a permit is \$2.70 per acre. 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 605 Canada oil and gas permits covering 43 million acres in offshore areas were issued during the past year, as follows:

East coast	588 permits	42,301,906 acres
West coast	7 permits	327,309 acres
Hudson Bay	10 permits	390,828 acres

This brought the number of offshore Canada oil and gas permits (except the Arctic coast) to 2,750, covering 206 million acres, as follows:

East coast	1,650 permits	134,211,815 acres
West coast	279 permits	18,018,562 acres
Hudson Bay	821 permits	53,864,747 acres

On March 31, 1967, the Division held approximately \$10 million in the form of guaranty deposits made by permittees against the work requirements of their permit holdings. The total revenues received during the fiscal year 1966-67 on behalf of offshore permits, including permit fees, transfer fees, forfeitures, maps, and exploratory licences, amounted to \$154,068.60, most of which was derived from permit fees.

Mineral Claims. Offshore mineral claims are issued for mineral rights other than oil and gas rights under the Canada Mining Regulations. Each mineral claim covers an area not greater than 1,500 feet square (approximately 52 acres). A total of 163 offshore mineral claims were recorded during the past year, of which 84 are located off the west coast and 79 off the east coast. This brought the total number of mineral claims to 286, distributed as follows: east coast, 79; west coast, 142; Hudson Bay, 65. Total revenues received from the issuance of mineral claims and prospecting licences during the fiscal year 1966-67 amounted to \$817.00.

Federal Lands in the Provinces. Oil and gas leases for lands falling within this category are issued under the Public Lands Oil and Gas Regulations. Each lease comprises approximately 160 acres, is valid for 10 years, and is renewable if capable of production. A fee of \$5.00 is payable upon issuance, and there is an annual rental of \$1.00 per acre. The rate of royalty payment is 12 1/2 per cent on oil and 15 per cent on gas.

During the past year, 27 oil and gas leases were issued; of these, 16 were in Alberta, 6 in Saskatchewan, and 5 in Manitoba. This brought the total number of federal oil and gas leases in the provinces to 209, as follows: 101 in Alberta; 77 in Saskatchewan; 27 in Manitoba; 4 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, 1967, 51 oil and gas leases were productive, as follows: 25 in Alberta; 18 in Saskatchewan; 8 in Manitoba. The total revenues received during the fiscal year 1966-67 on behalf of oil and gas leases, including royalties, lease sale bonuses, rentals, extension fees, lease fees and assignment fees, amounted to \$301,657.62, most of which was derived from royalties.

The Emergency Gold Mining Assistance Act. The Act was extended on December 12, 1963, for four years to the end of 1967 without change in the formula for computing the amount of assistance payable.

The amending legislation restricted the eligibility of lode gold mines commencing production after June 30, 1965. Such mines are eligible for assistance only if they provide direct support to an existing gold-mining community. A gold mine is deemed to provide such support if most of the persons employed at the mine reside in gold-mining communities listed in the amending Act.

The administration of the Act is conducted 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 of exploration and development expenditures. They review and report upon the allowance of costs which are in question. An examination of mining and milling practices and of production and ore-reserve records is part of the inspection. 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 under the current formula is computed by adding 25 per cent to the product of the rate of assistance and the number of assistance ounces. The number of assistance ounces is two thirds of the total number of ounces produced in the assistance period. The rate-of-assistance factor is determined by taking two thirds of the amount by which the average cost of production per ounce exceeds \$26.50. Thus a gold mine

which has an average cost of production less than \$26.50 an ounce is not eligible for assistance. The maximum rate of assistance is \$12.33 per ounce.

There were 44 lode gold mines and 25 placer gold mines in receipt of assistance during 1965. Seven 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 1966, 210 separate applications were examined by the Audit Services Branch, approved by this Department and transmitted to the Chief Treasury Officer for payment.

The amount of assistance paid per 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	-	\$14,397,419.04	or	5.54	per ounce produced
1964	-	\$15,069,735.80	or	5.69	per ounce produced
1965	-	\$15,686,000.00	or	6.55	per ounce produced
1966	-	\$14,834,000.00			Not available

## Explosives Division

The Explosives Division administers the Explosives Act, first passed in 1920, as an instrument of public safety to control explosives manufacture, sale, storage, importation and transportation by road. The Division discharges its task by licensing and inspecting factories, magazines and transportation, assessing new explosives and equipment, contacting representatives from federal and provincial government agencies, explosives manufacturers and construction and transportation industries.

The Division also publishes literature in the form of reports on production, consumption and importation of explosives, accidents in which explosives are involved, and pamphlets on safety, and minimum standards for storage and handling of explosives.

In the past ten years the production of explosives has more than doubled, with corresponding increases in the number of factories, magazines and transportation vehicles.

Many new developments have occurred, such as the introduction of portable mixing units, new techniques in loading blast holes and a much greater variety in the types of explosives.

The output of commercial blasting explosives in licensed factories during 1966 was 300 million pounds, plus an additional quantity of ammonium nitrate and fuel oil estimated at 50 million pounds blended at the site on mining properties.

The number of licensed explosives factories increased to 34. Specialization is as follows:

Military explosives and pyrotechnics.....	4
Fireworks .....	2
Commercial ammunition.....	6
Blasting explosives for sale.....	18
Blasting explosives for private use .....	4

The Division issued 1,681 licenses for the storage of explosives and 404 permits for the transportation of explosives by road.

During 1966 there were five fatalities in the use of explosives, compared with eight in 1965. There was one fatality in manufacture and one in the transportation of explosives by road.

For the first time since 1952, misuses of abandoned detonators resulted in death; two young children were killed and 17 others sustained injuries. Forty-four persons were injured by fireworks or home-made explosives.

There were 37 prosecutions under the Act - 16 for illegal storage and 21 for violation of transportation regulations.

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





**WATER GROUP**

## Marine Sciences Branch

The Marine Sciences Branch is responsible for the physical survey and research of Canadian coastal waters and of the oceanic areas adjacent to Canada. Through the Canadian Hydrographic Service, it produces nautical charts and associated publications of these and of inland navigable waters. As an extension of its latter role, it provides field support to limnological studies of the Great Lakes. The Branch's oceanographic research embraces physical and chemical studies of the marine environment and of the geophysical and geological properties of the ocean bottoms. The latter studies are oriented toward an assessment of submarine mineral resources.

The extensive and varied activities of the Branch are co-ordinated into three operational regions -- Eastern, Central, and Western -- with a headquarters in Ottawa which provides special and supporting services for the organization as a whole.

In 1966 the Branch's fleet totalled 10 ships, 66 sounding launches and 85 smaller craft. Two helicopters and two chartered vessels were also employed. These vessels were engaged in charting and research of Canadian and adjacent waters from the coast of British Columbia and the western Arctic to the expanses of the western Atlantic. Three new survey and research ships were under construction -- CSS Parizeau and CSS Vector for operation on the west coast, and CSS Dawson for operation on the east coast. These ships were to be delivered in the latter half of 1967. Six new sounding launches of higher speed were purchased. These are substantially increasing the efficiency of hydrographic survey.

### HEADQUARTERS

In Ottawa, chart production, and tidal analysis and prediction were emphasized.

Two hundred and eighty-seven charts, including twenty-seven new charts, were published. Over one-quarter million charts, were distributed. Published charts were kept up-to-date by the production of 78 new editions, 97 corrected reprints, 5 supplementary prints and 28 reprints. Of the new charts published, three were medium-scale charts of the Atlantic Coast designed for offshore navigation and fishing, and two were small-craft charts, one covering Lakes Simcoe and Couchiching.

Nine Information Bulletins were revised and published. Of these, 165,000 copies were distributed. A new Information Bulletin was published showing the water routes to Expo '67. This bulletin was received with great enthusiasm by many organizations and tourist bureaus of both Canada and the United States; over 100,000 prints were distributed.

Collation of the bathymetric data of the western Arctic Ocean was continued. Plotting sheets for the quadrant 90°W - 180°W were completed and sent to the International Hydrographic Bureau which acts as the co-ordinator of the General Bathymetric Charts of the Oceans Project.

The predictions in the Tide and Current Tables were prepared by computer programs and the output was used directly in the printing, marking the first time that any country has achieved this degree of automation.

Several major studies in tidal research have been completed, namely, the effect of tidal barriers upon the M<sub>2</sub> tide in the Bay of Fundy for the Atlantic Tidal Power Programming Board and a major text on the analysis of tides, which has been submitted for publication. Studies are continuing on the mathematical modelling of the St. Lawrence River.

The Canadian Oceanographic Data Centre continued to develop its role of a national centre for the processing, storage and retrieval of oceanographic data. It extended its processing of Great Lakes data.

### WESTERN REGION

The Western Region includes the Pacific Coast of Canada, the western Arctic and the navigable waters in British Columbia. Its activities, at present, concentrate on hydrographic surveys and tidal-current investigations.

Along the southern British Columbia coast, CSS Wm. J. Stewart continued a survey in the Strait of Georgia (Gabriola Passage to Nanoose Harbour) and commenced a survey of the approaches to Burrard Inlet. CSS Marabell completed a survey at Menzies Bay, as required at new ore-loading dock facilities, and surveys to meet R. C. N. requirements at Uchucklesit and Neroutsos Inlet. A survey was commenced at Prideaux Haven in Homfray Channel.

Along the northern coast the general charting program was continued with CSS Wm. J. Stewart carrying out conventional surveys in the Chatham Sound area and the Marabell completing Observatory Inlet and continuing with Portland Inlet.

In the western Arctic, CSS Richardson conducted surveys in the Beaufort Sea region from late June until late August, after which it sailed for the Pacific Coast for the quadrennial refit. Severe ice conditions and damage to the ship in ice made it a somewhat unproductive year in the accumulation of hydrographic data. Hydrographers posted on board CCGS Camsell conducted surveys at Paulatuk, Spence Bay and on a circumnavigation of King William Island, including a voyage to Bellot Strait and return. This was the first time that any vessel had circumnavigated King William Island.

In the study of tides, the survey vessel Parry continued its survey of currents on the southern British Columbia coast. The observations taken in 1966 are being used in compiling a current atlas for the waterways between Juan de Fuca and Georgia Straits. A similar current survey is being made in and near the tidal rapids on the northern approaches to the Strait of Georgia. An auto-announcing tide gauge has been installed at Tofino, as part of the tsunami warning system for the Pacific. The gauge can be dialed by telephone and responds with the present tide heights, tendency (rising or falling) and preceding high and low water. If a seismic sea wave is suspected a call to the station will disclose immediately whether abnormal tides are occurring. A new tide station in the western Arctic gauging set was established at Cape Parry and commenced operation in 1966. Extension of the Arctic gauging to Spence Bay, Coppermine and Sachs Harbour is being planned.

### CENTRAL REGION

Although the primary activities of the region again consisted of conventional charting, the development of a broadening sphere of research continued. This unit of the Branch assumed responsibility for the Lake Surveillance Program. It undertook hydrographic-automation studies and continued strong support to the hydrographic field training given to 36 new employees.

The trend, started in 1965, of developing highly mobile and flexible operational field charting units, was intensified with the acquisition of additional high-speed sounding craft and portable medium-range electronic positioning equipment. One helicopter was utilized throughout the field season on a time-shared basis by three parties and again provided invaluable assistance.

The charting activities of this region concentrated on waterways used by small boats.

The charting of the Trent-Severn system continued, with surveys being completed from Balsam Lake to Bobcaygeon. Some revisory information was obtained in the areas surveyed in 1965. To date, Small Craft Chart Folio (2028) and a revised edition of Chart 2015 have been published as a result of these surveys. Additional chart folios are in an advanced stage.

The hydrographic survey of Rainy Lake, begun in 1965, was completed during the 1966 field season. The survey of Lake of the Woods was to start in 1967. Lake of the Woods is one of the most popular boating areas in northwestern Ontario and has a summer population of over 100,000.

An urgent program of locating and surveying a small-boat channel from Sorel to the Expo Marina site in Montreal Harbour was completed. The development of this channel, which was buoyed in April 1967, was essential to ensure a safe and orderly flow of pleasure-boat traffic to Expo during centennial year.

A shore-based survey unit, operating from Tobermory, continued surveys in the entrance to Georgian Bay and completed large-scale charting of the southwestern approaches to the bay to facilitate pleasure-boat navigation in that region. During the early months of 1967 this unit also made preparations for a hydrographic survey of the popular but dangerous pleasure-boat route between Port Severn and Parry Sound.

In the early months of 1967, preparations were made for charting Presqu'île Bay and the approaches to Trenton during that field season. This survey will facilitate production of new charts of the western approaches to the Bay of Quinte and the southern approaches to the Trent-Severn Waterway.

As a part of its additional tasks, the Region seconded three hydrographers to carry out hydrography in the Arctic Archipelago as part of the Polar Continental Shelf Project. Soundings were obtained using submerged transducers towed from aircraft and located with the aid of electronic positioning systems. Early in 1967 the hydrographic team was increased to five experienced hydrographers because of an expanded Arctic charting program.

Hydrographers from this Region also assumed operational responsibility for carrying out the Lake Surveillance Program with the main activities centred in Lake Ontario. The operational base of this unit was Kingston, Ontario, with one chartered ship and an independent sounding launch being used for data collection.

#### EASTERN REGION

The period of this report, which includes the fourth full year of operation of the Bedford Institute of Oceanography, was a time of continuing progress. An extensive program of hydrographic survey was undertaken, and several oceanographic research projects were carried through to the stage where positive and important results were becoming evident.

CSS Baffin completed the combined hydrographic and geophysical survey of the Tail of the Bank, the portion of the Grand Bank south of 45°N. This required a total of almost 22,000 miles of sounding and was only possible by extensive modifications to the LAMBDA electronic-positioning system which enabled the ship to be accurately positioned up to distances of 500 nautical miles from the station on Sable Island.

CSS Acadia first surveyed Havre Aubert in the Magdalen Islands where extensive changes have been made in recent years. The ship's main project was the continuation of the survey of Hamilton Sound, the sheltered passage inside the Fogo Islands, which is being increasingly used by vessels bound for Botwood, particularly in the winter when it is generally clear of ice.

The main project of CSS Kapusking was the completion of the survey of Chaleur Bay and its approaches. The charts resulting from this will be of great value to fishermen and to ships bound for the extensive industrial developments on its coasts. At the end of the season a survey was made of Carousse Bank, off Cape Canso, N. S., to complete the offshore survey of the Scotian Shelf.

CSS Maxwell was used to carry out a variety of small projects. A detailed survey was made of the Lurcher Shoal, off Yarmouth, N. S.,

to enable the Department of Transport to prepare plans to replace the lightship marking this hazard by a permanent light house. In Newfoundland, surveys were made of Trepassy Harbour, the waterfront at Cornerbrook and wharves in Harbour Grace and Carbonear. On the North Shore of the Gulf of St. Lawrence, surveys were made at Natashquan and in Sept Iles Harbour. Semi-permanent tide gauges were established at Port Cartier, Mingan Harbour, on the North Shore, and at Ellis Bay and Southwest Point on Anticosti Island. At the end of the season surveys were made of Port Bickerton, and the new deep-water wharf at Sydney, N. S., and of the bar in the entrance to Sydney Harbour.

Hydrographers assigned to Department of Transport icebreakers in the eastern Arctic completed the survey of the southern portion of Milne Inlet, the harbour which will be used when the extensive iron-ore deposits in North Baffin Island are developed. Extensive reconnaissance surveys were made in the channels around Bylot Island and in Jones Sound.

Of the oceanographic studies, the following merit special mention.

The investigation of the physical oceanography of the Gulf Stream system between the Grand Banks and the Azores, representing several years' work, has yielded a comprehensive atlas and an important paper presenting a new concept of the current patterns and water-mass transports in this area. Good progress was made on the challenging problems of the mechanism of formation and the rate of production of the deep waters of the western North Atlantic, an undertaking which demands that the observations be made in mid-winter. Thus, in early 1966, numerous oceanographic stations, each extending to the bottom and covering virtually all of the Labrador Sea, were occupied by CSS Hudson. In early 1967 the coverage was extended to Irminger Sea and Denmark Strait, but with more comprehensive instrumentation, including an array of 25 current meters and 15 temperature recorders moored by the Hudson in Denmark Strait for 40 days. This cruise was a joint undertaking of physical oceanographers from the National Institute of Oceanography, Woods Hole Oceanographic Institution, and the Bedford Institute of Oceanography. The moored array, using some \$125,000 worth of equipment, was provided by WHOI. Despite appalling weather, most of the objectives of the cruise were met, including important new data on the variability of the processes of deep-water formation.

Geophysical surveys were carried out on the southern part of the Grand Banks, the Labrador Coast, Ungava Bay, Davis Strait, Baffin Bay and on a segment of the Mid-Atlantic Ridge. Of outstanding scientific interest was the comprehensive exploration by the Hudson of some 2,500 square miles of the western flank of the Mid-Atlantic Ridge centred at 45°30'N and 28°30'W. A major accomplishment of this cruise was the full utilization of a technique for producing on-the-spot bathymetric, magnetic and gravitational maps of the area, and then using the knowledge thus gained to determine the most interesting and promising places at which to sample the bottom by coring, photography and dredge hauls. This technique was made possible by the now reliable data-logging and -processing system, Geodal, developed by the scientists of the electronic-instrument-research-and-design group in the Institute. The full scientific results must await completion of detailed study of the great mass of samples and data obtained, but already it is apparent that new light will be cast on the processes governing the formation of this great ridge, suspected by many authorities of being the key to many riddles in the geophysical and geological history of the earth.

An intensive study, begun three years ago, on the growth of polar sea ice and on related processes in the sea water beneath is now yielding results. The temperature field as a function of time in a developing ice sheet at Cambridge Bay, Victoria Island, in the Northwest Territories, has been precisely observed and an analysis of the results reported in a recent paper. The process of salt ejection from the ice as it grows and the resultant effects in the sea water below have been studied both in the field and in a

laboratory model. Such work is adding to the fundamental knowledge of our Arctic marine environment upon which the success of future exploitation will depend.

The continuing marine-geological investigation of the continental shelf encompassed a wide variety of projects. Field work extended from the Arctic to the Bay of Fundy and included such major embayments as Hudson Bay and the Gulf of St. Lawrence. Of more than usual interest was the progress made in delineating the sedi-

mentary structures underlying the Scotian Shelf by the study of exposed strata along the continental slope, culminating in the recovery of rock samples bearing significant amounts of hydrocarbons. The samples were in the form of fresh blocks of siltstone torn from outcropping strata of the wall of the canyon known as "The Gully", mostly in the depth range 750 to 1,500 metres, a few miles to the east of Sable Island. Much interest in these results has been shown by firms engaged in oil exploration on the Atlantic Shelves, notably Mobil, which are proceeding to drill on Sable Island.

## Policy and Planning Branch

The Policy and Planning Branch was established in January 1967. It succeeded the Resource Development Branch which had been established in April 1965, by the former Department of Northern Affairs and National Resources to co-ordinate federal resource policies; to improve liaison with the provinces on shared resource programs; to conduct broad economic and other studies of resource conservation and development; and to administer certain resource programs.

The Resource Development Branch did not become operative until July 1965, when the various units comprising the Branch were brought together. During 1965 the Branch's efforts were devoted mainly to current work, organization and staff recruitment.

The reorganization of the federal administrative framework for resource management had major implications for the recently formed Branch. Effective January 1, 1966, the Branch was transferred to the former Department of Mines and Technical Surveys. The Branch's advisory, research, planning and interdepartmental and federal-provincial co-ordination functions were transferred with the Branch, as was responsibility for Dominion Lands, offshore minerals below the 60th Parallel and the Roads to Resources Program. The Resource Management Division, however, together with responsibility for resources north of the 60th Parallel, remained with the Department of Northern Affairs and National Resources (now Department of Indian Affairs and Northern Development).

The factors which gave rise to the Resource Development Branch applied equally well to the new Department of Energy, Mines and Resources. These factors included: increased pressure on our resources; technological advances which have made possible large-scale developments often beyond the technical and financial capacity of individual provinces, and often with regional, national or international implications beyond the jurisdiction of the provinces; new concepts of comprehensive, multi-purpose resource development which require a co-ordinated inter-disciplinary and inter-jurisdictional approach in resource policy; new concepts of regional economic development and the establishment of agencies and programs to stimulate growth in less favoured areas, which again require a co-ordinated inter-jurisdictional approach in planning, including co-ordination between regional policies for resources and regional policies in other sectors; and increased emphasis on the economic and social as well as the engineering and technological aspects of resource development. These factors were of particular and growing significance in the field of water resources.

A reorganization study of the Department recognized these factors, and in January 1967, the Resource Development Branch became the nucleus of the Policy and Planning Branch of the Department's Water Group.

On its establishment, the Policy and Planning Branch assumed responsibility for advisory services on water and related resource policies and programs; for interdepartmental and federal-provincial co-ordination and liaison; for basic and applied economic and inter-disciplinary research; for departmental, interdepartmental and federal-provincial resource investigations and studies; and for negotiation and administration of joint programs in the water field.

The Branch is organized into three major divisions, together with administrative and personnel support services, as follows:

- (1) Policy Co-ordination and Administration: Continuing studies to formulate advice and recommendations on regional and national renewable-resource policies and programs; interdepartmental co-ordination and federal-provincial liaison in the study and implementation of resource policies and programs; liaison between agencies of the federal government and the Canadian Council of Resource Ministers; and negotiation and administration of joint federal-provincial water programs.
- (2) Resource Planning: Staff support for water-resource investigations, including comprehensive basin and regional planning studies, undertaken directly by the federal government or through federal-provincial or international agreements; studies of the economic, social, legal and other aspects of regional and national water policies and programs; development and implementation of federal and federal-provincial "systems" for the collection, compilation and processing of certain water data including a water-use inventory.
- (3) Resources Research: Research directed towards the best use of the national resources of Canada, through integration of existing knowledge in the economic, sociological, scientific and technological fields; a source of specialized advice to other divisions and branches; administration of a program of grants in aid of university-sponsored research.

It is evident from the above that, during the period covered by this report, a great deal of the effort of this embryo Branch has been expended on preparatory work. Even so, the Branch was able to initiate or participate in a number of programs.

The Branch provides the secretariat for two senior interdepartmental resource committees, viz., the Advisory Committee on Water Use Policy and the Interdepartmental Committee on Resources. It also maintains liaison between federal agencies and the Canadian Council of Resource Ministers.

In support of the Council of Resource Ministers, the Branch co-ordinated federal preparations for the National Conference on Pollution and Our Environment, held in Montreal in November 1966. This important conference produced a large number of guidelines on water, air and soil pollution. In early 1967, the Branch initiated an evaluation of the guidelines relating to water pollution. This led to recommendations for federal action on water pollution, recommendations which were presented to the Council of Resource Ministers for consideration in May 1967.

In November 1966, the Government of the United States invited the Government of Canada along with other nations to participate in an International Conference on Water for Peace to be held in Washington from May 23 to 31, 1967. Following the government's decision to accept this invitation, the Branch assumed responsibility for arranging Canada's participation in the conference. With the full co-operation of the ten provincial governments, a National Committee on the Water for Peace Conference was established. The secretariat for this committee, and for a similar interdepartmental committee, was provided by and through the Branch. Largely as a result of the co-operation achieved through these committees, it was possible to arrange vigorous Canadian participation in the conference in a very short time. Canada's contribution included a country situation paper, over fifty technical papers, a major exhibit and a large and highly qualified delegation of water-resource ministers and experts drawn from both the federal and provincial governments.

Among research projects started by the Branch were studies on pollution, the use of air-photo interpretation for watershed planning, an historical study of federal resource policies, and an examination of the theory of market structures and their implications for resource development.

In addition to the above, the Branch is represented on the Canada-Ontario Co-ordinating Committee for the Northern Ontario Water Studies. It participated in continuing negotiations on the proposed Saskatchewan-Nelson Basin Studies and other similar efforts.

The Branch also co-operated with the Science Secretariat in an inventory and assessment of water-resources research in Canada. The results of this study will be extremely useful to the Branch in the administration of the Department's grants in aid of water-resources research, an example of which is the grants in aid to the University of Manitoba for an interdisciplinary study of western water resources.

## Inland Waters Branch

(Note: During the period covered by this report, the Inland Waters Branch did not yet operate as such but rather as two separate branches -- Water Resources and Water Research. The relevant activities are therefore described under these two former headings.)

## Water Resources Branch

The Water Resources Branch comprises the Canadian Hydrometric Survey, the Planning, Great Lakes and Research Divisions and Branch administration. The director is a member of the Northern Canada Power Commission. Senior Branch engineers serve as members of numerous federal-provincial and international engineering boards and boards of control.

The Branch carries out systematic hydrometric and sediment surveys throughout Canada, studies and analyzes problems involving waterways of federal-provincial and international concern, compiles a water-power-resource inventory of Canada and administers legislation pertaining to international rivers, water power and water conservation.

### THE CANADIAN HYDROMETRIC SURVEY

The Canadian Hydrometric Survey conducts a systematic survey of streamflow, water levels and water-borne sediment throughout Canada, and 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 effort is aimed at satisfying requests from the provinces.

The Canadian Hydrometric Survey 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.

During the fifteen months under review, some 150 stations were added to the gauging network, bringing to approximately 2,000 the total number of streamflow and water-level stations. Sediment data are gathered at 55 of these stations, an increase of 17 stations during the period.

A start has been made on placing all water-level and streamflow data on magnetic tape for rapid retrieval. At the same time, special equipment has been obtained and work initiated on automating the extensive computations which so far were performed manually in the determination of streamflow data.

An Arctic River Work Group has been established to assess the problems of obtaining winter flows in Arctic rivers and to develop special equipment for determining flows under ice cover.

Development of a training program for standardizing field operations across the country was begun and a program to produce an index of all hydrometric and sediment-survey data was initiated in 1966.

An intensive program of sediment surveys on the lower Fraser River was continued to provide a better basis for economic and engineering design of projects associated with the maintenance and improvement of the navigation channels of 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.

### PLANNING, GREAT LAKES AND RESEARCH DIVISIONS

The Planning, Great Lakes and Research divisions carry out most of the special studies and engineering investigations for which the Water Resources Branch is responsible. Senior staff members of

these divisions represent the Branch on some 30 engineering boards and committees of an international, federal-provincial or inter-departmental nature.

During the fifteen months under review, conservation projects took up most of the staff's time, followed by Great Lakes-St. Lawrence River studies, hydrologic studies and the International Hydrological Decade program.

In hydraulic and hydrologic studies, computer methods offer the prospect of considerable savings in time. The use of digital computers increased markedly over previous years, permitting a substantial increase in work assignments.

#### PLANNING DIVISION

More than half the time of all three divisions was used by the Planning Division, due to the number and diversity of its investigations and studies.

The Canada Water Conservation Assistance Act provides a statutory basis for financial assistance to the provinces in the construction of major works for water conservation and/or control. To this end, work was continued in connection with applications for assistance, hydrology studies, checking of structural designs, study and approval of contract documents and inspection of a number of projects being constructed under the Act.

With ratification of the Columbia River Treaty by Canada and the United States, the Columbia River Treaty Permanent Engineering Board was established to ensure that the objectives of the treaty are carried out. The chairman of the Canadian section of the four-man international board is a senior officer of the Division.

Following agreement between Canada and Ontario in 1965, field surveys were initiated in the Planning Division for co-ordinated studies of Ontario's northern water resources and their economic development.

Among several unrelated hydrologic studies undertaken were: the determination of hydrologic zones in the Eastern Rockies; studies of base flow, half flow and water balance in the Marmot Creek Basin; flood study of Nova Scotia.

Assistance was given to the Atlantic Development Board in an investigation of present and potential sources of water supply in relation to present and future demands in the Atlantic Provinces.

An agreement was signed by the governments of Canada, Nova Scotia and New Brunswick for a two-year study of the development of electric power from the tides of the Bay of Fundy and the transmission of that power to markets in Canada and the United States. The Division is represented on the Engineering and Management Committee which, together with the Atlantic Tidal Power Programming Board, was established to carry out the study.

Engineering studies and negotiations with the United States for a treaty covering co-operative development of the Saint John River continued during the period.

#### GREAT LAKES DIVISION

The Great Lakes Division maintains a regulation and study office in Cornwall, Ontario, which is responsible for Lake Ontario-St. Lawrence River regulation. In addition, the Cornwall office has been responsible for detailed studies relating to the development of new regulation plans for the Great Lakes, and for carrying out a hydrologic study of Lake Ontario.

Officers of the Division in Ottawa took part in studies initiated by the International Great Lakes Levels Board and the Board's working committee in the four principal categories - shore property, navigation, power and regulation. A pilot computer study of Lake Ontario was carried out to develop methods of simulating water inflow to the lake and to establish new regulation procedures. The pilot study has produced mathematical models for simulating inflow to all the Great Lakes. Similarly, various preliminary regulation plans for computer application are being developed for further regulation of the Great Lakes. The Division undertook a number of other projects on behalf of the International Lake Superior Board of Control, International Niagara Board of Control, International Niagara Committee and the Co-ordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data.

The Nelson River Programming Board was assisted in a comprehensive hydro-electric power study of the Nelson River. A start on Phase 1 of a co-operative plan of development has been made, and an agreement with Manitoba, to arrange the details of federal participation, is being negotiated.

Assistance was given in connection with Stage 2 of a study by a federal-provincial working committee of the problems associated with long-distance power transmission, with particular reference to the physical and economic possibilities of establishing a national power grid.

Liaison with other federal and provincial agencies on the Inter-departmental Committee on Energy Statistics continued with a view to resolving common problems inherent in the collection and use of energy statistics.

#### RESEARCH DIVISION

The principal function of the Research Division is the Canadian contribution to the International Hydrologic Decade, an ambitious ten-year program of investigation shared by more than fifty nations and designed to fill many of the gaps in man's knowledge of water.

Canada, with a wide range of hydrologic environments, is in a unique position to contribute to world knowledge in this field. Some 169 projects involving a variety of subjects are being sponsored co-operatively in Canada by federal and provincial agencies and by universities.

The role of the secretariat, which is part of the Research Division, is mainly administrative. Its work consists chiefly in the preparation of minutes of Canadian National Committee meetings, liaison with provincial committees, preparation of reports for national and international distribution, and the carrying out of national surveys on subjects within the Decade's field of interest. The secretariat helped to arrange lecture tours for foreign specialists in Canada. The semi-annual "News Bulletin", containing highlights of Canadian activities in the Decade program, was published and distributed by the secretariat; and assistance was given in the organization of national and regional seminars.

A schedule for a series of workshop and familiarization seminars was established in 1965. These sessions commenced in January 1966 with a workshop seminar on "Research Basin Studies" held in Ottawa. Regional workshop seminars on the same topic were held in Calgary and Toronto in April. The fourth workshop seminar on "Ice Formation and Breakup in Lakes and Rivers" was held in Quebec City in November. The first familiarization seminar on "Principles of Hydrology" was held in September at the University of Saskatchewan. It offered scientists trained in the various disciplines associated with hydrology the opportunity to gain a better understanding of the full science of hydrology.



## Water Research Branch

The Water Research Branch was created from units in the Department of Mines and Technical Surveys on September 7, 1965. The four pre-existing units of the Department brought together to form the Branch are:

Groundwater Section (from Geological Survey),  
Industrial Waters Section (from Mines Branch),  
Glaciology Section (from Geographical Branch),  
Tides and Water Levels Section (from Marine Sciences Branch).

In addition a new unit was formed to conduct limnology research in the Great Lakes.

The purpose of the Water Research Branch is to add to the knowledge of Canada's water resources and to contribute to the understanding of the hydrologic sciences. Due to the stimulation of programs by the International Hydrologic Decade and the increased tasks in water pollution abatement assigned to the Department, the research and survey programs of the pre-existing units were revised and expanded. Almost all of the Department's I.H.D. work was concentrated in this Branch.

The increase in water studies and the consequent reorganization introduced major problems of recruitment in a field of scarce manpower supply, and of acquiring space for new facilities both in Ottawa and in regional laboratories and offices. Some of the latter problems were partially solved by concentrating much of the Branch in new quarters in No. 8 Temporary Building, in July 1966. Later in the year, planning proceeded for integration of the Water Research Branch with the Water Resources Branch, to allow all inland water survey and research work to be conducted within one branch.

### HYDROLOGY DIVISION

The principal function of the Hydrology Division is research in hydrogeology and glaciology. In addition, advice is provided to other government agencies on water management and supply problems. The Division's program includes much of the Department's contribution to the International Hydrologic Decade. It has 25 I.H.D. projects in progress and participates in nine others with federal or provincial agencies.

The Groundwater Section continued its hydrogeological research and basin studies in different hydrogeological regions of Canada, in order to provide knowledge of Canada's groundwater resources. Most of this work is also in support of Canada's I.H.D. commitments.

The national observation-well program was expanded and a number of experimental observation wells were installed. A computer-operated system is being designed for storage, retrieval and processing of the data from the observation-well network as well as from other studies.

In British Columbia, representative basin studies were carried out in the Fraser Lowland and in the southern Interior Plateau.

In the Prairie region a number of studies were continued to add to the knowledge of groundwater-flow systems and groundwater chemistry. Representative basin studies were continued at Good Spirit Lake, Saskatchewan, and Oak River, Manitoba. Investigations of the influence of Lake Saskatchewan on aquifers in the upper Cretaceous bedrock continued. Mass-transfer studies and a study of the hydrochemical interpretation of groundwater flow were carried out in the Moose Mountain area, Saskatchewan. A palaeohydrological study of the three Prairie Provinces collected over 800 ostracod specimens to be used in assessing the past changes in Prairie hydrology as an aid in predicting future ones. A water-balance study of a mountain bog was started in the Kananaskis wetland.

All these Prairie studies have contributed to the knowledge of groundwater flow and have provided field data for computer simulation of groundwater-flow systems, as well as much new information on the important part played by Prairie sloughs in the overall hydrology of the area.

In Ontario, near Iroquois Falls, the hydrogeology of a forested basin is being studied to obtain information on the hydrogeology of unproductive wetland areas as found in a large clay plain.

In the Maritimes area a hydrogeological study was conducted within the North Nashwaaksis basin in co-operation with New Brunswick agencies, and a preliminary water balance was established to assist with provincial snow-melt studies. On Prince Edward Island further instruments were installed for studying the salt water-fresh water relations along the coast. This knowledge will be useful in fully developing the groundwater resources of the island.

The Groundwater Section also advised other federal government agencies on water supply problems, provided consultation and advice to ARDA and ADB on major water investigations, and contributed papers to the National Conference on Pollution and our Environment, and the International Conference on Water for Peace.

The Glaciology Section conducts research on Canadian glaciers to increase our understanding of how they function and how they relate to other parts of the hydrologic cycle. At present the work consists chiefly in the collection of data for office studies and the measurement of the mass balance -- or the annual increase or decrease in mass -- of five glaciers in an east-west profile across the southern Cordillera. The material will serve as a background for future scientific studies.

The studies of the five glaciers -- as against three glaciers in the preceding year -- are part of an international network of glacier studies extending from South America to Alaska, and being done as part of the International Hydrologic Decade program.

Another I.H.D. commitment is compilation of an inventory of Canadian glaciers, and the first part of this task is to determine the distribution and area of glaciers in Canada. The area has been calculated to be 204,000 square kilometres (78,000 square miles); distribution is being compiled. Planning is under way for the more complex problem of a continuing inventory providing quantitative results related to chronological changes.

The Section co-operated with the Geographical Branch in measurements at Decade Glacier on Baffin Island and made a field survey of the Per Ardua Glacier on Ellesmere Island in co-operation with the Defence Research Board.

### GREAT LAKES RESEARCH DIVISION

The Great Lakes Research Division was organized during the year for carrying out comprehensive research to increase knowledge of 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 reactions at the air-water interface; and the relations 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 physical and chemical limnology program was oceanographically oriented and was substantially planned and staffed by person-

nel from the Marine Sciences Branch. M/V Brandal was fitted out as a research ship in Halifax, then brought to the field base at Kingston where the necessary shore facilities were established in co-operation with the Department of National Health and Welfare. The latter participated in the field studies by conducting bacteriological measurements and sharing in the chemical measurement program. M/V Brandal made 18 one-week cruises in Lake Ontario and 1 one-week cruise in Lake Erie to gather data for studies of chemical balance, heat exchange, thermal structures and circulation. The approximately 54,000 pieces of serial data collected were processed in co-operation with the Canadian Oceanographic Data Centre.

During the winter, analysis of the data was started and planning for future research was continued. This involved the development of instrumented research towers and anchored buoys as well as many other specialized instruments for use from the ships.

The limnogeological work embraces geological, geochemical, geophysical and biological-palaeontological investigations of the sedimentary processes occurring within the Great Lakes, and their bearing on pollution. Sediment sampling and seismic-reflection profiling were carried out in Lake Ontario in co-operation with the Geological Survey of Canada and provided a regional reconnaissance of bottom conditions and sediment distribution throughout the lake. The nature and general distribution of the materials on the lake bottom were delineated as well as the principal areas of thick unconsolidated deposits underlying the lake bottom.

During the winter, laboratory investigations were started of various physical properties of the samples from Lake Ontario, utilizing standard techniques available in the Geological Survey sedimentological laboratory. A start was also made in developing rapid analyses using specialized instruments and in setting up a biogeochemical laboratory to investigate the biological constituents of lake-bottom sediments.

In co-operation with the Ships Division, Marine Sciences Branch, two major research vessels were planned and a contract let for the construction of one of them.

An engineering section began preparation of suitable machine and electronics shops to provide the equipment and instruments required by the ships, research towers and anchored buoys. Considerable time was spent in planning the new Canada Centre for Inland Waters to be constructed at Burlington, Ontario, including temporary facilities to allow operations to proceed at this centre during construction of permanent facilities.

#### WATER QUALITY DIVISION

The Water Quality Division does basic and applied research on water quality in its broadest sense. This includes studies on the quality of Canadian surface waters, and research on treatment methods for improving water quality for industrial and municipal use and for pollution abatement. Also included is research into corrosion prevention and treatment of industrial waste water. The Division's laboratories provide water analyses to a wide variety of users and conduct research into analytical methodology.

As a part of its commitment to the International Hydrologic Decade, the water-quality network was expanded from 60 sampling stations to 140 sampling stations, on 125 rivers. In addition, the Division is co-operating with provincial and federal agencies and universities in I.H.D. studies on four research basins and planning similar work on four additional ones.

The Division continued to assist the Departments of National Defence and Public Works on boiler-water treatment and to provide techni-

cal assistance to provincial, and other public and private agencies on water quality and treatment. A water-corrosion study in co-operation with National Association of Corrosion Engineers was completed. Research on methods of analysis was continued in connection with the American Society for Testing Materials, B-19, and in co-operation with the U.S. Department of Health, Analytical Reference Service, National Centre for Urban and Industrial Health.

Co-operative studies were carried on with the Federal Department of Fisheries and the New Brunswick Department of Natural Resources on pollution in the mining area of northeastern New Brunswick. Recommendations were made to the Atlantic Regional Advisory Committee of the Atlantic Development Board on a number of problems relating to abating pollution from toxic heavy metals.

In western Canada the long-term survey of water quality continued for the International Joint Commission and assistance was provided to the Eastern Slopes (Alberta) Watershed Research program on problems concerning water from coal mines entering the headwaters of the Saskatchewan River system.

Difficulties were encountered in recruiting for the expanded work because of lack of qualified personnel and lack of suitable space. In Ottawa, quarters were being renovated on Spencer Street and interim arrangements made for staff in other temporary quarters. The eastern regional laboratory commenced operations at the Bedford Institute of Oceanography in Dartmouth while laboratory space was being prepared in Moncton. The western regional laboratory started work in a complex of four trailers at the site of the new Geological Survey building in Calgary, while awaiting preparation of rental quarters. Considerable effort was expended in planning for the future accommodation of much of this division in the Canada Centre for Inland Waters at Burlington, Ontario, and arrangements were made to transfer the trailer complex from Calgary to allow water-quality operations to start at Burlington in the following year. The introduction of automatic analyzers allowed the Division to increase its water analyses in response to the greatly increased demands and I.H.D. requests.

Plans were carried forward for computer storage, retrieval and print-out of analytical data. The programming is being designed to be compatible with requirements of other divisions in the branch and where possible with developing provincial systems.

#### TIDES AND WATER LEVELS SECTION

The objectives of this Section are to maintain continuous records of water levels in Canada's coastal waters and the navigable waterways of the St. Lawrence River and Great Lakes. From these records, water-level, tidal and current tables are prepared and distributed as quickly as possible. In addition, tidal predictions are provided and research and development undertaken to improve methods of collecting and analyzing data.

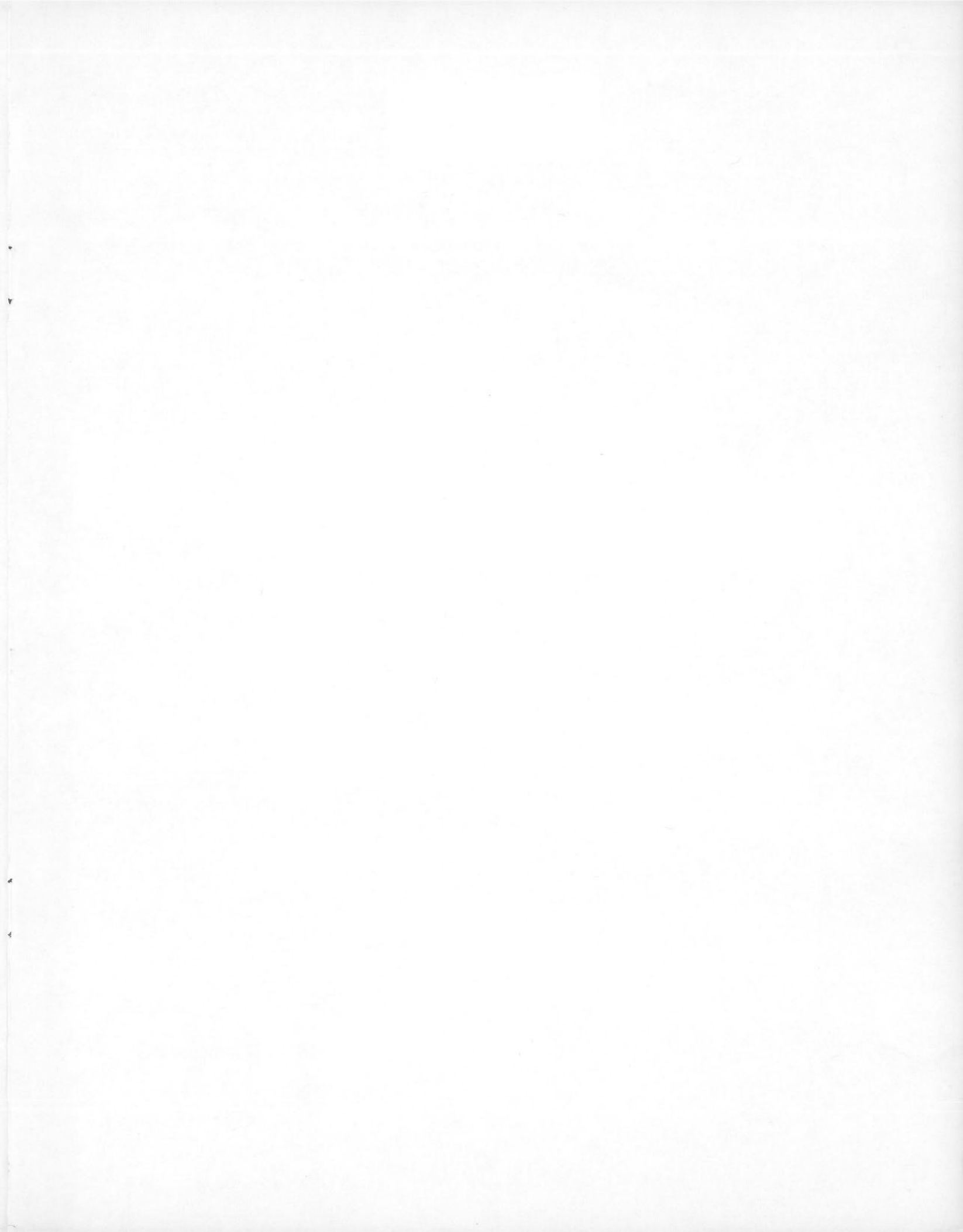
After several years' preparation the first completely "made-in-Canada" set of Canadian Tide and Current Tables was issued during the fall. Tidal values for the first time are now predicted on large scale in Canada, and the tables are compiled and printed with the use of computer techniques. Similar techniques are used in presenting the gauging data for the Great Lakes - St. Lawrence River system. Many agencies in and outside of Canada are now requesting these data in the computer-usable format developed by this Section. The tsunami warning centre at Honolulu is provided with up-to-the-minute tidal values from the Tofino Gauging Station on Vancouver Island. The automatic telephone and radio-announcing devices installed at the Tofino Gauging Station and tidal and current-measuring equipment used by hydrographic field parties were exhibited on board CSS Baffin during a visit to Monaco in conjunction with the 9th International Hydrographic Conference, in the spring of 1967. Several papers presented by the Canadian delegation constituted the major contribution on tidal problems during the concurrent Symposium on Tides.

Special tidal surveys were carried out between Quebec City and Father Point to provide data for physical and mathematical model studies of this section of the St. Lawrence River.

New punch paper-tape gauges developed for tidal measurements were installed to further automate the data processing. In addition, these gauges lent themselves with some slight modifications for in

situ recordings, and two experimental gauges were laid in the middle of the St. Lawrence River.

To reduce the space required for storage of original records of past data, microfilming has been undertaken and is nearing completion.



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