ANNUAL REPORT

Calendar Year 1965

Mines and Technical Surveys

ANNUAL REPORT——————

——CALENDAR YEAR 1965

Department of Mines and Technical Surveys
Ottawa

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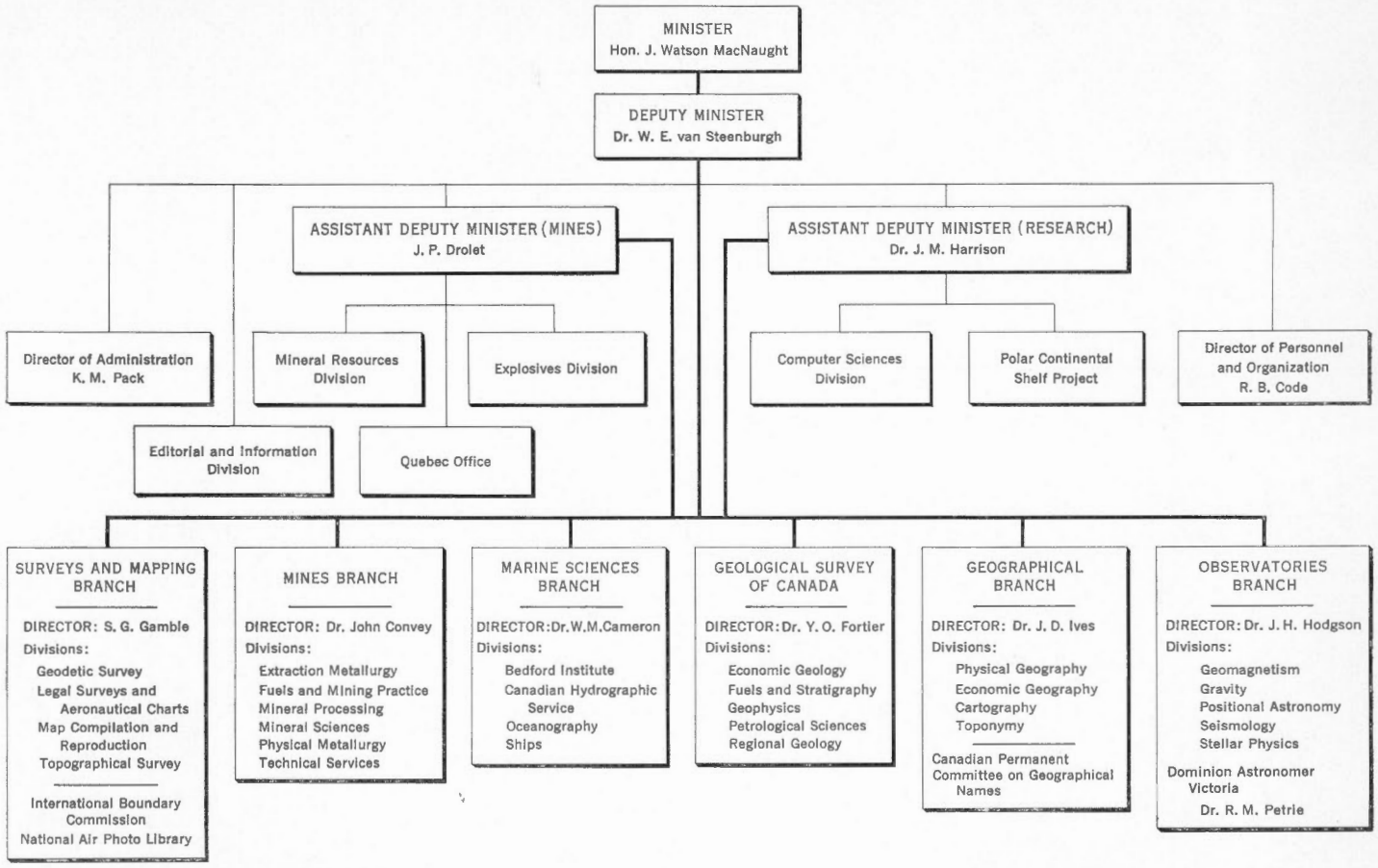
CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS



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Introduction

In 1965 the Department of Mines and Technical Surveys conducted an intense, ever-widening research and survey program of importance to many aspects of Canadian endeavour. Some projects were of immediate benefit to industry (e.g. mineral exploration, mining and metallurgy); others were designed to further a particular branch of science or engineering; still others provided information basic to mapping and describing the country's physical features. And while many of the year's activities were of long-term significance, most were designed to stimulate, directly or indirectly, the development of Canada's resources and to strengthen her world position in technology and science.

The Surveys and Mapping Branch continued its accelerated mapping program. A prime aim: to complete the reconnaissance scale topographical map coverage of Canada by 1967. Nevertheless, many of the Branch's current projects reflected a pressing need for maps of larger scale with priority dictated by the requirements of industry and resource development. Often the work called for radically new techniques. For example "Aerodist", an electronic distance-measuring device used from the air was brought into play over northern Quebec and the Arctic Islands; Echo I and Echo II satellites were used as survey targets in geodetic work.

In 1965 the Geological Survey of Canada sent out a field force of 110 full-time and 36 short-term survey parties. Several operations—involving areas of over 200,000 square miles—were supported by helicopter; and, thanks to the ingenious use of aircraft, the Survey expects to complete its geological reconnaissance of Canada within the next few years. A measure of the demand for geological information is the fact that in 1965 the Survey provided over 310,000 copies of maps and reports.

At the same time geologists gave greater attention to more detailed investigations and to the development of new avenues of geological research. Special projects called for palaeomagnetic studies under way in western Quebec, studies of microfossils in Precambrian iron-formations, geophysical surveys to aid the search for water in the Prairies, the development of a continuously recording magnetometer and research in geochemical prospecting. These were a few in a broad spectrum of projects designed, in one way or another, to spur the discovery and development of Canada's mineral and other resources.

The department's Geographical Branch is involved in studies of the natural landscape and man's impact upon it. Of particular significance was the Branch's work in the Arctic; and its land-use mapping, urban surveys and port studies. Many of the projects under way in 1965 were undertaken at the request of other federal agencies. In Ottawa geographers were producing a new desk-sized Atlas of Canada with publication scheduled for 1967.

Meanwhile, the Branch was instrumental in forming the National Advisory Committee on Geographical Research. The new organization will foster a national approach in geographical research and promote optimum use of talent and facilities in this field.

The department's Observatories Branch carried out an airborne magnetic survey over the northern Atlantic region from Hudson Bay to Finland, and enlarged and improved its network of seismological observatories across the country. Near Penticton, B.C. the Dominion Radio Astrophysical Observatory brought into operation the final segments of the T-shaped radio telescope. The completed instrument stretched across some 16 acres.

Preparations for the new Queen Elizabeth II telescope continued: in 1965 the Observatories Branch placed the order for the giant, 150-inch mirror and worked on the mechanical design. The telescope will be located on Mount Kobau in south-central British Columbia.

Mines Branch research involved the entire spectrum of metals, industrial minerals and fuels, and application and use of the processed products. The year's program included projects of importance to producers of iron and steel, uranium, lead and zinc and products thereof. Other projects were designed to advance the technology of oil and gas and to promote greater use of maritime and western coal. The Branch also sought to improve mining techniques and to overcome problems associated with underground work—a program furthered greatly by the establishment of a rock-mechanics laboratory at Elliot Lake.

Departmental responsibilities in the realm of oceanography and hydrography, shouldered by the Marine Sciences Branch, were carried out with the help of 11 ships, 57 sounding launches, 80 smaller craft and three helicopters. Involved were waters of the Pacific coast, the Western Arctic and inland British Columbia; the Great Lakes, Georgian Bay and the St. Lawrence River; the Western Atlantic, the Eastern Arctic and Hudson Bay.

The Bedford Institute of Oceanography, the staff of which has increased sevenfold since it opened its doors in July 1962, undertook some sixty projects. Most of these called for the application of the physical sciences and engineering to oceanographic research problems; but some were in the realm of applied research, instrument design and development. Equally important were the hydrographic surveys leading to the production of marine charts.

Towards the end of the year the department established a new branch bringing together various programs in the field of water research. The new organization investigates the physics and chemistry of continental waters. Its fields of interest are ground-water, lake-water and areas of glaciology that deal with the effect of melt-water on the hydrology of rivers. The branch also maintains continuous records of water levels of the St. Lawrence River and the Great Lakes.

The Polar Continental Shelf Project continued to serve as a vehicle for departmental research and that of other agencies in the Arctic archipelago and the Arctic ocean. In 1965 a field force of 90 scientists and support staff undertook investigations in marine and terrestrial geology, geomagnetism, geomorphology, glaciology, gravity, seismology, hydrography, and other fields. Their operations ranged from the northern tip of Ellesmere Island to Queen Maud Gulf with the main base located at Mould Bay on Prince Patrick Island.

Several departmental publications in various stages of preparation were destined to "tie-in" with the 1967 centennial. Under way was a history of surveying in Canada ("Men and Meridians"); a new edition of the Geology and Economic Minerals of Canada; the desk-size descriptive Atlas of Canada and a companion volume with Gazetteer; and a comprehensive multi-authored volume on Hudson Bay.

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 vehicle through which the researches and surveys of other government agencies are carried out in the Arctic archipelago and 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.

In 1965 the field operations of the Polar Continental Shelf Project ranged widely over the archipelago, from Alert in the north to Queen Maud Gulf adjacent to the mainland in the south. The main base of operations was at Mould Bay, on Prince Patrick Island, with smaller semi-permanent establishments at six other locations within the islands. About 90 persons were engaged in the field work, which involved five branches of the Department of Mines and Technical Surveys, four other government departments, and six Canadian and foreign universities.

Some of the principal features of the 1965 program were:

Marine Geology.—Bottom sampling (piston coring) of the continental shelf and continental slope offshore from Prince Patrick Island continued as part of the Geological Survey of Canada's long-term study of Arctic marine sedimentary processes and continental shelf and inshore sedimentary deposits.

Terrestrial Geology.—Logistic support was provided where appropriate to Geological Survey of Canada parties in Ellesmere Island, and to university groups working on Somerset Island and Victoria Island.

Geomagnetism.—Field tests were made of newly developed geomagnetic and magnetotelluric equipment, in preparation for future experiments to study variations in magnetic conductivity of certain parts of the archipelago. In other experiments the rate of progress of standard chemical reactions at various geomagnetic latitudes was studied.

Geomorphology and Periglacial Studies.—A study was made of the nature and development of selected periglacial features on the Arctic coastal plain, including pingo-like mounds, suspected sand dunes, compound deltas, and various features associated with the relative change of sea level in an area of permafrost and seasonal Arctic streams. The land forms so produced are being compared with fossil land forms believed to be of similar origin, formed in connection with former ice ages in areas that are now temperate. A companion study has attempted a quantitative assessment of mass wastage in a high Arctic environment, with measurement of soil movement and its relation to precipitation, temperature, soil composition, site geometry, and climatic cycle.

Glaciology.—A core drill was driven completely through Meighen Icecap at its apparently thickest part, and preliminary measurements made toward determining the thermal profile and ice plasticity. Accumulation, ablation, and movement measurements continued on the Meighen and Melville Island icecaps. Logistic support was provided for certain university studies on glaciers on Devon and Axel Heiberg islands.

Gravity.—The regional gravity survey continued over the continental shelf and continental slope offshore from Prince Patrick Island, over waters of the archipelago north of Melville Island, and over Somerset and Prince of Wales islands and adjacent regions.

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Heat Flow.—Sea-bottom heat-flow measurements were again obtained in the region around Prince Patrick Island, where anomalously low readings had been obtained in 1964 in a region where, from geomagnetic considerations, there had been some reason to expect higher than normal values. The work in 1965 was directed partly toward determining the reliability of measurements in relatively shallow water.

Historical Studies.—The opportunity was taken to carry out a brief field examination, with local hydrographic and magnetic readings, of an area which may contain the remnants of one of Sir John Franklin's ships, lost in 1848. Some fragments of a vessel were found.

Hydrography.—Hydrographic surveys were continued both on a reconnaissance (1:500,000) scale on the Arctic Ocean and within the western archipelago, and on regular charting scale (1:50,000) in the Cardigan Strait area. The reconnaissance charting was done by spot-sounding through unbroken sea ice, and the regular charting by helicopter-towed echo-sounding methods in areas of open water.

Resistivity.—Measurements were made of the electrical resistivity, in three directions, of a cold, static ice mass, and of the variations of resistivity with time. The variations appear in part to be independent of standard parameters of temperature, pressure, chemical purity, etc.

Sea-Ice Studies.—A systematic aerial survey was carried out of the distribution, break-up, dispersal, movement and reformation of sea ice in the major waterways of the Queen Elizabeth Islands and the adjacent Arctic Ocean. The movement of the ice pack, and of particular components of it such as the floating ice islands, can be followed from year to year.

Seismic Surveys.—A seismic-refraction traverse was undertaken across the west end of the Sverdrup sedimentary basin and the Innuitian fold belt, from Ballantyne Strait across Melville Island to northeastern Victoria Island. Recordings made from the traverse and other seismic experiments showed, in addition to the thickness of the crust and the depth of the sedimentary basin, an apparent directional damping or anisotropism of seismic energy in an area east of Prince Patrick Island roughly coincident with an observed anisotropism of geomagnetic fluctuation.

Topographic and Control Surveys.—Control surveys were run to determine the transmitter positions and the base line for a Decca Lambda chain to cover the western approaches to M'Clure Strait. Other control surveys were run in connection with the glaciological, seismic and hydrographic work.

Miscellaneous.—Other studies carried out by or through the Polar Continental Shelf Project included: a survey of plant and insect life on southern Melville Island; acoustic studies in unbroken polar pack ice over deep water; and collections of fossil dinosaur and recent vertebrate skeletons.

MINERAL RESOURCES DIVISION

Canada's 1965 mineral production increased in value by 10.3 per cent to set a record of $3,737 million up from $3,388 million in 1964, the previous record. The value of output of each of the three sectors of the industry—metals, industrial minerals and mineral fuels—registered increases to new highs, with the metals sector having the strongest advance in both absolute and percentage terms. Capital investment in the mineral industry remained strong at near-peak levels. Plans announced for new and expanded facilities seem to assure that growth in the years ahead will remain at the high rate of recent years. The mineral-industry base continues to broaden both geographically and by commodity. Considerable success in exploration for ore deposits in widely scattered locations was a dominant feature of the mineral industry in 1965. Exports of minerals and mineral products continued to be a strong factor in helping Canada's balance of payments position. Crude and fabricated mineral materials accounted for one third of total Canadian exports in 1965.

The work of the Mineral Resources Division lies mainly in the field of resource-economics, as related to the fast-growing Canadian mineral industry, 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, 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.

To carry out its duties concerning legislation, taxation and administration in the field of mineral resources, the Division is divided into three sections with a supporting administrative section. The three sections are: Research and Special Projects, Materials, and Taxation and Legislation.

General Advisory Activities.—Research continued in many areas of national and international concern on mineral matters for which the Division must prepare government submissions.

By means of basic-resource investigations and economic research, officers of the Division are able to provide advice on a wide variety of mineral matters of national importance and to advise on mineral taxation and legislation. Service rendered by the Division in this field during 1965 included continuing assistance to the Canadian Tariffs and Trade Committee representing Canada at Geneva in discussions relating to the General Agreement on Trade and Tariffs (GATT); an assessment of tin production, consumption, demand, and price in conjunction with work on the Third International Tin Agreement; assistance in standardizing aluminum statistics for correlation and comparison; advice on expected mineral traffic through the St. Lawrence Seaway to 1980; and advice on the supply-demand patterns for lead and zinc in relation to Canada's output and trade.

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.

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Analyses and recommendations were provided to the Department of National Revenue on tax benefits that apply to the mineral industry under the Income Tax Act. Reports were prepared on 27 applications for three-year tax exemptions. Two applications for certification as operators of an industrial mineral mine on a non-bedded deposit were processed.

During the second half of the year, the chief of the Division and a member of the Division's Research and Special Projects Section were seconded to work with Dr. J. R. Donald, Special Consultant on Coal to the Minister of Trade and Commerce, on the Cape Breton coal problem. The assignment was nearing completion by the end of the year.

International Activities.—Officers of the Division presented reports at meetings of several international organizations concerned with minerals and mineral trade. Statements were prepared for other meetings which Division officers did not attend. Meetings in which the Division participated included 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.

Wartime Oils Limited.—Federal government administration of Wartime Oils Limited ended in 1965. Royalty payments from production will continue to be made to the government through the Chief Treasury Officer of the Department.

Foreign Aid Training.—The Division, on behalf of the External Aid Office, arranged 15 technical training programs for foreign trainees and provided consultation on 16 additional applications. This training was sponsored mostly by the Colombo Plan and took place in the Department of Mines and Technical Surveys as well as in private industry. Eighteen trainees completed training programs in 1965. At the end of the year nine trainees were on study courses, and 13 planned programs were awaiting arrival of candidates. Twenty-three foreign students attending 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-development policies and projects.

Publications of the Division.—The Division carries on a continuing publication program which in 1965 included the completion of Mineral Information Bulletins on iron ore, petroleum, and a preliminary report on the industry for 1965; a Mineral Survey on underground mine haulage, and the Minerals Yearbook. Draft manuscripts were completed for a report on uranium, and work proceeded on the preparation of reports on nickel, beryllium, zinc, copper, and manganese. Several papers were prepared on mineral-industry topics for delivery at national and international conferences or for publication in technical journals.

Information Activities.—The Division has a continuing program of educational filmstrips on minerals. During the year, three filmstrips in the Junior Series for elementary schools were completed. The titles are "Learning About Rocks and Minerals", "Life in a Mining Town" and "Mining in Canada". The filmstrip "Learning About Rocks and Minerals" was distributed in a kit with manuals, mineral specimens, test materials, and supplementary literature.

The Division's photographic library and mineral-resource-records centre continued to grow. During the year 82 black-and-white and 53 colour photographs of the Canadian mineral industry were added to the photographic library. Progress was made in cross-referencing the file prints on punch-cards.

The booklet "Entrance Awards for Mineral Industry Courses at Canadian Universities" was updated with the assistance of the Mining Association of Canada, and work proceeded in the Division to prepare copy for printing a new edition.

The 15th edition of the popular map "Principal Mineral Areas of Canada" was issued and work continued on preparation of a pictorial brochure "Mining in Canada".

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 year's end, the Mineral Occurrence Index contained descriptions of over 8,600 mineral showings and deposits.

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 provided for a restriction on the eligibility of lode gold mines commencing production after June 30, 1965. Lode gold mines brought into operation after that date are eligible for assistance only if the mine provides 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 (Mines). 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 that 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 book of account.

The amount of assistance payable to an operator is computed under the current formula 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. The maximum rate of assistance is $12.33 per ounce. Thus a gold mine which has an average cost of production less than $26.50 an ounce is not eligible for payment of assistance.

There were 43 lode gold mines and 24 placer gold mines in receipt of assistance during 1965. Six 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 1965, two hundred and eighteen 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 "
1950— 8,993,490.51 or 2.55 "

1951— 10,728,503.71 or 3.30 per ounce produced
1952— 10,845,978.62 or 3.76 "
1953— 14,680,110.42 or 4.62 "
1954— 16,259,179.23 or 4.29 "
1955— 8,885,478.73 or 2.97 "
1956— 8,667,235.38 or 3.46 "
1957— 9,679,753.32 or 3.53 "
1958— 11,420,463.70 or 4.29 "
1959— 12,001,753.43 or 4.91 "
1960— 12,362,517.59 or 4.86 "
1961— 12,666,658.77 or 5.19 "
1962— 14,389,049.55 or 6.07 "
1963— 14,397,419.04 or 5.53 "
1964— 14,692,139.79 or 5.65 "
1965— 9,758,435.28 not available.

EXPLOSIVES DIVISION

The Explosives Division has been active since 1920 when the Explosives Act was introduced as an instrument of public safety to control explosives manufacture, sale, storage, importation and transportation by road.

The output of commercial blasting explosives in licensed factories has doubled in the past four years from 145,000,000 pounds in 1961 to 290,000,000 pounds in 1965. This figure does not include an estimated 50,000,000 pounds of ammonium-nitrate-fuel-oil blasting agents which are blended on a "do-it-yourself" basis on mining property.

Blasting explosives are divided into three main categories:

(a) Nitroglycerine dynamites

(b) Ammonium-nitrate-fuel-oil mixes (AN/FO's)

(c) Slurry explosives.

Until 1957 nitroglycerine dynamites accounted for more than 90 per cent of total explosives production. Today they account for approximately 35 per cent only, with most production confined to the AN/FO's and slurries.

There are 26 factories licensed under the Act for the manufacture of explosives, as follows:

Military explosives and pyrotechnics	3
Fireworks	3
Commercial ammunition	5
Blasting explosives for sale	11
Blasting explosives for private use	4

Among the manufactures for private use are four mobile slurry-mix pump trucks operating on mining properties in Ontario and Quebec. This is a fairly new development in explosives manufacture. It is suited for large open-pit mines where wetness precludes the use of AN/FO or where explosives with more energy are required.

There were 1,600 licenses issued for the storage of explosives and 385 permits for the transportation of explosives by road. Experience with totally enclosed vans for the transportation of explosives has been very satisfactory. There have been no incidents of fire since this requirement was instituted two years ago.

During the year there were eight fatalities in the use of explosives compared with 12 in 1964.

There were two fatalities in manufacture when a dynamite mix-house was destroyed by a blast of unknown origin in September. The blast communicated through the nitroglycerine transmission lines to a nitroglycerine storage building.

There were 46 prosecutions under the Act, 37 for illegal storage and nine for violation of transportation regulations.

The Division publishes a separate and more detailed annual report which is available on request.

Surveys and Mapping Branch

The Surveys and Mapping Branch continued its accelerated mapping program in 1965 and intensified its research and foreign aid. The joint Canadian-American expedition on Mount Kennedy and the coordinated efforts of survey organizations from both countries on the Satellite Triangulation program marked yet another milestone in international cooperation between survey organizations.

The Geodetic Survey had nineteen parties in the field. The Topographical Survey kept pace with the plan to complete map coverage of Canada at 1 : 250,000 scale by 1967. The Legal Surveys and Aeronautical Charts Division published three new series of charts, maintained its legal-survey commitments on Indian reserves and National Parks and worked closely with the Representation Commissioner in reviewing descriptions of adjusted federal electoral-district boundaries. Map Compilation and Reproduction increased map production over 1964 and had two organizational changes, with the Air Photo Production Unit being transferred in from the Division of Administration, and the Map Distribution Office being transferred from the Division to Branch Administration.

The Interdepartmental Committee on Air Surveys carried out air-survey photography in all provinces and in both territories of Canada to meet the requirements of nine federal departments. Experiments in colour photography continued as demands for this type of photography increased. The committee published a complete report on the 1963 Seminar on Air Photography Interpretation.

The International Boundary Commission had three parties in the field working on boundary maintenance.

The Map Distribution Office processed 50,852 requests for maps totalling 1,236,219 maps, an increase of 19 per cent over 1964, with a revenue of $258,757.

The National Air Photo Library received 71,171 current survey photos, bringing the total library collection to well over three million.

During the year, 5,725 requisitions for a record 554,867 prints from air-survey negatives were processed.

In a program designed to preserve a pictorial history of Canada for the period 1920–40, more than 800,000 air-photo prints will be copied on 70-mm film. To date more than 200,000 prints have been completed.

The Saskatchewan Department of Forestry requested the library to store its present and future negatives. Some 200 rolls were received in 1965.

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

A national Advisory Committee on Control Surveys and Mapping was established by Order-in-Council late in 1964 with the Branch Director as chairman, the membership to consist of representatives from other federal departments, provincial departments, universities and industry. Members were appointed by the Minister of

Mines and Technical Surveys during 1965. The first meeting was held in Ottawa in October 1965. It is hoped that the recommendations of this committee will be of material assistance to the department and the government in determining its surveying and mapping policies.

The Branch established a foreign-aid section which functions as liaison staff with the External Aid Office in connection with survey projects in foreign countries. Two field engineers were engaged in an aerodist control survey in Nigeria and Tanzania and one engineer carried out a reconnaissance for a control-survey project in Trinidad and Tobago. Students from Africa and the West Indies were trained in Ottawa in the various activities of the Branch.

The Branch organized a research and development section to coordinate research, training and development in the various divisions.

Senior Branch officials represented Canada at a number of international meetings and seminars, including the Guatemala Congress of the Pan-American Institute of Geography and History, the Fédération Internationale Géométrique in Rome, a symposium on electronic distance measurements at Oxford, England, the International Association of Geodesy Symposium on Mathematical Geodesy in Turin, Italy, and the International Symposium on the use of Artificial Satellites for Geodesy in Athens.

During the year there were 18 major tours through the Branch by students, teachers, military personnel, members of Parliament, a number of town planners and visitors from the United States, Mexico and South America.

GEODETIC SURVEY

Seventeen field parties extended horizontal and vertical control, which provides a national framework for mapping, charting and major engineering projects. In addition, the Survey participated in two cooperative Canadian-United States projects—the Mount Kennedy survey and the Satellite Triangulation Program—and continued work on several investigational projects.

The extension of the network of first-order horizontal control was carried on in the Yukon Territory, the Northwest Territories and six provinces. In the Yukon a joint Canadian-United States party established a first-order traverse connecting existing surveys near Kluane Lake, Y.T., to similar surveys at Yakutat Bay, Alaska. In the course of the survey the position and elevation of Mount Kennedy were determined. In the Northwest Territories the triangulation arc which had reached Rankin Inlet from the west in 1963 was extended south to the 60th parallel. The Survey cooperated with the Topographical Survey in the establishment of two first-order aerodist networks which connect the Quebec mainland to Baffin Island to the north and to Southampton Island to the west.

In the western provinces, triangulation arcs were established from Fort Nelson, B.C., to Meander River, Alberta; in the Okanagan Valley from the international boundary to Salmon Arm; from the international boundary through Lethbridge to the vicinity of Calgary; and from the vicinity of Medicine Hat to Alaska. The Okanagan Valley work was done with the cooperation of the province of British Columbia, and in the course of this survey position and azimuth control were established for the Observatories Branch's radio telescope at White Lake and for the Queen Elizabeth II Observatory on Kobau Mountain. Municipal control was also established at Lethbridge and Medicine Hat and in metropolitan Winnipeg. Near Calgary, a connection was made to the site of the proposed Observatories Branch's photographic zenith telescope at Priddis.

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In the eastern provinces a triangulation arc was extended from Payne Bay to Sugluk in northern Quebec, and a network intended for the study of crustal movement was established straddling the St. Lawrence River from Isle d'Orleans to Tadoussac. Reconnaissance was carried out for municipal surveys in Greater Ottawa, North Bay, Brampton, Galt, Guelph, Kitchener-Waterloo and the Halifax-Dartmouth area and for an arc extending from Halifax towards Guysborough.

The Canadian-United States Satellite Triangulation Program continued operations at Whitehorse, Cambridge Bay, and Lynn Lake until mid-March when the stations were closed for the summer. In June five new sites were located in eastern Canada, at Timmins, Ontario; Halifax (Shearwater), Nova Scotia; St. John's, Newfoundland; Goose Bay, Labrador; and Frobisher Bay, N.W.T. In August and September the five new stations together with the stations at Lynn Lake and Cambridge Bay were occupied and remained active for the balance of the year. Personnel from Surveys and Mapping Branch and from the Army Survey Establishment, Department of National Defence, were trained at Beltsville, Maryland, and assisted in the operations at St. John's, Goose Bay, Frobisher and Cambridge Bay.

A geodimeter party, using both Model 4D and Model 6 instruments, measured four lines in the "crustal movement" network on the St. Lawrence and all lines in the metropolitan Winnipeg network. A number of short lines were measured in the Okanagan Valley arc, the arc through Lethbridge, and at Medicine Hat. The party also measured six lines in the arc of old triangulation from Calgary to Edmonton.

Precise levelling operations were carried out in six of the provinces, and an inspection party inspected 1,571 bench marks in southern Ontario. A winter party levelled from Mile 100 on the Athabasca River to Fort McMurray in Alberta. During the normal field season, lines were run from Fort St. John, B.C., to Clear Prairie, Alberta; from Grand Prairie to Bezanson, Bezanson to Hinton and Hinton to Nordegg in Alberta; from Prairie River to Prince Albert and from Melfort to Choiceland, Saskatchewan; from Smeaton, Saskatchewan, to Flin Flon, Manitoba; along the north shore of Lake Erie, Ontario; from Pointe Claire to Isle Bizard, from Beaupre to St. Tite des Caps, from Richmond to Baieville, in Quebec; and from Fredericton to Hardwood Ridge, Fredericton to Saint John, Saint John to Rothesay, and MacAdam to St. Croix, in New Brunswick. In addition, levels were run in the vicinity of the South Saskatchewan River dam, in the city of Regina, in the area between Toronto and Hamilton in Ontario, and in the Chicoutimi area of Quebec.

Regarding astonomic work, four Laplace azimuth stations were established to control triangulation networks, one in the Northwest Territories, one in British Columbia and two in Quebec; and, in addition, the precise astronomic latitude and longitude of 36 triangulation stations were determined for investigational purposes, at five points in the Northwest Territories, 19 points in British Columbia and 12 points in New Brunswick.

A precise astronomic latitude determination was made at the proposed site of the zenith telescope at Priddis, Alberta, and an azimuth determination was made at Lake Traverse in Algonquin Park, Ontario, to lay out an east-west line required by the National Research Council in connection with its radio telescope. A new system of determining and recording time has been developed using a crystal clock and printing chronograph in conjunction with a radio time-signal receiver; a prototype unit has been built.

During the field season a technician and two technological institute students, specially trained in the maintenance of electronic equipment, worked with triangulation parties. In the laboratory the development and improvement of electronic and radio equipment was continued. The laboratory is handling the maintenance and repair of all divisional electronic and radio equipment and also does some work for other divisions of the Branch.

During the year the Survey continued its interest in international geodetic organizations. Staff members attended several meetings and seminars in Canada and the United States. One member attended the Symposium on Electronic Distance Measurement at Oxford, England, in September.

TOPOGRAPHICAL SURVEY

The Topographical Survey in 1965 enjoyed a year of normal operations and cleared a record amount of mapping for final reproduction. Covering more than 292,000 square miles, production consisted of 30, 367 and 61 maps at the 1:25,000, 1:50,000 and 1:250,000 scales respectively.

Compilation of mapping at the 1:250,000 scale was less than for the record year of 1964 because of the more rugged terrain being encountered in the northern arctic islands. Production of 1:50,000 mapping, however, was maintained at the 1964 level despite the heavy cultural detail being met with in the revision program. Output of 1:25,000 mapping increased by 50 per cent over 1964.

The goal of completing map coverage of Canada at the 1:250,000 scale in 1967 appears attainable. Coordinated programs of the Topographical Survey and Map Compilation and Reproduction divisions and Army Survey Establishment of National Defence have produced 814 of the 925 maps required.

The aerodist system was successfully used for the fourth field season in a joint Topographical-Geodetic Survey operation carrying geodetic control across wide expanses of water in Hudson Bay and Hudson Strait.

Officers of the field staff assisted in setting up and observing from satellite triangulation stations at Cambridge Bay, N.W.T., Lynn Lake, Man., and St. John's, Nfld. Other field officers participated in External Aid foreign mapping projects.

Thirty-seven field officers and some office staff carried out surveys in all parts of Canada except Newfoundland.

In a joint operation, Topographical and Geodetic survey crews projected nets of trilateration by means of the aerodist system from Ungava to Southampton and Baffin islands as links in the geodetic system of first-order control. The coordination was extended to securing supplementary control for 1:50,000 mapping around Deception Bay and for 1:250,000 mapping of the intervening islands.

A second major party obtained supplementary control for 1:50,000 revision mapping of thirty sheets in the foothills of southern Alberta and then moved to the Yukon to secure control for detailed mapping of 17,500 square miles in the mining district north of Mayo. A smaller air-supported party obtained control for 1:50,000 mapping of 7,000 square miles around the Baffinland iron prospect on Baffin Island.

Field work for other 1:50,000 revision mapping was carried on for 75 sheets in the Eastern Townships of Quebec and 12 sheets in the vicinity of Madoc.

Control for 1:25,000 mapping was established for one sheet each at Saint John and Fredericton, N.B.; five sheets along the Richelieu River in Quebec; 24 sheets in the Kitchener-Brantford area; four sheets at Fort William-Port Arthur, Ont.; and one sheet each at Kenora, Ont., Brandon, Man., and Red Deer, Alberta.

Various field parties assisted municipalities in the establishment of coordinate municipal control in Charlottetown and Summerside, P.E.I.; Burlington, Oakville, South Toronto Twp., Ottawa, North Bay and Kenora, Ont.; Winnipeg, Man.; and prepared for similar surveys in Halifax and Dartmouth, N.S. More than 750 permanent monuments were established for use in controlling municipal surveys.

Extension of control for expected 1:50,000 revision mapping was continued by tellurometer traversing east of Red Deer, Alberta and by spirit levelling along the South Saskatchewan River. Field inspection of completed compilations was performed

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for 20 maps at the 1:25,000 scale and 24 sheets of revised 1:50,000 mapping. Two winter parties extended spirit-level control for water-resource studies in Quebec and Manitoba.

Special projects consisted of assistance to the Polar Shelf Project, the Observatories' gravity program and Defence Research Board's glaciological research; positioning of 71 radio aids to navigation for the Department of Transport; and surveys for large-scale plots of seven settlements for Northern Affairs. Two field officers established aerodist control for External Aid mapping in Tanzania and two other officers did a reconnaissance for proposed mapping in Trinidad.

The computing and control subsection made good use of the allotted time of 125 hours on the Departmental IBM 1620 computer in computation of field-survey data for mapping, resolution of coordinate surveys for seven municipal areas and resolution of the complex aerodist field records. Processing of airborne-profile records supplied the vertical control required for mapping and aerodist computations. Survey control data from more than 100,000 cards on file with this subsection were supplied on request to various survey agencies across Canada.

Emphasis in compilation continued to be on 1:250,000 mapping but important advances were made in revision of 1:50,000 mapping and continued production of 1:25,000 mapping. Within two years, a large part of compilation capacity now devoted to the reconnaissance scale will be diverted to attacking the back-log of new and revised 1:50,000 mapping that has accumulated in the past five years. Plans are in effect to have equipment and programs in readiness for the change in accent: rotation of supervisory staff to familiarize them with improved techniques and new programs is a part of these plans.

Numerical adjustment of aerial triangulation with the aid of the electronic computer has become standard procedure for all detailed mapping. The adjustment by computer of subsidiary control greatly facilitates compilation processes.

In September 1965, the editing unit was integrated with the air-survey section to afford more efficient control over work flow from start of compilation to clearance from the division. The field-survey section was given responsibility for inspection and field completion of compilations subject to that technique. The Topographical Survey continued the inspection of aerial photography carried out by contract for the federal government and recommended payment for acceptable work.

Special plotting projects, numbering 28, were undertaken for the Observatories Branch, Geographical Branch, Geological Survey of Canada, and Marine Sciences Branch of this Department; for the departments of Agriculture, Northern Affairs and National Resources, Public Works, and Transport; and for Atomic Energy of Canada and the Polar Shelf Project.

The technical-assistance unit employed two senior officers and three staff members full time, two field officers for several months in Nigeria and Tanzania and two officers on a feasibility study of mapping in Trinidad and Tobago. Besides supplying technical advice to other departments, the main function of this unit is to handle specifications and contracts for aerial photography and mapping under the U.N. Colombo Plan, Special Commonwealth Aid to Africa Plan, and the Commonwealth Caribbean Assistance Program. In this respect, the staff assisted in negotiating contracts for extensive topographic mapping in Nigeria and Tanzania and for photography, field surveys, and mapping in Trinidad.

Distribution of advance information prints of new mapping many months in advance of normal publication continued and is a service greatly appreciated by resource-development agencies.

Among the principal items of equipment purchased during the year were three Wild B-8 plotters, 14 Balplex projectors, three tracing tables and nine pantographs to modernize the compilation capacity of the division, and an EK5A coordinate printer and an IBM summary card punch to assist numerical adjustment procedures.

LEGAL SURVEYS AND AERONAUTICAL CHARTS

In accordance with the Representation Commissioner Act, the division cooperated with the Representation Commissioner and reviewed descriptions of the readjusted federal electoral-district boundaries. Preparation was started for legislation to ratify the north boundaries of Manitoba and Saskatchewan, and the northern part of the boundary between Manitoba and Saskatchewan. Legal surveys in Indian reserves, National Parks and territorial lands were undertaken as usual, and aeronautical charting continued to be one of the Division's most active fields of mapping.

Five interprovincial and territorial boundary commissions were active in 1965. In addition to the work mentioned above, preparation of the report for the north boundary of British Columbia was continued, and the reports and atlases for the north boundary of Manitoba and the northern part of the boundary between Manitoba and Saskatchewan were completed. Surveys to complete the demarcation of the unsurveyed portions of the Manitoba-Saskatchewan boundary were begun, and the inspection and restoration of the north boundary of Alberta was completed.

Eighteen field parties were engaged on legal surveys in the public lands of Canada for federal government departments. In addition, instructions were issued for 109 legal surveys on Crown Canada lands for private and provincial agencies. Of the 58 Indian-reserve projects completed, the largest were the identification and targeting of 6,000 lot corners for a legal survey by photogrammetric methods of the 50,000-acre Six Nations Reserve near Brantford, and the survey of a new 27,000-acre reserve in northern Saskatchewan. The retracement of 21 miles of Cape Breton Highlands National Park boundary, a control and integrated survey of Field townsite in Yoho National Park, and the survey of eight new historic sites were the main projects for the National Parks Branch. In the Northwest Territories, subdivisions for administrative staff and Eskimo settlement were surveyed at Holman on Victoria Island and at Eskimo Point, Whale Cove and Coral Harbour in the eastern Arctic.

In aeronautical charting, three new series of charts were published in addition to extensions to existing series. To meet the ever expanding needs of the aviation industry, and to make aeronautical charts more readily available, 112 firms were appointed as dealers authorized to sell aeronautical charts. For the most part these dealers are at airports throughout the country.

Survey documents in the Canada Lands Surveys Records numbered 573 plans and 74 field note books. About 26,500 document extracts, publications and astronomical field tables were despatched. Nine meetings were held by the Board of Examiners and examinations were written by 55 candidates. Of these, ten qualified for certificate of preliminary examination and three for a commission.

MAP COMPILATION AND REPRODUCTION

Map and chart production during 1965 was slightly higher than in the preceding year.

There were two major organizational changes: The Map Distribution Office, formerly a part of this division, was placed directly under the administration of the Branch; and the division acquired the Air Photo Production Unit, which had been temporarily under the departmental administration. Thus the division lost 14 and gained 69 employees. Its staff at the end of the year stood at 330.

The conversion of the eight-mile map series to the scale of 1:500,000 was 82 per cent complete, with 180 maps. The status of the 1:50,000 series stood at 27 per cent published, or 5,892 sheets of a planned 21,788. In the 1:250,000 series, 71 per cent of the maps were published, or 661 of a planned 928.

Maps received from the Topographical Survey for reproduction numbered 507. These consisted of 42 maps at a scale of 1:25,000; 406 maps at 1:50,000; and 59 maps at 1:250,000.

Maps received from the Army Survey Establishment for reproduction numbered 27. Of these, 8 were at a scale of 1:25,000, 11 at the scale of 1:50,000, and 8 at 1:250,000.

The number of maps and charts printed came to 4,248, compared with 4,147 for 1964. Of the total, 2,093 maps were printed on the large offset presses and 2,155 on multilith.

The total stock of maps reached 11,529,944.

Among the major special projects were the following:

—The annual revision of the National Capital Commission map of Ottawa and environs.

—A revision of the Map of Canada at 64 miles to the inch.

—A new map of Gatineau Park.

—A highway map of Canada and the northern United States for the Government Travel Bureau.

—A set of maps illustrating proposed federal electoral districts under the Electoral Boundaries Readjustment Act.

During the year, the work of the newly incorporated Air Photo Production Unit increased in both scope and output. New functions included a colour section; copying of National Air Photo Library prints from nitrate negatives on 70-mm film; inspection of film from air surveys for the Interdepartmental Committee on Air Surveys; the production of one positive and two negatives from glass negatives of the International Boundary Commission; the printing of National Air Photo Library copies of current survey negatives; the annotation and filing of 202 rolls of air film flown by the government of Saskatchewan; and a special-projects section handling miscellaneous ground photography.

INTERNATIONAL BOUNDARY COMMISSION

Three Canadian field parties were engaged in maintenance operations along widely scattered sections of the International Boundary. Field parties from the United States section of the Commission did similar work.

One Canadian field party worked on the Quebec-Maine boundary. Monuments were inspected and repaired and the boundary vista was recleared and chemically treated to a skyline width of 20 feet for 18 miles on the Highlands boundary. Survey lines were recleared between reference monuments on the southwest branch of the St. John River and measurements were made with geodimeter to give more accurate positions for monuments on the Quebec-Vermont boundary.

A second party was engaged in re-surveys along the St. Clair and Detroit rivers. New reference monuments and triangulation stations were established to replace those lost due to erosion and Seaway construction.

A third party, on the British Columbia-Washington boundary, inspected monuments and recleared and chemically treated 26 miles of boundary vista through the Fraser Valley and at Point Roberts. Further tests were made of herbicides applied by helicopter to control growth along the British Columbia boundary.

An officer from the Canadian section was one of two Canadians who assisted the United States Coast and Geodetic Survey on an expedition to establish precise control in the Mount Kennedy area. A survey was also carried out in Pearse Canal, southeast Alaska, to establish the location of a small island near the International Boundary line.

The United States Commissioner and the Canadian Commissioner made a joint inspection of boundary conditions and of the work of the various field parties.

Marine Sciences Branch

The Marine Sciences Branch carries out research and surveys of coastal and of oceanic waters adjacent to Canada. As an extension of its charting role, the Canadian Hydrographic Service, a division of the Branch, produces nautical charts and associate publications of Canadian inland navigable waterways.

The field operations of the Branch are carried out in three regional organizations: Western, Central and Eastern. Certain specialized activities, such as chart production, tidal analysis and research, are undertaken at Branch headquarters, Ottawa.

Ship Division

The Branch's fleet in 1965 totalled 11 ships, 57 sounding launches, 80 smaller craft and had a complement of 472 officers and crew. Two Bell helicopters, owned by the Department, one Hiller helicopter chartered for six months and two chartered vessels, M/V *Theron* and M/V *Theta,* were used in support roles.

The east-coast program of survey was seriously interrupted by a lengthy and heavy repair on the main engine gear clutches of CSS *Baffin.* CSS *Cartier* was declared beyond economical maintenance and operation, and arrangements were initiated for disposal.

The designs and specifications for two new tidal and current vessels were completed, tenders called and contracts awarded. Construction is to begin early in 1966.

Designs and specifications for a replacement vessel for CSS *Ehkoli* were completed and tenders received for construction.

Design and specifications for a new ship for research in the Great Lakes are nearly completed. Construction will begin late in the summer of 1966 and the vessel will be commissioned in time for operation during the 1967 season.

WESTERN REGION

The Western Region includes the Pacific Coast of Canada, the Western Arctic and the inland waters of British Columbia. At present the work of the Branch in this region is concentrated on hydrographic surveys. Development of extensive oceanographic research has been deferred temporarily in favour of emphasis on Great Lakes research which is required by the increasing pollution in those waters.

Hydrographic Surveys

CSS *Wm. J. Stewart* completed a survey between William Head and Otter Point in Juan de Fuca Strait, and commenced a survey of approaches to Nanaimo Harbour.

CSS *Marabell* completed surveys in Oak Bay and East Point areas and special surveys at the entrance to Quatsino Sound and in Ballenas Islands vicinity to meet requirements of the Royal Canadian Navy.

Conventional hydrographic surveys were carried out in the Chatham Sound area by CSS *Wm. J. Stewart* and in the Observatory Inlet area by CSS *Marabell*. These contributed to the general charting program.

The area of operation of CSS *Richardson* was from Tuktoyaktuk to Coppermine. Sounding continued between Pullen Island and Warren Point, using transponder beacons. Control was extended eastward to Liverpool Bay by tellurometer, and detailed surveys of Coppermine approaches were carried out.

Tidal Current Projects

A synoptic survey of tidal currents in the Gulf Islands area is under way. The compiled data will be used for a current atlas covering the area from Juan de Fuca Strait to Georgia Strait. Haro Strait and adjacent passages were surveyed in 1965.

Current surveys contributing to a current atlas for the area Discovery Passage to Cordero Channel continued in 1965, with observations concentrated near Yuculta Rapids.

Current surveys were carried out in Vancouver harbour near major wharves to aid in ship docking and to assist in planning new port facilities.

Oceanographic Projects

CSS *Ehkoli* was operated by the Branch in support of the Institute of Oceanography at the University of British Columbia. The vessel was also used on occasion for scientific studies by the Pacific Biological Station, Nanaimo, the Technological Research Laboratory, Department of Fisheries, Vancouver, and by the Departments of Botany and Zoology at the University of Victoria.

The Canadian Hydrographic Service cooperated with several other federal and provincial government agencies in an oceanographical survey in the waters between Race Rocks and Trial Island, south of the greater Victoria area. The service was also involved in the planning, directing, operating and analyzing of the survey which was designed to provide information on current and drift patterns for the guidance of the British Columbia Pollution Control Board, Department of Lands, Forests and Water Resources.

Mooring tests are being conducted off the west coast of Vancouver Island preparatory to continuous monitoring of sea-temperature variations.

CENTRAL REGION

This region continued its main activities in hydrographic charting and water-level gauging. With the acquisition of office trailers and small fast sounding vehicles, a trend towards development of highly mobile and flexible operational units was established. One helicopter was used by several parties for control work, chart revision and the location of shoals.

Charting Activities

CSS *Cartier*, serving her last year on hydrographic operations, carried out detailed surveys at the eastern end of Lake Erie. Long Point Bay was charted at a large scale for small-boat charts. The approaches to Port Colborne and the Welland Canal were re-charted, and a new survey completed of Port Dover.

A shore-based party, operating from Fort Frances, commenced a semi-controlled survey of Rainy Lake in northwestern Ontario. This project was partly completed, the work to be finished in 1967.

The survey commenced in the St. Lawrence River in 1964 was continued and completed in 1965 from Neuville to the Quebec Bridge. Small projects were carried out in Quebec City, Three Rivers and Montreal.

This year marked the commencement of a major small-boat charting project to provide detailed large-scale small-boat charts of the complete Trent-Severn canal system. The survey started at Port Severn on Georgian Bay and was carried through to the western end of Balsam Lake. Expected completion date of this continuing survey is 1967. This party also conducted a revisory survey of the existing chart of Lake Simcoe.

Three hydrographers were placed aboard the Department of Transport vessels *Macdonald* and *d'Iberville* and conducted minor surveys at Resolute Bay and Sherwood Head in the eastern Arctic. The primary area of survey was Milne Inlet, at the north end of Baffin Island, of special interest to the mining industry.

Tides and Water Levels

This group carried out the annual inspection and maintenance of 82 permanent tidal and water-level recorders, established at 79 locations in the Great Lakes, the St. Lawrence and Ottawa rivers, and the eastern Arctic. Five permanent gauging stations were reconstructed and three temporary installations made.

Limnological Studies

The regional hydrographer was assigned the responsibility for field operations in support of limnological studies in the Great Lakes, to commence in 1966. During 1965 preparations were under way for the purchase of equipment and for the detailed planning of this extensive operation.

EASTERN REGION

Operations in the Eastern Region centre on the Bedford Institute of Oceanography and involve coordinated studies of the hydrography of the western Atlantic and of the eastern Arctic.

The Bedford Institute of Oceanography opened its doors in July 1962 with a nucleus laboratory staff of 34 persons, 14 of whom comprised the Atlantic Oceanographic Group of the Fisheries Research Board. In a little over three years the staff has increased sevenfold, and a broad and active oceanographic research and survey program has come into being. During the first two years, as key scientific and survey personnel arrived, the main features of the work in the Institute took shape; its broad objectives have remained largely unchanged to date. As new staff joined, attention was focused on strengthening projects rather than launching new undertakings.

The general framework is the oceanographic application of the physical sciences and engineering to activities ranging from long-term phenomenological research, through applied research and instrument design and development, to surveys required in the production of marine charts. Within this framework some 60 projects were in hand during the year. It is only possible to remark on a few.

Oceanographic Research

The *air-sea-interaction group* carried out laboratory and field trials of breadboard equipment for the measurement of wind stress on the sea surface. The result justifies the development of rugged and reliable instrumentation, including the stable platform, to permit extended and unattended observations in open waters. Work on this vital objective is under way. The measurement at the air-sea interface of energy exchanges, of which wind stress is only one, is considered fundamental to a quantitative interpretation of the interdependence of atmosphere and ocean.

The *frozen-sea group* has a similar basic objective, except that the interface includes an ice sheet. Extensive and unique data on heat flow and temperature profiles in sea ice at Cambridge Bay were obtained, and data analysis is well in hand. Investigations of the behaviour of the water column beneath the ice was commenced, and this vital facet of the over-all problem is to receive major attention in the March-April 1966 field work.

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In *physical oceanography* an extensive network of stations was occupied in the Labrador Sea, Davis Strait and Baffin Bay which should add significantly to knowledge of the composition, movements and source of the deep waters in these areas.

An operation in the estuary of the St. Lawrence successfully carried out a sequence of truly synoptic oceanographic observations. Seven strings of water bottles with thermometers were moored on each of eleven days in the same cross-section of the estuary and set to trip simultaneously with an eighth station which was observed from the ship. Eighteen current meters were also moored in the section. The mooring and tripping system for this complex array was developed in the Bedford Institute. Results of the analysis of the data are awaited with interest for the light they should throw on the circulation in this area and on the usefulness of the geostrophic approximation in coastal waters.

The *marine geophysics group* forged ahead on several fronts of which the mid-Atlantic Ridge survey was perhaps the most outstanding. It employed a sophisticated data-logging system, GEODAL, developed by the engineering services section. The system permitted not only on-the-spot program adjustment in the light of incoming data but greatly reduced the time required for data processing. A good series of detailed maps and analyses resulted from a 20 X 60-mile section of the ridge centred at latitude 45°35′N and longitude 27°30′W covering bathymetry as well as gravity and magnetic anomalies. Models of the structure of the ridge have been tested by these data, and the results have added to an understanding of the processes at work in producing the vast mountain range and its remarkable rift valley.

The *marine geology group*, seconded from the Geological Survey of Canada, was engaged in many projects extending from the high Arctic to the southern waters of Nova Scotia, chief among which was the Hudson Bay operation. It was a large-scale multi-discipline survey aimed principally at delineating the basic geological and geophysical features of the Bay. Under the head of the marine geology section, who was scientist-in-charge, a very complex and comprehensive program of observations was completed as scheduled by teams from six universities, four branches of the Department, several other governmental agencies and with collaboration by six industrial concerns, using four ships, several launches, a ship-based helicopter and an RCAF North Star aircraft. The enormous amount of data collected from more than 30,000 miles of ship tracks, 25,000 miles of flying and some 900 stations, as well as by other means, will be the basis of many studies and papers.

Hydrographic Surveys

Hydrographers from the Bedford Institute made up nine field parties, most of which carried out two or more projects. Some highlights are mentioned.

The eastern part of Chaleur Bay was surveyed, completing the first modern survey of this economically important bay. The area from Long Point to Beaver Point, including Naufrage Harbour on the east coast of Prince Edward Island, was surveyed.

The approaches and harbour facilities at La Tabatiere, Quebec, were surveyed, as were the International Wharves in Sydney, Nova Scotia.

Surveying of Sir Charles Hamilton Sound, Newfoundland, was continued and the survey of Main Tickle was carried out for a study on the feasibility of completing a causeway linking New World and Twillingate islands.

Extensive, precisely controlled track soundings of Hudson Bay were obtained and Churchill Harbour and the tidal portion of the Churchill River were surveyed.

A party surveyed Shepody Bay and the Dorchester Cape area. A tidal and current survey was carried out in Minas Channel and Minas Basin as background to a study of power tidal development in that area.

A permanent tide gauge was installed in Pictou and nine gauges were installed in the Saint John River, N.B. In all, 44 current stations were occupied.

A long-awaited and much-desired computer, a CD 3100, was installed in November and soon thereafter was at work on a wide variety of problems.

Members of the staff contributed 28 papers to the scientific literature in 1965, and in addition, they have produced 16 BIO Manuscript Reports and 20 BIO Internal Notes.

BRANCH HEADQUARTERS

Canadian Hydrographic Service

The chart-production staff of the Canadian Hydrographic Service produced 35 new charts during the year including two fisheries charts with Decca and Loran lattice overlays, respectively, and a chart of the Muskoka Lakes for the use of small-boat owners and tourists. Existing charts were maintained by the publication of 60 new editions, 95 corrected reprints, and ten supplementary prints. Three special charts were produced together with 16 new editions of Information Bulletins and 37 special charts were reprinted. A total of 214 navigational charts were published during the year and 20 similar charts cancelled or withdrawn.

The total number of charts listed in the catalogue rose in 1965 to 978, of which 56 are special charts.

A total of 253,197 charts were distributed by this service in 1965, to which 1,560,451 hand corrections were made prior to distribution. The service originated approximately one-fifth of all Notices to Mariners published by the Department of Transport.

The second edition of the Saint John River Pilot and the second edition of the Labrador and Hudson Bay Pilot were published during the year, in addition to nine supplements to existing Pilots.

New editions of the Newfoundland Pilot, St. Lawrence River Pilot and Nova Scotia and Bay of Fundy Pilot are in hand for publication in 1966.

An oceanic-bathymetry unit was established to provide for Canadian contributions to the General Bathymetric Chart of the Oceans, a cooperative project being coordinated by the International Hydrographic Bureau. It completed seven plotting sheets for one area of Canadian responsibility and commenced the polar plotting sheets for the western hemisphere for which Canada has also assumed responsibility.

The Tides, Currents and Water Levels Section carried out studies on tides to enable predictions to be published on national and international basis. Prediction data are exchanged in both tabular and punch-card format with other countries, several of whom have requested details of computer programs and the equipment used.

Six separate editions of the tide tables covering the coastal waters of Canada were predicted and compiled for publication during 1965. Total distribution of tide tables amounted to 70,000 copies.

Oceanographic Research

A small research section under the chief oceanographer at Branch headquarters has continued studies of the oceanography of Hudson Bay which will be included in the departmental Hudson Bay Centennial Volume.

The St. Lawrence River has received special attention during the past year. Not only have the oscillations of the river in response to tidal forces been examined from a theoretical point of view, but it appears that significant non-tidal perturbations in the river are associated with surface wind stress and horizontal pressure gradients in the Gulf of St. Lawrence. The influence of changes in river runoff has also been studied. Each of these associated studies shows promise of improved techniques for the more precise forecasting of river levels.

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Studies of the tides in the Bay of Fundy using various mathematical models are directed toward forecasting the effect of a tidal power dam which might be constructed on the upper reaches of the Bay. Studies have been extended from a simple one-dimensional model to a more complex two-dimensional approach with promising results.

Canadian Oceanographic Data Centre

This centre, which is responsible for the processing of all Canadian oceanographic data, extended its service during 1965 to processing limnological data gathered by Canadian agencies in the Great Lakes. Techniques are being developed to facilitate the exchange of these data with United States agencies.

Bathythermographic data are now being processed for East Coast agencies using the aperture frame card. Historical data are also being processed by this system. The centre has also extended its activities toward more complex data analyses including automatic plotting.

Geological Survey of Canada

The Geological Survey of Canada carries out systematic geological investigations in Canada and compiles and publishes such information in the form of reports, maps, and other graphic representations. The scope of its activities extends into many aspects of the geological sciences, including geochemistry, geophysics, geomorphology, mineralogy, palaeontology, petrology, surficial and bedrock geology, and petroleum geology. The Survey's objectives are fourfold: (1) to systematically investigate, describe, and explain the geology of Canada in order to determine the nation's potential mineral resources, and to provide data to industry and others to aid in the discovery, exploration, and development of these and other resources; (2) to carry on other research that will contribute to our knowledge of the origin of rocks and minerals, thereby expanding the potentials of the science and enabling geologists to investigate and explain the geology of Canada more effectively; (3) to develop new instruments and methods as aids to geological investigations and to the search for mineral deposits; and (4) to assist in the scientific training of young Canadians to meet the requirements of science and the nation's economy for qualified manpower.

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 mainland and Arctic archipelago, and in the unconsolidated Quaternary deposits. In addition, it undertakes activities directed towards the investigation of specific topics, interest in which often arises from the broader regional studies. As the first systematic reconnaissance of Canada is approaching completion, the country's major geological features are reasonably well established, and attention may now be given to fundamental aspects of Canadian geology.

In 1965 the Geological Survey sent out 110 full-time and 36 short-term field parties. Of the former, field investigations were made up as follows: bedrock geology, 38; surficial, engineering, and groundwater geology, 25; stratigraphy and palaeontology, 15; mineral deposits, mineralogy, and petrology, 18; geophysics, 9; and geochemical, structural, or other geological studies, 5. Brief reports of these investigations were published in G.S.C. Paper 66-1 early in January, 1966.

Several helicopter-supported large-scale reconnaissance operations were carried out. Operation Amadjuak completed in one field season the initial study of southern Baffin Island, an area of about 50,000 square miles. Operation Grant Land completed half of a two-year investigation of some 30,000 square miles in northeastern Ellesmere Island. Operation Liard, a three-year investigation of about 30,000 square miles of the northern Rocky Mountains and neighbouring plains, was completed during the year, as was Operation Nahanni, a reconnaissance of about 12,500 square miles in Logan and Mackenzie mountains of Yukon Territory and the adjoining District of Mackenzie. Operation Selwyn, a three-year reconnaissance covering a 26,000-square-mile area south and west of the area covered by Operation Nahanni, was commenced during the field season. Farther south, reconnaissance studies

of some 20,000 square miles of the British coast mountains were completed, and half of Operation Bow-Athabasca, astride the British Columbia and Alberta provincial boundary, was completed. In eastern Canada, an operation covering about 14,000 square miles of southern Labrador was undertaken and completed. These are but a few of the many large-scale helicopter-supported operations undertaken by the Geological Survey in recent years, which collectively have speeded up the geological reconnaissance of Canada by decades, and assure the completion of initial-stage reconnaissance of the country within the next several years.

On a more detailed and topical scale, Geological Survey activities encompassed a broad spectrum of projects, ranging from the study of trace elements in certain base-metal deposits to petrological studies of ultramafic rocks in north-central British Columbia; from vertebrate palaeontology on Somerset Island in Canada's Arctic to geophysical surveys for water in Saskatchewan; from stratigraphic studies of Precambrian sediments in the District of Mackenzie to geomorphological studies in northern Alberta; from crater investigations in Quebec to studies of granitic rocks in British Columbia; from biochemical investigations in Ontario to dam-site investigations in the Yukon River area; from palaeomagnetic studies in western Quebec to the study of microfossils in Precambrian iron-formations; and from mineral localities for amateur collectors to studies of saltwater intrusion in Prince Edward Island. Many of these activities have been reported on briefly in G.S.C. Papers 66-1 and 65-2.

The successful operation of a modern geological organization requires the availability of a wide variety of electronic and other equipment and the skilled staff to operate and maintain such equipment, to provide services for the field personnel and to carry out theoretical and applied research in the various geological disciplines. Laboratory studies ranged from the development of a continuously recording magnetometer, groundwater-pressure equipment, and radiocarbon-analysis equipment, to the interpretation of aeromagnetic data and the identification and interpretation of mineral and fossil collections.

To stimulate geological research at Canadian universities, the Survey awarded 74 grants amounting to $150,000 to 19 universities. Requests for grants totalled $264,263 (up $58,000 from 1964), and 18 applications could not be accommodated. Support was provided for 17 Ph.D. thesis projects, and staff members presented lectures and conducted guided tours for numerous university groups. A staff geologist returned to the Survey in September after completing a two-year assignment as Commonwealth Geological Liaison Officer in London, England.

The Survey regularly publishes the results of its scientific activities in the form of memoirs, bulletins, papers, and geological maps. During the year the following publications were made available to the public: two memoirs, two economic geology series reports, ten bulletins, 45 paper series reports, two miscellaneous series reports, 39 geological maps, and 707 aeromagnetic maps. Approximately 310,000 copies of maps and reports were distributed in response to 20,025 requests. Staff members presented more than 100 papers at meetings of national and international societies, many of which were or are being published in scientific journals. One of the Survey's economic geologists received the Leonard Medal from the Engineering Institute of Canada during the year for the best paper published by the Canadian Institute of Mining and Metallurgy or the Engineering Institute of Canada on a mining subject.

In addition to its Ottawa headquarters, the Geological Survey maintains offices in Calgary, Vancouver, Yellowknife, and Whitehorse, and has staff at the Bedford Institute of Oceanography in Dartmouth, Nova Scotia. The Branch has a continuing

staff of 445 (of whom 200 are scientists), and provided summer employment and training for 128 graduate and 186 undergraduate university students.

A contract for the construction of a new two-million-dollar Geological Survey building in Calgary was let during the year, and construction began in November. The building is expected to be ready for occupancy in November 1966.

REGIONAL GEOLOGY

The Regional Geology Division carries out bedrock geological investigations in three of the orogenically disturbed regions of Canada—the Canadian Shield, the Appalachians, and the Cordilleras—in order to determine the types of rocks present, their distribution, structures, relationship to mineral deposits, and origin. Personnel of this Division thereby contribute to the assessment of the mineral potential of these regions.

A total of 41 geologists were engaged in field research on 40 projects distributed as follows: 15 in the Cordilleran region, 20 in the Canadian Shield (of which 9 were in the western Shield, and 11 in the eastern), and five in the Appalachian region.

In the Cordilleran region three staff geologists completed reconnaissance studies of about 20,000 square miles of gneissic and granitic rocks in the Coast Mountains between the 52nd and 55th parallels, operating in exceedingly rugged terrain, with the aid of a helicopter and a research barge provided by the Fisheries Research Board. Two other staff geologists, with supporting technical personnel, completed the geological examination of Wrigley Lake and Glacier Lake map-areas, thereby concluding Operation Nahanni, a helicopter-supported reconnaissance investigation of the Logan and Mackenzie mountains in Yukon Territory and the District of Mackenzie commenced in 1963. Then they started Operation Selwyn, a three-year helicopter-supported investigation of the geology in the southern Selwyn Mountains, Hyland Plateau, and Cassiar Mountains. Other Survey geologists completed reconnaissance studies in the Canoe River, Bonaparte River, and Kananaskis Lakes (west half) map-areas, in central and southeastern British Columbia. Large bodies of magnesite (magnesium carbonate) were discovered in the Kananaskis Lakes area. Reconnaissance studies were commenced in the west half of the Lardeau area in southeastern British Columbia and continued in the central part of Vancouver Island and the adjoining Gulf Islands. A Survey officer completed detailed studies of stratigraphy and structures in the copper-bearing Greenwood area in southern British Columbia, and another commenced a study of recent volcanic centres and their relation to regional tectonics on some of the coastal islands and around Mt. Edziza in northern British Columbia. A geology professor from the University of British Columbia, seasonally employed by the Survey, completed detailed studies of the easternmost part of the Shuswap metamorphic complex near Revelstoke, and four seasonally employed graduate students undertook structural and/or stratigraphic studies in the Revelstoke, Manning Park, and Grant Forks areas of British Columbia and the Tombstone area in the Yukon.

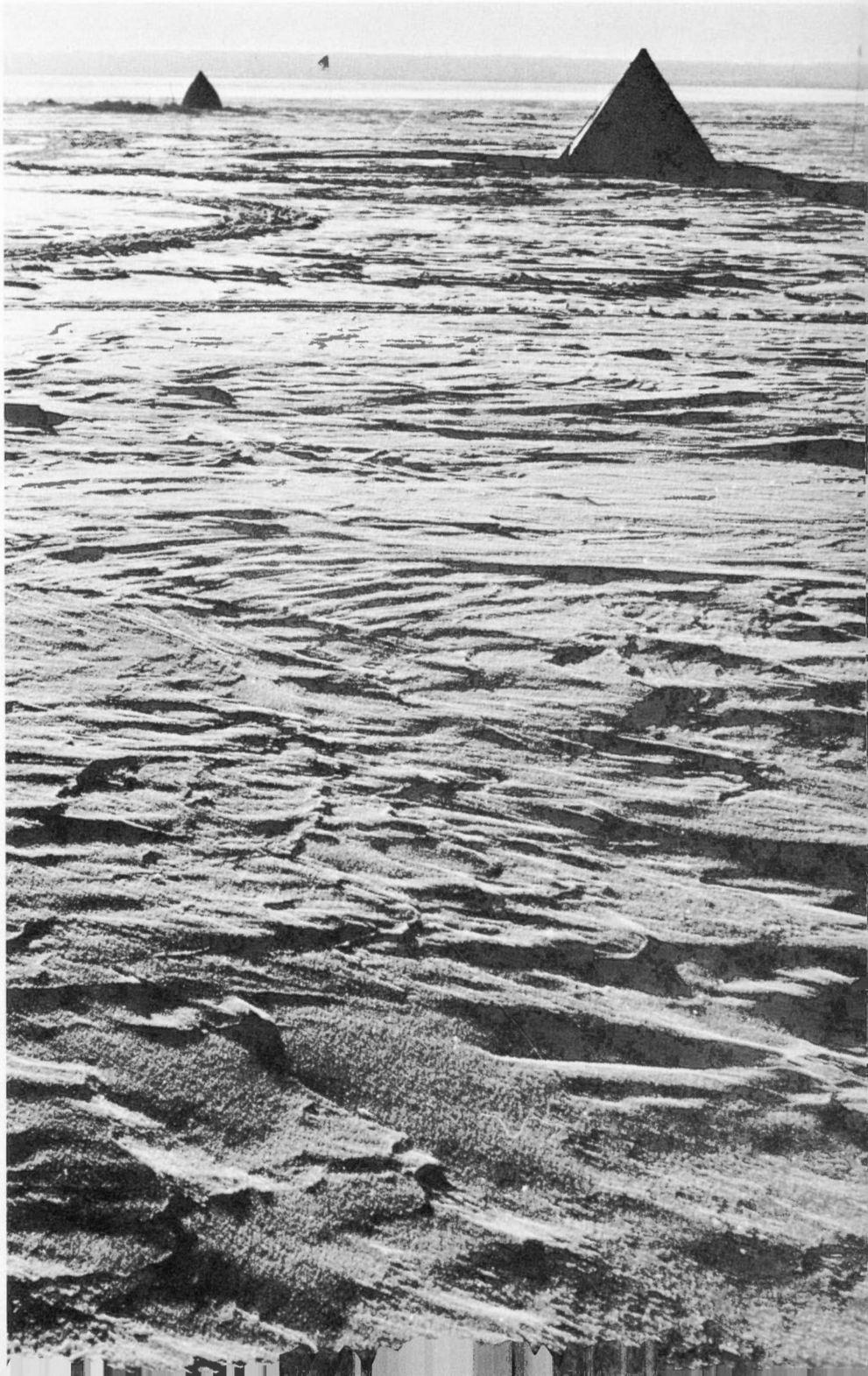
In the western half of the Canadian Shield, completion of reconnaissance studies in 1964 has permitted the assignment of geological staff to areas and problems of significance to geological knowledge and/or of importance in mineral exploration in northern Canada. Six of the nine field parties carried out their investigations in the District of Mackenzie, two in the District of Keewatin, and one in Manitoba. Helicopters were shared by all parties, rather like geological "taxi-cabs", instead of being concentrated under one party in regional studies as in previous years. This is the first time the Survey used helicopters in this manner, and it proved most satisfactory. Two staff geologists and a university graduate student commenced detailed studies of gneissic and granitic rocks in the region between Great Slave Lake and Lake Athabasca, part

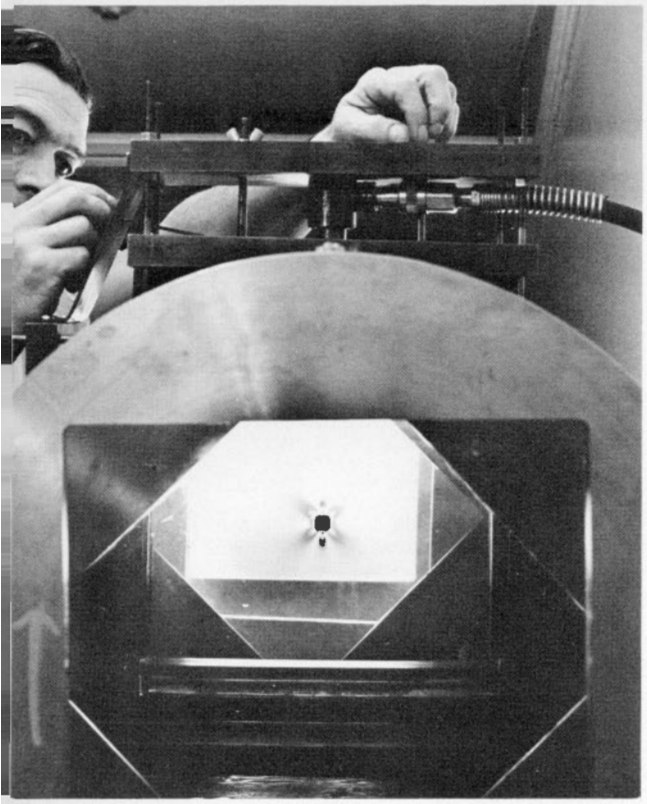
of a project to elucidate the tectonic history of this large area. Three parties continued bedrock and stratigraphic investigations, two in the gold-bearing Contwoyto Lake area, east of Great Bear Lake, the third in the Schultz Lake region of the central barren grounds. A Survey officer completed the reconnaissance study of the stratigraphy and structure of the Hurwitz Group of sediments, which will provide basic information for the study of the geological evolution of southeastern District of Keewatin. He was subsequently selected to represent the Geological Survey on a year's exchange with the Australian Bureau of Mineral Resources, Geology and Geophysics. Another officer completed stratigraphic and structural studies of some sedimentary rocks in the Rocknest Lake area, District of Mackenzie, some 300 miles north of Yellowknife, an investigation of geological problems that arose from the 1959 helicopter-reconnaissance Operation Coppermine. A Survey geologist completed field activities for a synthesis of the geology of northeastern Manitoba, and another examined critical areas and correlated geological and aeromagnetic data in the Upper Nelson River area in addition to investigating the geological boundary between the Churchill and Superior structural provinces.

In the eastern part of the Canadian Shield, which comprises the Precambrian terrain in Ontario, Quebec, Newfoundland-Labrador, and on Baffin Island, Survey geologists conducted 11 projects, ranging from large-scale air-supported operations to detailed investigations. A helicopter-supported field party commenced and completed Operation Amadjuak, the reconnaissance examination of southern Baffin Island south of 66° north, in order to ascertain the economic potential of the region near Frobisher. Another helicopter-supported party commenced the reconnaissance-geological study of a relatively unknown part of southern Labrador, to establish the major geological features there and their relation to mineral occurrences. In September the chief of this field party attended by invitation the opening of the Maritime Cement Company at Brookfield, Nova Scotia; the company is working a limestone deposit whose economic potential he had recognized while carrying out systematic Geological Survey field work in that region several years ago. A new staff geologist conducted preliminary reconnaissance studies of mineralized volcanic rocks in the Timmins-Kirkland Lake belt, while another commenced similar studies of the volcanic rocks near Noranda in the mineralized Noranda-Timmins greenstone belt. A field party continued a 1964 study of the stratigraphy and structure of the Huronian rocks and the nature of the Grenville structural front in the Panache Lake area on Lake Huron, and a graduate student employed by the Survey commenced a thesis project on the metamorphism and stratigraphic sequence in a major basinal structure in the Hastings area in southeastern Ontario. A structural and petrological specialist completed detailed studies of the Morin anorthosite north of Montreal, after which he was granted leave to lecture at Queen's University for the academic year, where he is substituting for that university's structural and metamorphic geology specialist. Another Survey officer completed reconnaissance investigations in the Sioux Lookout area of northwestern Ontario, a region of interest to the mineral industry for base metals, and investigated the bedrock geology of part of the Moose River area to determine the cause of a recently discovered strong northeasterly trending aeromagnetic anomaly there. A field party commenced detailed regional studies near the iron deposits of the Baffinland Iron Mines, in northern Baffin Island, and a Survey petrologist continued field and laboratory investigations of the age, petrology, and tectonic importance of diabase-dyke swarms in the Canadian Shield.

In the Appalachian Region two survey officers continued detailed geological investigations of the lower Palaeozoic sedimentary and granitic rocks in the Antigonish Highlands and Cobequid Mountains of northeastern Nova Scotia. In Newfoundland, one staff geologist commenced reconnaissance stratigraphic and structural studies in the Great Northern Peninsula, while a second commenced similar studies in the Red

Geographical Branch scientists study the Barnes Ice Cap on Baffin Island. Here, wind-blown snow surrounds the party's pyramidal tents and imparts a desert-like quality to this remote and barren region.

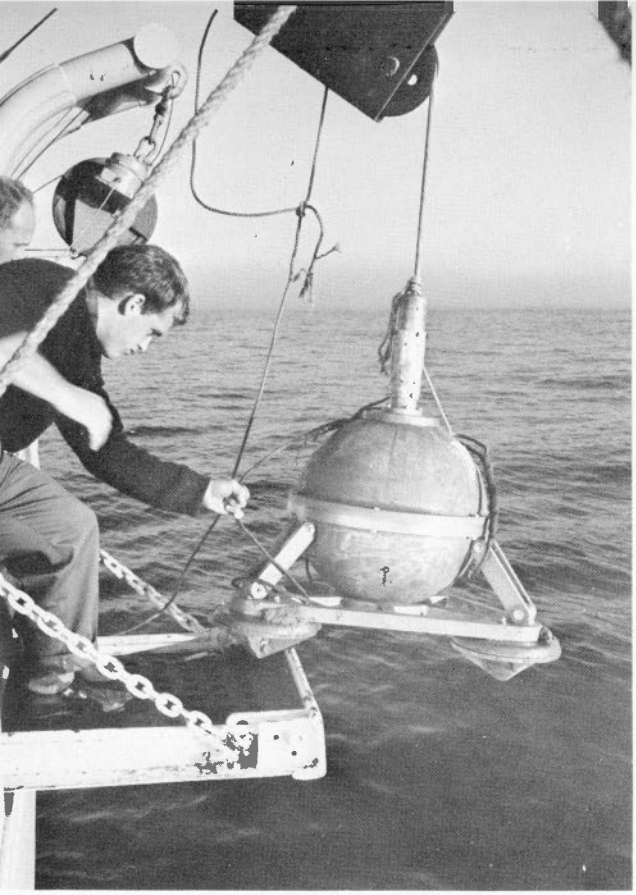




A technician at the Mines Branch uses laboratory equipment that simulates rock stress normally developing around a mine opening. Photoelastic technique permits visual inspection of stress pattern (black dot in centre).

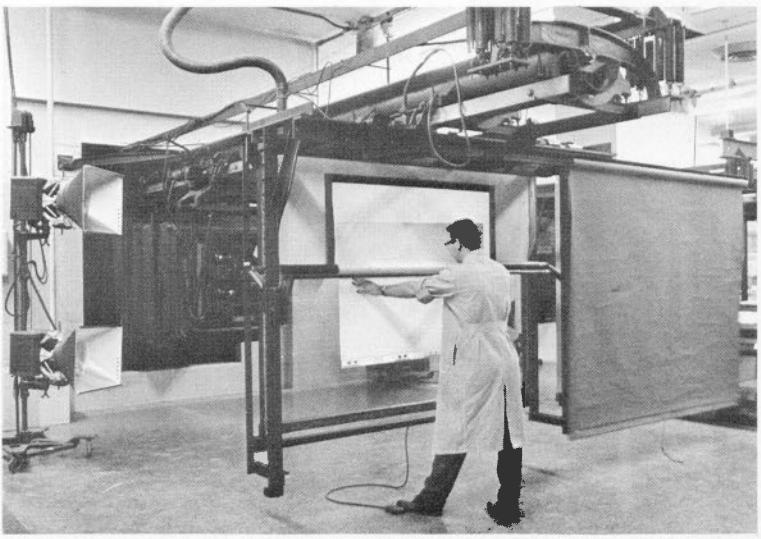
Toxic, heavy-metal pollution of waters from industrial operations is determined in the part-per-million range at rates of 40 to 60 per hour, in the Water Research Branch.

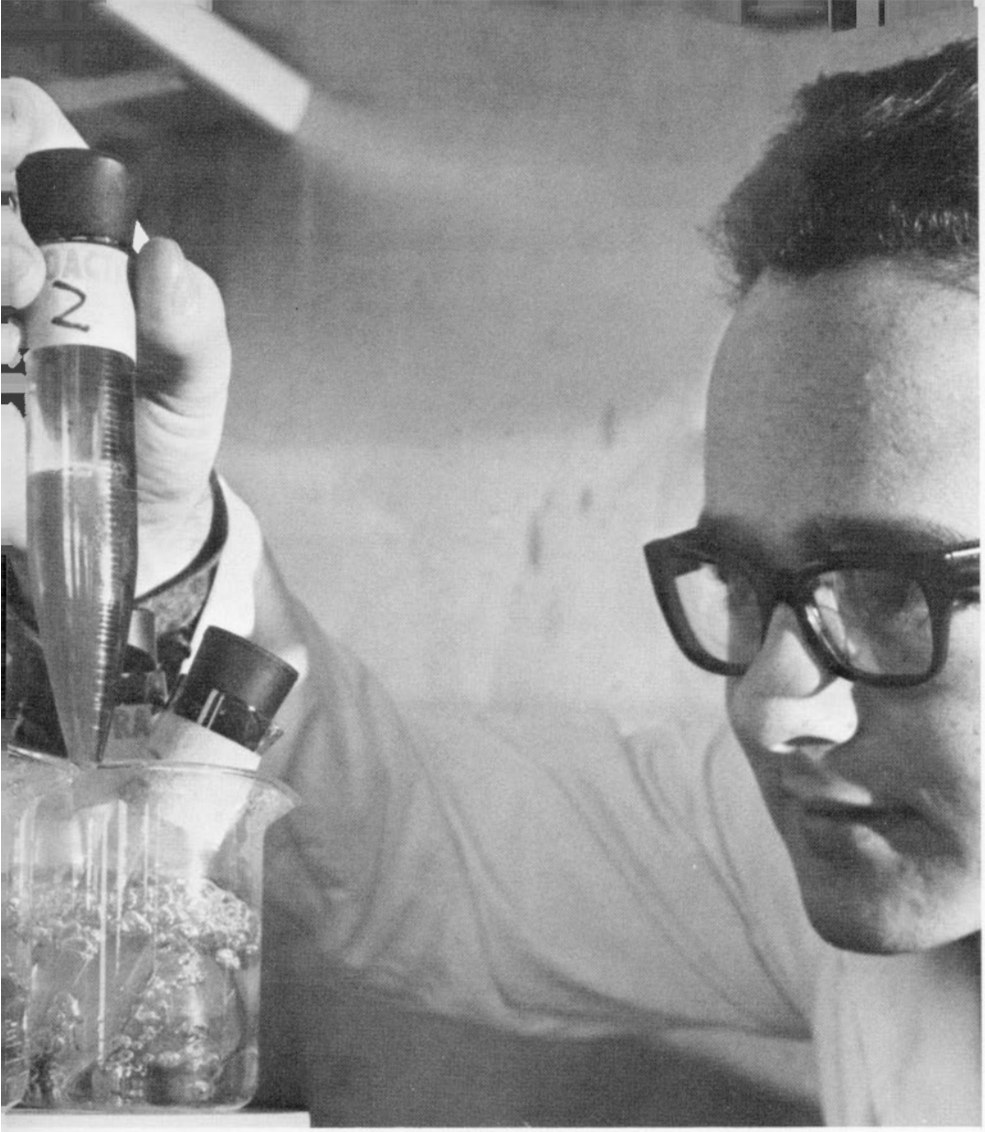
The new Time Laboratory at the Observatories Branch, completed in 1965, contains the electronics for maintaining a precise Canadian time service. Time from the laboratory is made available by short-wave station CHU (3330 kcs, 7335 kcs and 14670 kcs), and by direct line to local scientific laboratories, the CBC, the railways, and the Peace Tower on Parliament Hill.



A gravimeter is lowered over the side of the CSS HUDSON to the floor of Hudson Bay. The Observatories Branch took thousands of such readings during a geophysical investigation of the floor of the Bay in 1965, under the direction of the Marine Sciences Branch.

This huge photographic unit in the Surveys and Mapping Branch is known as a monotype-process camera and is used for enlarging or reducing topographic map manuscripts and other copy to produce negatives at exact sizes required for reproduction.





Geochemistry, the study of the distribution of the chemical elements in geological materials, is proving a valuable aid to the geologist in the study of orebodies.

Indian Lake (east half) area of central Newfoundland, an area containing the Buchans base-metal mine. These two projects, when completed, will finish the Geological Survey's systematic four-mile mapping of all of Newfoundland except for a small area in the southern part of the Avalon Peninsula. Another geologist completed a detailed structural study of the Ordovician slate and phyllite succession in the Bay d'Espoir area of southern Newfoundland, which will permit a better understanding of the structural relationship in areas to the east and north.

FUELS AND STRATIGRAPHY

This Division is concerned primarily with the geological investigation of the unmetamorphosed, stratified, and largely marine fossiliferous post-Precambrian rocks in which Canada's oil, natural gas, and coal are most generally found. Its scientific personnel investigate the succession, lithology, structure, age, and correlation of the sedimentary bedrock formations and carry on research in structural geology, stratigraphy, palaeontology, and the petrologic and organic constitution of coal seams.

The Division has a staff of 47 scientists and 21 supporting personnel, and is composed of the following five sections: (1) Petroleum geology; (2) Arctic Islands;(3) Palaeontology; (4) Coal Research; and (5) Western Plains office. The division maintains permanent repositories in Ottawa and Calgary for well cores and cuttings, and makes this material available to visiting geologists for study.

Regional and detailed field studies involving stratigraphy, structural geology, and palaeontological investigations were carried on in widely separated parts of Canada, including the mountains, foothills, and plains of western Canada, the Arctic archipelago, and parts of eastern Canada, providing basic data for the assessment of the oil and gas potential in these regions.

Survey officers completed a helicopter-supported reconnaissance project (Operation Liard), initiated in 1963, covering a large little-known area in northeastern British Columbia. Natural gas is already being recovered from parts of the area and copper showings are being prospected. Large deposits of barite and fluorite were found in Devonian rocks in this area. Operation Bow-Athabasca, a two-year helicopter-supported reconnaissance geological and structural study of 12,000 square miles in the southern Rocky Mountains of British Columbia and Alberta, was commenced and revealed strata from most of the systems between the Precambrian and Cretaceous. Detailed structural and stratigraphic investigations continued in the surface and subsurface of the southern foothills of Alberta, and in the Cypress Hills region of Alberta, stratigraphic studies continued on the Ordovician, Silurian, and Devonian of southwestern Ontario, and examination was made of wells drilled in the Stone Creek oil and gas field of New Brunswick and on Prince Edward Island.

Survey stratigraphers began a two-year project, aircraft-supported Operation Grant Land, to study the stratigraphy and metamorphic and structural geology of some 30,000 square miles in the structurally deformed northeastern part of Ellesmere Island. In this project they are cooperating with the Geological Survey of Greenland, a member of which was included in the field party, in order to relate geological formations and structural features across the narrow body of water separating northeastern Ellesmere Island and northwestern Greenland. Stratigraphic studies of Bathurst Island were completed and a two-year program of field studies on Cornwallis Island and neighbouring smaller islands was commenced. These investigations are expected to aid in the delineation of areas of possible economic potential for natural hydrocarbons

Survey palaeontologists study and use fossils to determine the succession of sedimentary formations, and to furnish regional and inter-continental stratigraphic correlations. During the year they prepared 124 reports on 1,628 lots of fossils submitted by Survey or other geological personnel, and added 1,431 fossil types to the Survey's

Type Collection, of which 968 were described in Survey bulletins and papers. In addition, special studies were commenced or continued on trilobites from Anticosti Island, bryozoan and microfossils from Arctic Canada, microfossils from the Maritime Provinces and Gaspé, eurypterids from various localities, Devonian spores from Gaspé, and Cambrian to Cretaceous fossils from central, western, and Arctic Canada.

Petrological studies of coals are carried out at the Survey to obtain information valuable for coal geology, coal mining, and coal utilization. In addition, a staff member is studying Carboniferous spores to aid in unravelling the stratigraphy of the coalfields and regions with Carboniferous and Permian rocks. Research on the petrographic properties of coking coals from British Columbia was carried out, environmental studies of coals from New Brunswick, Nova Scotia, Alberta, and British Columbia were made during the year, and technical assistance and information was given to the Syndicate mine in the Springhill coalfield, at the request of the Nova Scotia Department of Mines.

Stratigraphic studies of Cretaceous rocks in the western Cordillera currently under way by personnel in the Survey's Calgary office are directed to the gathering of basic data from subsurface and outcrop, leading to the determination of facies variations, correlation of strata, and potentialities as source and reservoirs of coal, oil, and gas. During the field season a large-scale regional stratigraphic study of these rocks was completed in northeastern British Columbia, southeastern Yukon, and the southern District of Mackenzie. Stratigraphic studies were also continued on pre-Devonian rocks of the southern Rockies, and studies of Mississippian rocks in the Edson area of Alberta and from the Bow River area to the North Saskatchewan River areas commenced. A manuscript of the subsurface Palaeozoic rocks of the District of Mackenzie, northeastern British Columbia, and western Interior Plains has been completed, and studies of Devonian outcrops along and near the Alaska Highway between 58°30′ and 60°00′ undertaken. These projects are part of the Western Plains Office's regional subsurface studies in the western provinces, Northwest Territories, and Arctic archipelago, as an aid to exploration for oil and gas, and for research into the migration and accumulation of natural hydrocarbons.

ECONOMIC GEOLOGY

The Economic Geology Division is concerned primarily with aspects of geology having a direct economic application, and towards this end undertakes the study of the geology of mineral deposits, geochemical processes and geochemical prospecting, Pleistocene geology, and various aspects of groundwater and engineering geology. Its staff consists of 51 technical personnel with a supporting staff of 11.

The geology of mineral deposits falls mainly into two classes: Those dealing with the geological factors responsible for the concentration of particular metals and other mineral commodities, and those dealing with the geological environment and development of certain mineralized belts or metallogenic provinces. Studies of the geology of beryllium, copper, iron, lithium, manganese, nickel, tin, uranium, and vanadium were carried out in various parts of Canada in 1965. Included was a detailed study of the geological setting and origin of high-grade iron deposits in the Mary River area of Baffin Island. Metallogenic studies were continued in the Shield, the Appalachian region, the northwest Cordillera, and on Vancouver Island. A comprehensive study of massive sulphide bodies in Newfoundland was also undertaken. Detailed investigations of sulphide and other ores were carried out in the Survey's laboratories, and one of these, on the sulphides in the Muskox Intrusion in northern District of Mackenzie, was completed.

The Geological Survey is conducting field and office research into the occurrence, source, movement, quantity, and quality of groundwater, is developing methods,

techniques, and instruments needed to carry out these groundwater investigations, and assists other government agencies in groundwater investigations. Considerable emphasis is given to the study of groundwater-flow systems within several types of drainage basins in Manitoba and Saskatchewan, and a new basin study was started in an area of high relief southeast of Kelowna, British Columbia. Most of these are approved International Hydrological Decade projects, and illustrate the important and responsible role played by the Geological Survey in this world-wide program. In addition, Survey officers developed a method of measuring water-pressure changes in landslide areas, and provided engineering-geology advice on the Red River Floodway, Manitoba, the Welland Canal, and on five potential damsites in northwestern Canada. Plans were announced in October for the transfer of the Groundwater Section of the Survey to the new Water Resources Branch of the Department in April 1966.

Geochemical research seeks to define the conditions under which elements are concentrated or dispersed in nature, as an aid to the understanding of ore formation and the search for orebodies. During 1965 Survey geochemists carried out research in geochemistry and geochemical prospecting in the following regions: a large geochemical survey in the Bathurst-Jacquet River area of New Brunswick; an investigation of the trace elements in sulphides of Mississippi Valley-type lead-zinc deposits in various parts of Canada; biogeochemical field work in Ontario, Manitoba, and British Columbia; preliminary investigations on the application of geochemical prospecting in the Cobalt area, Ontario; investigations on circular structures in Quebec; and analytical studies of some Devonian carbonate rocks in the Swan Hills and Virginia Hills oilfields of Alberta. These were augmented by laboratory research in the chemistry of ore genesis, isotope geochemistry, and radio-chemistry. Investigations into the solubility of feldspars under high-temperature aqueous conditions were continued, and a method was developed for the rapid mechanical plotting of geochemical data on maps.

The Survey's Pleistocene geologists deal with surficial unconsolidated deposits mantling the bedrock, organic remains associated with them, constructional and erosional landforms making up the landscapes, and the development and evaluation of methods of mineral exploration through an understanding of the surficial deposits. These deposits, largely of glacial origin, are the base on which our agricultural soils have developed, provide the source of most of the sand and gravel used in construction, and serve as reservoirs for much of the nation's groundwater resources. Two Pleistocene geologists undertook field investigations in the Arctic, one along the coastal plain of the District of Mackenzie, the other in southern Baffin Island in conjunction with reconnaissance Operation Amadjuak. Others conducted field studies in the Klondike placer-area, the Yukon, the Columbia River area, British Columbia, the Iosegun and Kananaskis areas in Alberta, the Interlake area, Manitoba, in southwestern Ontario, and in the Eastern Townships of Quebec. Studies of bog, pond, and lake deposits in the Great Lakes region continued, and are expected to yield valuable information on recent climate trends.

PETROLOGICAL SCIENCES

The Petrological Sciences Division makes mineralogical and petrological determinations, chemical analyses, and age determinations on rocks and carbonaceous materials for officers of the Survey, and for the study and interpretation of rocks and minerals, their geological association, and processes leading to their formation. The Division is composed of the following four sections: (1) Isotope Geology; (2) Analytical Chemistry; (3) Mineralogy; and (4) Petrology, each of which is responsible for analytical services and basic research in a specific field of geology. During 1965 a Data Processing Unit was established to apply the new methods of data handling to the output of the Division. Its operations are expected to expand to handle data for the entire Geological Survey.

The major effort of the Isotope Geology Section during the year has been devoted to age determinations based on isotopic measurements of potassium-argon, rubidium-strontium, and uranium-thorium-lead systems. In the potassium-argon program, a new argon-38 spike-preparation apparatus was added, which has been designed to permit simultaneous filling of 185 spike tubes instead of the present 20, and one set of calibration analyses instead of 20 to establish gas pressure in the tubes. In addition a new low-cost mass spectrometer was obtained, which will improve the methods of argon analysis and relieve the analytical load of one of the existing mass spectrometers, thereby improving the general operation of age determination. A total of 209 potassium-argon ages were determined during the year, and the Survey's potassium-argon facilities are currently being taxed to their capacity. Facilities for rubidium-strontium age measurements were brought into full operation. About 360 mass spectrometer determinations were made and resulted in 12 isochron ages of granitic, volcanic, sedimentary, and ultrabasic rocks from various parts of Canada. The radiocarbon laboratory operated two sample counters (2-litre and 5-litre volumes) continually, and completed 216 carbon-14 age determinations during the year. Research on bone material has shown that only the collagen fraction provides a reliable carbon-14 date, the carbonate fraction proving quite unreliable. Stable-isotope investigations were continued on sulphide minerals from Keno Hill, Yukon, on lead minerals from rocks in the Kootenay district of British Columbia, and a start was made on tracing the movement of enriched stable isotopes from the soil to the stems and leaves of plants.

The Analytical Chemistry Section provides chemical and instrumental analyses of rocks, minerals, and related materials for the solution of geological problems, adapts and develops methods for analyses of geological materials, and compiles chemical data on geological materials. The major part of its work is the production of analyses for use in Geological Survey research: 4,937 samples were submitted by Survey officers for chemical analysis during the year, and 4,749 were completed. Improvements in procedures and techniques were made during the year, and the analytical production is operating at its capacity. All chemical analyses prepared by the Geological Survey between 1846 and 1955 were published in 1965 in G.S.C. Bulletin 115.

The activities of the Mineralogy Section included the preparation of rock and mineral specimen sets for the general public as well as for Canadian embassies throughout the world and a display for Expo 67; identification of minerals for Survey personnel and the general public; addition of X-ray powder-photograph patterns of minerals to the Survey's reference collection; examination of mineral concentrates for the Survey's potassium-argon-dating program; maintenance and extension of the Systematic Reference Series of the National Mineral Collection; study of new and rare minerals; relationships of mica compositions to the composition of associated minerals and the host rock; and an X-ray investigation of the serpentine group of minerals.

The Petrology Section conducts field and laboratory research into the theories and problems of petrology and carries out systematic studies of specific rock types, from which better understandings of the economic or regional petrological problems encountered by other units of the Survey can be obtained. During the year geological studies continued on the origin and emplacement of granitic rocks in parts of British Columbia, where the mountainous terrain provides a third dimension to the field observations, and of ultrabasic rocks in British Columbia and in the Porcupine-Abitibi region in eastern Ontario. Technical assistance was given to the Department of National Defence in a deep-drilling program near Flin Flon, Manitoba, and several members of the section were actively involved in the scientific and logistical aspects of an International Upper Mantle Symposium held at departmental headquarters in September. The Petrology laboratory provided various services to Survey officers, including specific

gravity determinations, mineral and rock staining, and identifications of mineral properties and compositions by petrographic methods. The Survey's meteorite research continued.

GEOPHYSICS

Survey geophysicists conduct and interpret geophysical surveys as an aid to the understanding of the geology of Canada, and carry out research on the development of new geophysical methods and instruments to assist geological investigations and prospecting. During 1965 the Geophysics Division was reorganized into the following seven sections: (1) electromagnetic and resistivity; (2) federal-provincial aeromagnetic surveys; (3) magnetic methods; (4) remote sensing; (5) rock magnetism; (6) seismic; and (7) theoretical geophysics. The reorganization spreads authority and responsibility amongst the senior specialists of the division, and creates more easily identified boundaries between the functions of the sections.

Survey geophysicists played a key role, with personnel of the Marine Sciences and Observatories Branches, in obtaining valuable data on crustal and shallow seismology, gravity, magnetism, water temperatures, salinity, currents, and bottom sediments in Hudson Bay, using the C.G.S. ***Hudson*** and a charter vessel during August and September. This investigation was sparked by interest arising from previous surveys by the Geophysics Division in which the existence of a sizeable sedimentary basin in Hudson Bay had been indicated. The division also provided planning, instrument technicians, and digital-compilation staff for a high-sensitivity rubidium-vapour aeromagnetic survey of part of Hudson Bay by the National Aeronautical Establishment.

An experimental airborne resistivity survey was conducted over the Winkler and Nokomis areas in Manitoba and Saskatchewan respectively to test the INPUT (Induced Pulse Transient) electromagnetic system to see if the technique could be used for reconnaissance mapping of surficial deposits. Excellent correlation was obtained over the Winkler aquifer and was confirmed by a DC ground resistivity survey. Good correlation was also obtained in the Nokomis area. Two other areas were flown, but the results have not yet been assessed. It is concluded that the INPUT system can map changes in resistivity between clay, till, sand, and gravel in the top 100 feet of surficial deposits in the Prairies. The possibility of applying this technique on a world-wide basis is considered to be a real contribution to the International Hydrological Decade program.

Members of the Division continued their management role in the federal-provincial aeromagnetic survey program, and a second set of three-year contracts in the nine-year scheme was let during the year. The first set was completed in 1964. Aeromagnetic surveys were conducted in eastern District of Keewatin, western Yukon, southeastern British Columbia, across the Manitoba-Ontario boundary, and in northwestern New Brunswick. Geophysics personnel checked 476 one- and two-mile aeromagnetic map compilations resulting from the federal-provincial program and compiled and checked an additional 152 map-sheets from surveys by the Geological Survey.

An aeromagnetic map published by the Survey in June revealed magnetic characteristics that led to the discovery of a sizeable magnetite iron-ore prospect in the Grenville structural province 35 miles northeast of North Bay.

Development of a light-weight highly sensitive continuously recording Overhauser magnetometer continued during the year, and the instrument has now been satisfactorily bench-tested. It is expected to prove very useful for aeromagnetic surveys over mountainous terrain. It was recently patented by the Canadian Government.

Geophysical personnel participated in the testing of a high-sensitivity rubidium-vapour magnetometer over part of Hudson Bay, and the results indicate that the instrument will be of value in sedimentary areas by detecting shallow-anomaly sources caused by faults and folds within the sedimentary rocks. It is also expected that the instrument will prove useful over igneous and metamorphic terrains.

The Survey conducted a test survey in the Vaudreuil area, Quebec, and along the north shore of Lake Ontario with an airborne infrared scanning instrument, which showed great promise for hydrogeological purposes in detecting pollution effluents, currents, thermal wastes, and underwater obstructions in surface waters. Geophysicists also conducted seismic surveys in Hudson Bay, the Gulf of St. Lawrence, Alberta, and northern Ontario.

Research on palaeomagnetic equipment was undertaken and computer programs were prepared to speed up the large volume of calculations stemming from the palaeomagnetic investigations.

Considerable progress was made during the year in the analysis of aeromagnetic data on the enormous magnetic anomaly in the Moose River area of northern Ontario, and in the compiling of an aeromagnetic map of Canada.

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 year under review the Branch continued a number of promising research projects and started several new ones.

Tests and investigations carried over from previous years dealt with the effects of uranium additions to various alloys, welding at low temperatures, petroleum hydrogenation in a high-pressure pilot plant, catalytic cracking of petroleum, coking of Canadian coals, the co-precipitation of electronic ceramics, automatic grinding of gold ores, bacterial leaching of uranium, and surveys of water quality in many regions of Canada.

Other projects involved such diverse matters as advice to the Royal Canadian Mint on new coinage metal, the development of automated equipment for evaluating catalysts used in the desulphurization of crude oils, the formation of the Canadian Carbonization Research Association in conjunction with coal research in the Branch, a study in depth of sulphide minerals with special attention to their structural classification, a new tin-flotation process as technical assistance to Bolivia, and the establishment of an eastern laboratory in the Atlantic Provinces.

PHYSICAL METALLURGY

The Division conducts fundamental and applied research on metals and alloys for the support and expansion of the Canadian mining and metals industry. Current activities embrace the development of new materials, the improvement of established metals and alloys, and the development of new uses and metallurgical processing techniques. In addition to work on immediate, practical problems, fundamental studies are conducted in fields where new data and knowledge may prove fruitful in future years.

To sustain the enviable international position achieved by the Division in many specialized fields of physical metallurgy, staff members served on numerous executive and technical committees of professional societies and advisory groups. In addition, senior staff scientists participated in cooperative research and exchanges with other institutions throughout the world.

Many investigations were conducted on behalf of both producers and users to assist in the evaluation of failures of metal components, or where unwitting service abuse could be discovered through metallurgical examination, and thereby avoided in future. In recent years such investigations have originated in about equal proportion in industry and governmental or defence agencies, but with the usefulness of such work amply demonstrated, private industry is developing increasing self-sufficiency in this regard. However, in 1965, the proportion was still approximately 35 per cent for industry and 65 per cent for government, defence and similar agencies. Industry may be expected to continue to rely upon the Division for highly specialized knowledge and facilities.

Included in the wide range of failed or damaged products and equipment given extensive metallurgical examination were several boiler tubes, components of a paper-making machine and a pneumatic rock drill, military rifle and weapon parts, aircraft components from crashed or damaged aircraft, a rock-crusher mantle head, steel rails from Labrador iron-ore-transportation service, a ship's propeller, coining dies for coin minting, numerous welded parts such as armour plate, aircraft fuelling tanks, exhaust manifolds, salt-bath tanks and piping for underground electric cable.

Among items of more historical importance were identification and dating of metal relics from the Northwest Territories and from the bed of the St. Lawrence Seaway.

Among services rendered to other government departments was technical advice to the Royal Canadian Mint in connection with prospective changes in Canadian coinage metal.

Alloy research is an obvious field where much fundamental work is required in expansion of uses as well as in the development of new materials. In this field, work was done on a variety of steels, and included studies of potential benefits through uranium alloying additions. In light-alloy research, the premium quality concept was extended to high-strength aluminum casting alloys, and further work on Mg-Zn-Ag-Zr casting alloys confirmed and extended the potential of this system for very high-strength magnesium alloys. Work continued on the development of high-density uranium alloys for non-nuclear military applications and in the useful application of uranium additions to copper alloys. Studies of alloy systems in the refractory metals included work on niobium (columbium), titanium and zirconium.

Melting, refining and casting research embraced work on vacuum degassing of steel, studies of operational procedures on the properties of magnesium-alloy castings and investigation of the foundry characteristics of copper alloys.

Powder-metallurgy research included further evaluation of hyper-eutectic aluminum-silicon alloys producible only by this technique, and studies were made of composite materials of possible use as coinage metal in lieu of high-silver alloys.

In welding research, work continued in the low-temperature field, since this is of great practical importance in Arctic and winter-service conditions.

Corrosion research and studies of various surface treatments included galvanized coatings, the effects of composition on the corrosion of stainless steel and environmental cracking of high-strength steels.

Fatigue damage in metals was studied to better understand the mechanisms involved and to develop methods of evaluating the progress of damage prior to ultimate failure, and hence preventing catastrophic failure of components in service.

Of growing importance is the function of the division as the certifying authority for industrial radiographers, on behalf of the Canadian Government Specifications Board. In the past year examinations were held in 14 centres across the country, resulting in the certification of 79 senior and 34 junior radiographers. The importance of maintaining high standards in this field arises from the expanded use of welded structures, including gas pipelines, where radiographic inspection is a major factor in ensuring public safety.

Two ten-day courses were given to RCAF personnel, covering theoretical and practical industrial radiography.

The physics of melting and solidification provide a potential key to achieving improved cast metals, and studies continued on viscosity, density and surface tension of liquid metals as well as diffusion in, and the structure of, solidified alloys.

Metal-physics research embraced fundamental studies on dislocation movement, plastic deformation and slip-band structure in fatigued metal. Ion bombardment was applied to the determination of surface atom positions, and the novel apparatus and technique developed in the division may find wide application as an aid to teaching crystallography.

FUELS AND MINING PRACTICE

One of the major roles of the Mines Branch has been to forecast the nation's mineral-fuel requirements and to develop more efficient techniques of converting Canada's natural resources into products that will meet these needs. The rapid increase in demand for petroleum has stimulated research on the development of improved processes for refining heavy oils such as the Athabasca bitumen. Research has been confined to hydrogenation, catalytic cracking and catalyst development.

The hydrogenation research features the operation and process evaluation of a combined liquid-and-vapour-phase pilot plant operating at pressures up to 10,000 pounds per square inch. During the year numerous mechanical difficulties were overcome, and the stability of the operation has reached the point where various catalysts may be evaluated. The limiting temperatures and pressures where the onset of coking begins have been determined for the feed and catalyst now in use. This plant will be used to obtain process costs and to train mechanical and chemical engineers in refining techniques.

The Division is continuing the catalytic-cracking research 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 to process feed stocks too heavy for conventional refining operations. The progress made during the year consists of completing the installation of all the major vessels and the operating panel. The instrument lines have yet to be fully installed and the insulation and final testing remain to be completed.

Catalysis plays an important role in the refining of low-grade Canadian crude oils. Past research at the Division has concentrated on improving the physical form of the catalyst and catalyst support. One Canadian and one British patent have been issued to the Division during the year which describe the preferred process for manufacturing catalysts with a controlled pore-size distribution.

Possibly a more important aspect of catalysis is the correct selection of the catalytic substance. In this field of investigation a comparison of metal oxides with the corresponding sulphides was made to determine the relative rates of loss of activity. The performance of the sulphides was substantially better than that of the oxides from the point of view of deactivation by coke deposition.

A most significant advance has been made during the year in the development of automated equipment for evaluating catalysts with respect to their ability to desulphurize heavy crude oils. This equipment will substantially accelerate the capacity to determine those catalysts that make a genuine improvement in the refining art.

Research on coal at the Division was oriented to assist the coal industry to improve and expand sales to the metallurgical and utility industries. The purity requirements of coal for making cokes and chars are stringent and efforts at the Western Regional Laboratory continued to improve the compound water-cyclone system for cleaning fine bulk products. As a result of earlier research the Canadian company licensed to market the system exported in 1965 three 24-inch units of a capacity of 210 tons per hour to an Australian coal mine, and an additional order was placed at the end of the year.

The removal of fine solids from plant effluents was investigated. A densifier cyclone was developed that "strips" solids from effluents in the form of a paste or as slugs that can be shovelled and then trucked or stacked by a conveyor belt. This is not only important in improving recovery of coal and other fine materials, but also as a significant contribution for reducing pollution of rivers and lakes.

The carbonization program has been extended and received general support from the Canadian coal and steel producers through the formation of the Canadian Carbonization Research Association. The Association is carrying out agreed research programs which include the evaluation of coking coals by petrographic-bench and technical-scale methods, preheating coal to increase coke-oven capacity, heat-transfer studies and improvements in production of entities for form-coke by extrusion methods. The semi-industrial-scale vertical reactor has been completed and experiments will be made with the extruded entities.

Combustion-engineering research emphasized studies on the character of high- and low-temperature corrosion in the combustion of coal and oil, means of eliminating these undesirable phenomena and on the reduction of atmospheric pollutants from combustion.

Research work in mining is being conducted at three levels—basic studies, applied research and advanced technology—on the properties of rocks, ground control of underground workings, stability of open-pit slopes, rock breakage and airborne dusts.

With the establishment at the end of 1964 of a field laboratory adjacent to the Nordic mine at Elliot Lake, Ontario, ground-control and dust research has greatly improved. A staff of 16, including research engineers, scientists and technicians, have been located at this laboratory. The staff is to increase to more than 20.

Grants-in-aid totalling approximately $30,000 for the 1965-66 university year were granted to seven Canadian universities to assist in their post-graduate studies.

New modifications of the type and method of manufacturing of drill steel, developed at the drill-steel laboratory, are being examined and analyzed in close cooperation with the steel industry.

Standard data on the performance production under dry and wet corrosion are provided for interested mines and steel plants.

Evaluations are undertaken of laboratory-drilling times for various types of conical connectors between drill bit and steel, and the most efficient connector is recommended for industrial use in mine drilling.

The analytical laboratories for fuels analyzed 1,585 samples of solid, liquid and gaseous fuels, including 121 mine-air samples. The explosives laboratory examined 124 explosives and formulations, and the electric-certification laboratory completed 61 investigations of equipment; both laboratories also carried out a number of research projects.

MINERAL SCIENCES

A goodly portion of Canada's mineral wealth is contained in sulphides. Copper, lead, zinc, nickel, and the precious metals often associated therewith, occur in sulphide deposits. Although Canada has vast quantities of such materials, with more being discovered each year, it is surprising how little is known of the fundamental properties of sulphide minerals.

The treatment of ores and the various metallurgical processes involved are mainly traditional and classical, and are based on empiricism and on the sparse data available many decades ago. Most subsequent advances have been improvements in engineering practice. It is now realized that, if dramatic advances in mineral processing and in the various aspects of metallurgy are to occur, a much more extensive fundamental knowledge of the structure and properties of minerals must be made available. To sum up, in order to know how to take a mineral apart efficiently one must know how it is put together.

To this end, the Mineral Sciences Division has embarked upon a study in depth of sulphide minerals, with special emphasis on those occurring in Canadian orebodies. The disciplines involved are mineralogy, crystallography, solid-state physics, quantum mechanics and inorganic chemistry. The program has been under way for about a year, and some interesting avenues for exploration have been revealed.

One of the peculiarities of sulphide minerals as a group is that, to date, they have defied all attempts at orderly classifications based on structure. Along with this, many sulphide minerals have very complex structures. While such a set of circumstances may seem forbidding at the start, the rewards of success should be most gratifying. For this reason very modern and sophisticated approaches to the study of structure have been taken.

X-ray diffraction is a powerful method for elucidating structure, but the usual types of equipment have been found inadequate for the precision required in sulphide studies. At present, recently developed equipment of superior performance is being acquired.

Current chemical theories do not provide an adequate explanation for bonding in sulphide structures. Among the techniques being employed in the Division in an attempt to resolve this problem are optical absorption in the visible and infrared regions, electrical behaviour, and stability relations.

In the processing of minerals by flotation, leaching, roasting, etc., the reactions take place at the surface. Hence, the sulphide program also involves studies in surface chemistry. These studies are of particular importance in the sulphide minerals, since the surfaces of many tend to be altered readily by the atmosphere.

Electronic and magnetic ceramics are assuming an ever more important role in modern technology. The Division is responsible for several important aspects of the Branch program on studies of these materials. Investigations aimed at improving the fabrication and sintering procedures for the piezoelectric ceramic bodies continued. The consititution of these materials was studied by phase-equilibrium work in the lead-oxide-titania-zirconia system.

Ferrites, complex oxides of iron with other metals which have a host of uses in modern magnetic technology, are being subjected to exhaustive investigation. At present the work is confined to the hard or permanent-magnet type, which consists of iron oxide and, usually, barium oxide, reacted to form a hexaferrite. Lead oxide and/or strontia can replace all, or part, of the barium oxide. Studies are under way to determine the properties resulting from varying the amounts of barium oxide, lead oxide and strontium oxide in these hexaferrites. Owing to inadequate knowledge of the factors involved in producing ceramics of desirable magnetic properties, quality control in the process is most difficult. A clear understanding of these factors would be of great economic importance.

In both the piezoelectric and magnetic studies the preparation of the materials by a co-precipitation technique, leading to an accurate control of chemical composition, is a novel feature. The work is of strong industrial significance. A number of Canadian companies are engaged in producing the raw materials, and some of them are either producing or are interested in producing the finished bodies.

The Division maintained its collaboration with national and international standards organizations. Many analyses were done in connection with the work of the American Society for Testing and Materials Committee on devising standard methods for the analysis of metallic ores and related materials. The Division assisted in the standardization by the National Bureau of Standards of brasses and bronzes for use in spectrographic work, by providing the chemical determination of a number of elements.

The Division has for some time participated in the work of the chemical analysis group of the Materials Panel of the Advisory Group for Aeronautical Research and Development (AGARD) of NATO. During the past year, studies were conducted on AGARD samples of niobium rod and specially blended tantalum powder. Iron and carbon contents were investigated by chemical methods, and silicon by a spectrographic technique. Methods for the analysis of magnesium metal proposed by the Light

Alloys Committee of the International Organizations for Standardization were evaluated. In addition to these, several Canadian companies were assisted in standardizing reference materials for use in controlling quality in production.

EXTRACTION METALLURGY

In the field of extraction metallurgy, applied research was carried out on hydrometallurgical and pyrometallurgical processes and on electroplating techniques and corrosion prevention, and basic studies were conducted on chemical reactions of metallurgical importance. Most of the research was on long-term projects that were continued from the previous year.

As in previous years the hydrometallurgical processes used in gold mining received considerable attention. Research continued on the cyanide process, cooperative studies with industry were made on the application of automatic controls of gold mills, and technical liaison was provided between Canada's widely dispersed gold mines. The detrimental effect of residual xanthates, which are used as flotation reagents in making flotation concentrates of gold ores, on the subsequent cyanidation of the concentrate was studied in the laboratory, and a simple method for controlling xanthate additions was devised. In addition, the application of ion exchange for the recovery of gold from pregnant solutions was studied.

The Mines Branch shared in a cooperative project with industry to evaluate the benefits to be gained from an automatic control system installed on the grinding circuit of a western Quebec gold mine. The grinding circuit was examined in detail before and after the installation of the automatic control system, and the voluminous data obtained were prepared for analysis with the aid of a computer. At the same time, a parallel study was conducted at the Mines Branch, using a pilot-plant ball mill, to determine the correlation between mill in-put variables and the size distribution of the ground product, and their relationship to measured levels of mill sound.

In the research on uranium-ore processing, studies were conducted on the use of bacterial action in the leaching of uranium from crushed or ground uranium ore. Mineralogical studies of residues from bacterial leaching of whole ore showed that, in 19 weeks, the leaching action completely pervaded the largest particles investigated (minus-4 mesh). Uraninite, which is one of the principal uranium-bearing minerals in the uranium ores from the Elliot Lake area, could not be detected in samples of ore that had been exposed to bacterial action, and even pyrite and brannerite-anatase showed under the microscope that they had been attacked. It is clear that, given time, bacterial action can exert a substantial effect on these uranium ores.

The process for the production of mixed lead-zirconium-titanium oxides by chemical methods as a raw material for the manufacture of electronic ceramics was studied on pilot-plant scale. Sufficient quantities of material of closely controlled composition were produced for performance studies on the final product, and further improvements in techniques for making the oxide mixtures were achieved. The effect on the properties of the electronic ceramics of substituting strontium for part of the lead, and of adding other modifying agents, was determined. The work showed that the process which was developed in Branch laboratories is highly effective for the production of a pure material of closely controlled composition, and that the properties of the electronic ceramics made from such material are favourably affected by the development of such controls.

Studies on the refining of Canadian-produced tungsten concentrates were continued. The application of cation exchange for the purification of tungsten-bearing solutions made possible the development of a more effective leach process, the increased cost of the ion exchange step being balanced by a higher extraction of the tungsten. The grade of the final product was equal to that of commercially available tungstic oxide.

Other hydrometallurgical studies included one on the application of chlorination processes to the treatment of complex base-metal ores. An investigation of the possibilities of using a differential sulphation roasting technique to separate nickel and copper was completed.

In pyrometallurgy applied research was devoted principally to the shaft furnace-electric furnace combination under development in our laboratories. While a suitable configuration of the principal units had been worked out earlier, much design and development remained to be done on ancillary equipment. Process investigations were carried out to evaluate the efficiency of the unit in smelting iron-oxide ore, and in melting pre-reduced iron pellets. In smelting iron ore it was evident that utilizing the hot off-gases in the shaft furnace to pre-treat incoming ore recovered useful process heat and accomplished some measure of pre-reduction. In melting pre-reduced iron pellets, it was established that a substantial proportion of the electric power normally required for melting could be replaced by the burning of natural gas.

Electroplating research was largely concerned with the control of hydrogen embrittlement of high-strength steel during plating. Earlier work had shown the benefits in zinc and cadmium plating of controlling plating-bath compositions in minimizing hydrogen embrittlement, and similar controls were found to be equally effective in copper plating. The preparation of the plating surfaces was also shown to be a major factor in minimizing embrittlement.

In the corrosion program, the study of inhibitors of sulphurous-acid corrosion of low-carbon steel continued, with particular attention to the ammonium-oxalate-hexamethylenetetramine inhibitor which had been shown in the laboratories to be notably effective. It was found that picric acid in small proportions acts to substantially reduce the concentrations of these reagents needed for the protection of low-carbon steel.

Among the basic research projects under way, the kinetics of the leaching reaction of acidic ferric sulphate on the copper mineral chalcocite were investigated to determine the reaction mechanism and to identify the rate-controlling step. It is expected that the information obtained will have an application to leaching reactions in general. The remarkable ability of sodium sulphate to catalyze the sulphation of metallic oxides was studied, and a hypothesis as to its method of operation was developed. The thermodynamics of the manganous sulphate-manganese oxide-sulphur trioxide system was elucidated, and the kinetics of the formation and decomposition of nickel sulphate to form nickel oxide and sulphur trioxide were worked out.

MINERAL PROCESSING

The personnel of the Mineral Processing Division maintains a close association with the mining industry, providing information and technical advice, and carrying out various investigations on technical problems. Projects of broad potential interest were also initiated.

The high price of metals encouraged mine development and increased the demand for assistance by the metallic-minerals laboratories in the development of processing methods. The pilot plant operated at capacity; bench-scale investigations were made on 34 samples of various ores.

In the pilot plant, feasible processes were developed for samples from base-metal deposits in Ontario, New Brunswick and Quebec and were subsequently incorporated into production plants. Processes that were developed for samples from a base-metal deposit in Ontario and from chromite and pyrochlore deposits in Quebec are being evaluated.

Smaller-scale investigations were conducted on the beneficiation of ores from new mining projects and from operating plants. Samples from deposits of base metal, precious metal and ferrous ores in several provinces were included. A process was

developed for the flotation concentration of stibnite from a sample from the Yukon. Assistance was provided in solving problems on mine-backfill preparation and the recovery of metal from smelter slag.

Progress in process research of general application was retarded because of a shortage of staff, but some fundamental principles of iron-ore flotation, filtration and jigging were investigated. During a program of technical assistance to Bolivia, a new tin-flotation process was developed and patented.

Several hundred industrial-minerals samples from many sources from coast to coast were received for investigation. Nearly 200 samples of ceramic raw materials and products were evaluated. Forty-seven samples were received for processing in the industrial-minerals mill. More than 100 samples of non-metallic minerals were sent in for evaluation or processing in the laboratory. Numerous inquiries were answered.

Ceramics research centred principally on lead-zirconate-titanate bodies from pure co-precipitated materials, the making of a sewer-pipe body from an Ontario shale by isostatic pressing, the composition and hot-pressing of thermal-conductivity standards, the heat capacity of magnesium-silicate minerals and bodies prepared from these minerals and high-alumina cement, a dead-burned, hydration-resistant magnesia from Canadian magnesite, and the properties and processing of useful Canadian clays and shales. Close cooperation with industry on industrial problems led to several improved plant operations.

The growing need for improved construction materials to meet more rigid specifications has stimulated applied research for new and advanced techniques for evaluation of raw materials and finished products. An accelerated strength test for concrete and a ring test for determination of the tensile strength of brittle materials are two developments that have aroused considerable interest.

In the industrial-minerals mill, studies continued on the floatability of pure minerals, on electronic sorting and on ultrafine grinding. A comprehensive project on Canadian fluorite was initiated. Samples of various industrial minerals were received from several provinces for the development of processing methods.

Asbestos research received much attention, with special emphasis on surface area and its relationship to fibre harshness, and on new techniques for measuring fibre length and diameter. The study of the application of Canadian bentonite to iron-ore pelletizing continued. The search for commercial silica indicated that several deposits in Quebec and one in Manitoba might have value. Studies of Canadian sulphur and potash in world markets continued.

The industrial-waters laboratory analyzed 3,950 samples, continued its surveys of water quality in western Canada and in the international rivers in Manitoba and Saskatchewan, completed a survey in the Upper Great Lakes drainage basin, and updated surveys in the Hudson Bay, Arctic Ocean and Labrador basins. Water-pollution studies continued in the eastern Rockies, in the headwaters of the Saskatchewan River system and in various streams in New Brunswick. Assistance was provided continually to the Departments of National Defence and Public Works in solving problems of water supply and treatment. Several projects were initiated through the laboratory's participation in the International Hydrologic Decade.

An eastern laboratory was established temporarily at Dartmouth; it will be moved to permanent quarters in Moncton in 1966. In October the industrial-waters section became part of the Department's newly formed Water Research Branch.

Mineralogical assistance was provided to personnel working on various projects. Included were the study of the relationship between the clay mineralogy of argillaceous materials and their ceramic properties, and between the mineralogy and physical properties of concrete aggregates and building stones. In the course of such studies several mineralogical discoveries were made.

Continued efforts to improve mineralogical techniques resulted in an instrument for rapid determination of the density of heavy liquids, an improvement in the preparation of thin and polished sections and extension of the range of materials that can be stained selectively.

Observatories Branch

The Observatories Branch consists of six units: the Dominion Astrophysical Observatory, Victoria, which operates as an independent scientific institution under the direction of the Dominion Astronomer; the Division of Positional Astronomy, Ottawa; the Stellar Physics Division, Ottawa, which operates meteor-observing stations in northern Alberta and the Dominion Radio Astrophysical Observatory near Penticton, B.C.; the Division of Seismology, Ottawa, which carries out field work in various parts of Canada and operates 25 seismological observatories; the Division of Geomagnetism, Ottawa, which operates seven magnetic observatories and is involved in field work both inside and outside Canada; the Division of Gravity, Ottawa, involved in field work in all parts of Canada.

In addition to operating these institutions the Branch is planning the 150-inch Queen Elizabeth II telescope. This telescope will be located on Mount Kobau in south-central British Columbia where it will be the principal instrument of a proposed National Observatory. The mirror blank was ordered during the year, the optical dimensions of the telescope were decided on and preliminary studies of the mechanical design were carried out. A road to the top of Mount Kobau was under construction at the end of the year.

POSITIONAL ASTRONOMY

The main purposes of this Division are:

(1) to observe stars when they are in transit to improve our knowledge of their position and space motion;
(2) to observe stars whose positions are well known to determine astronomical time and latitude;
(3) to maintain Canada's time service;
(4) to determine ephemeris time from visual and photographic observations of the moon in its monthly circuit through the stars;
(5) to carry out related research.

During the past year some further improvements were incorporated into the new Mirror Transit Circle. Preliminary observations from it are currently under study to determine the capabilities of this radically new instrument.

Data from the large number of stars observed in the years 1955-1960 with the now discontinued Meridian Circle are gradually approaching the stage of publication. It is part of an international program in which the efforts of several observatories will be combined to improve one of the fundamental star catalogues.

The Photographic Zenith Tube (PZT) was operated every clear night to measure astronomical time and latitude. Results are forwarded each week to the international data centres where they are combined with results from similar instruments dispersed around the globe to give precise values for irregularities of earth rotation and wandering of the pole of rotation. Cloudy weather during the last two months of 1965 reduced the number of observations to 187 from the usual 200 plus.

Photographic observations of the moon together with visual timing of occultations have combined to indicate that time by earth rotation (UT) is slow by nearly 36 seconds compared to ephemeris time.

The time service at the Observatory not only has the most recent commercial atomic devices for maintaining precise frequency, but during the year was able to move into the new time laboratory. Here the electronic equipment is arranged for convenience of servicing and of displaying to visitors.

Time in Canada is maintained in agreement with the internationally coordinated time. The rate of the transmitting clock is controlled to within a few hundred-thousandths of a second per day so that the time as emitted is held within a thousandth of a second of the coordinated time. Precision of this order is required very generally in our automated society. Any deviation or interruption in the service brings comments from a surprisingly large number of users.

Apart from the CBC noon-time signal, the best-known outlet of Observatory time is the continuous signal over the three short-wave channels of CHU (3330 kcs, 7335 kcs and 14670 kcs). The bilingual announcement of time each minute has found wide acceptance. During the year provision has been made to apply an atomic frequency directly to the transmitting clock.

Information is supplied on request to calendar makers, law courts, game wardens and private individuals concerning astronomical phenomena such as times of sunrise-sunset, moonrise-moonset, phases of the moon, appearances of planets, and so forth. A record is also kept of festivals and anniversaries and daylight saving, so that enquiries in that respect may be answered.

Apart from research work, another function of the Observatory is its educational service to the public. Saturday evenings, from April to October inclusive, are set aside for this purpose, and visitors are given an opportunity to view celestial objects through the 15-inch telescope and to learn something about the operation of the Observatory and its research. During the remainder of the year provision is made for groups to visit the Observatory at pre-arranged times. During 1965 there were slightly more than 100 groups comprising some 3,100 persons. With the upsurge of popular interest in astronomy, due in part to the advances in space sciences, the Observatory's educational facilities have been broadened, and the services given have increased manyfold.

STELLAR PHYSICS

Considerable progress was made at the Dominion Radio Astrophysical Observatory, Penticton, in studies of the radio emission from our own galaxy and remote radio galaxies. Three major radio-telescopes are now in full operation at the Observatory.

The main program with the 84-foot parabolic telescope continued to be the survey of the sky at frequencies near 1420 Mc/s. The survey will provide measurements of the intensity of point sources and a map of the sky with a resolution of 36′ of arc. The development of a 100-channel receiver for hydrogen-line studies with this telescope was brought near completion. This receiver will drastically reduce the observing time required for studies of neutral hydrogen clouds in our own and external galaxies.

Early in the year the remaining portions of the 22-Mc/s array were brought into operation. The completed instrument is a T-shaped array with the crossbar about 4/5 of a mile long and a collecting area of 16 acres. In July a full sky survey was begun, and observations of 160 point sources have now been completed.

The 10-Mc/s array, which is similar to the 22-Mc/s array and which is a joint undertaking with the University of Cambridge, was used to map a substantial part of the galactic background and to measure the intensities of approximately 50 sources, including some quasars. Observations at 10 Mc/s are much more difficult than at 22 Mc/s because of ionospheric effects and the presence of man-made interference.

D.R.A.O. personnel continued to operate the 2700-Mc/s solar radio-telescope for the National Research Council.

The meteor observatories in Alberta continued their program of meteor photography using both cameras and meteor spectrographs to study the interaction of meteors with the upper atmosphere. A moderately strong return of the Leonid shower in November yielded several fine records of the decay of light during the first two seconds after the passage of the meteor.

A diamond-drill hole was successfully sunk to a depth of 2,385 feet below the ice of West Hawk Lake, Manitoba, and preliminary studies of the recovered core reveal severe shock effects which establish this lake as another old meteorite crater.

In an attempt to settle the serious conflict between the accepted values of the size and mass of the planet Pluto a theory was evolved, based on measures and calculations performed in Ottawa, of a possible astronomical event which could settle the problem. Many observatories in North America attempted the observations and the result established a limit to the diameter of Pluto which showed that the conflict must be due to an erroneous value of the plant's mass.

At Ottawa, the solar magnetograph, an instrument designed to map automatically the magnetic fields around sunspot groups was successfully put into operation. Further developmental work is continuing on problems of calibration and image guiding.

The Solar Flare Patrol continued operation throughout the year with the assistance of a grant from the National Aeronautics and Space Administration. Routine observations of solar activity were transmitted to data centres in the U.S.A., France and the U.S.S.R.

A solar site-testing project was initiated to test the suitability of Mount Kobau, the site chosen for the Queen Elizabeth II telescope, as a location for solar instruments. A contract was let for two special telescopes to be used for this purpose.

SEISMOLOGY

Further progress was made in the program of establishing a modern network of uniformly instrumented seismological observatories throughout Canada: new observatories were commissioned at Baker Lake, N.W.T., Flin Flon, Manitoba, and Great Whale River, Que. In addition the instrumentation at Seven Falls, Que., and Penticton, B.C., was brought up to standards, and a vault constructed at Suffield, Alta. A local seismic station at Shawinigan Falls, Que., was closed down. The Department now operates 22 first-order stations and three second-order local stations.

A sequence of more than one thousand micro-earthquakes occurred in the western Arctic archipelago in 1965 and is under investigation. In eastern Canada the largest shock reached magnitude 5 and occurred 30 miles from Moosonee, Ont. on December 19. In western Canada, the Seattle earthquake of magnitude 6.5 which occurred on April 29 was felt in British Columbia from Victoria to Trail. This earthquake triggered on departmental equipment in Victoria the first strong-motion record ever obtained in Canada, an invaluable record for structural engineers engaged in the design of structures proof against earthquake damage.

Considerable progress can be reported in the study of Canadian seismicity, and in cataloguing Canadian earthquakes. Another increase occurred in the requests for advice from and results of the Division in estimating seismic risk for engineering, safety and insurance purposes. The strong-motion-instrumentation program on the West Coast was pursued and six locations have now been instrumented.

International cooperation in teleseismic epicentral determination continued, and the first seismological bulletin produced automatically from the electronic computer was produced in manuscript form.

The medium-aperture seismic array at Yellowknife, N.W.T., was maintained in operation, and steps taken to improve the lightning protection. An array-processing analysis centre was brought into operation, and before the end of the year both earthquakes and one nuclear underground test explosion at Anchitka in the Aleutians were processed automatically in the Department. Great progress was made in the automatic editing of events.

Fundamental studies in earthquake seismology continued with the use of high speed computers, and data acquired automatically on magnetic tape recorders when necessary. A definitive catalogue of automatically determined earthquake-mechanism solutions was sent to press, and research continued on surface waves, the determination of earthquake mechanisms using shear waves, crustal reverberation using the character of the compressional waves, and instrumental problems. A controlled experiment on the character of compressional-wave arrivals from distant earthquakes was performed in western Canada using automatic wide-band seismic observatories.

The crustal-seismic-refraction group continued its studies on anomalous crustal characteristics in the western Arctic archipelago in cooperation with the Polar Continental Shelf Project. The same group cooperated in the Hudson Bay experiment of the Department. In addition, a seismic-refraction program in the interior plateau of British Columbia was completed. This section was reorganized during the year.

The heat-flow section made geothermal measurements in eleven boreholes in six provinces of Canada, reconstructed a vastly improved apparatus for measuring the thermal conductivities of rocks, and selected sites for the proposed drilling program during 1966 in an interesting area of northern British Columbia.

GEOMAGNETISM

A two-month 83,000-mile airborne magnetic survey, extending from Baffin Bay to the Finno-Russian border, was carried out by scientists of the Division of Geomagnetism, operating the three-component airborne magnetometer developed at the Dominion Observatory in a chartered DC-6 aircraft. The intensity and direction of the geomagnetic field were recorded continuously while the aircraft flew in a pattern of parallel lines spaced 100 miles apart over Greenland and the Norwegian Sea, and 20 miles apart over Iceland, Norway, Sweden, Finland and Denmark. The survey of the last four countries was made at their request, and the extra flying costs for this work were paid by the respective governments. The whole operation was designed as a contribution to the World Magnetic Survey, an international project which will result in greatly improved knowledge of the earth's magnetic field through measurements made by many countries during the present sunspot minimum, while disturbing magnetic storms are rare. Of particular interest to geophysicists are the results from a detailed survey over the Mid-Atlantic Ridge southwest of Iceland, and from the survey of Iceland itself, which has not had a systematic magnetic survey before.

In Canada, careful measurements were made at 16 repeat stations, mainly in the Northwest Territories, in a continuing program for the determination of the slow change in the magnetic field from year to year.

Five charts were published, at a scale of 100 miles to the inch, showing the elements of the geomagnetic field and their annual change, as of January 1, 1965, for all of Canada and the neighbouring waters. New methods were developed for fitting two-dimensional polynomial expressions to the results of magnetic surveys, in order to make better use of electronic computers in the production of magnetic charts. These methods were successfully applied to data from the 1963 airborne magnetic survey of the Canadian Arctic.

Time variations of the geomagnetic field were recorded continuously at eight permanent magnetic observatories—Alert, Mould Bay, Resolute Bay, and Baker Lake,

all in the Northwest Territories; Great Whale River, in northwest Quebec; Meanook, 100 miles north of Edmonton; Victoria, B.C.; and Agincourt, near Toronto. Four temporary recording stations were operated for four months in the vicinity of Baie St. Paul, Que., which is magnetically conjugate to an observatory in the Antarctic. Recordings made simultaneously at the six locations are being analyzed to learn more about the transmission of magnetic disturbances along the field lines joining conjugate points.

Portable recording magnetometers were also used, often in conjunction with earth-current recording equipment, to investigate local anomalies in the time variations of the geomagnetic field. Natural magnetic disturbances induce electric currents in the crust and upper mantle, which produce magnetic and electrical fields at the earth's surface. Theoretical models of various underground distributions of electrical conductivity are tested in an attempt to explain the observed fields. The electrical conductivity of rock is closely related to its temperature, and hence to its elastic properties. Thus correlations are sought with other geophysical disciplines, such as seismology and heat-flow studies. During 1965, investigations of this type were carried out in British Columbia and Alberta, in the Queen Elizabeth Islands, and in Ontario.

Interesting results have been obtained in palaeomagnetic measurements of rock samples from the Silurian Bloomsburg red beds, in a study of deformation of the great bend in the Appalachians which occurs in Pennsylvania. Unusually strong and stable secondary magnetizations have been acquired during the Appalachian orogeny, and disentangling the magnetic history of these rocks presents a challenging problem.

GRAVITY

Direct evidence about the earth's crust and upper mantle is obtained from measurements of gravity. The particular contribution of gravity lies in the discovery and mapping of mass distributions within the earth. Gravity surveying is both rapid and relatively inexpensive as a geophysical aid to the understanding of the surface geology and the deep structure of the continents. The Branch's regional gravity-mapping program, which includes gravimeter measurements over the continental shelves and inland waters, has been accelerated so that currently about 8,000 observations, spaced at eight-mile intervals, are added yearly, covering an area of some 300,000 square miles. In 1965 gravity field investigations were carried out both in southern Canada and in the Arctic regions using helicopter and fixed-wing-aircraft transportation, as follows:

(1) A regional gravity investigation of the Precambrian areas of northern Manitoba was completed between latitudes 54°N and 60°N and included a detailed study of the boundary of the Churchill-Superior geological provinces.

(2) Field observations were completed for a geophysical study of basic intrusions in the Stoney Rapids area of northern Saskatchewan. This investigation is being carried out in cooperation with the Department of Mineral Resources of the Province of Saskatchewan.

(3) As part of the Polar Continental Shelf Project, gravity measurements were made in Somerset and Prince of Wales islands in a study of the Boothia Arch and neighbouring sedimentary basins.

(4) The Branch's investigation of a northerly-trending anomaly belt in northern Ontario known as the Kapuskasing Gravity High was continued with detailed investigations over a number of alkaline intrusions which lie near the axis of the gravity high. Regional gravity measurements were made also to delineate the southern extension of this belt.

(5) An outstanding achievement was the completion of a reconnaissance gravity survey of Hudson Bay. Some 800 underwater gravity measurements were obtained along selected traverses during the Department's cooperative

oceanographic and geophysical investigation of Hudson Bay during the summer of 1965.

Excellent progress has been made in structural interpretation and in theoretical studies to evaluate and develop methods of quantitative analysis of gravity data. Crustal studies using gravity data were completed for the Alexandria area of southern Ontario, for Lake Superior, for the Muskox Ultrabasic Intrusion in the Northwest Territories, for an extensive area of Quebec and Laborador, and for the Island of Newfoundland. A number of difficult problems have been solved, which will facilitate application of gravity methods to structural studies of mountainous areas, to problems of isostasy and geodesy.

The Observatory continued its study of ancient meteorite craters by structural and topographic surveys, geophysical techniques, diamond drilling and laboratory analyses of drill-core and surface samples. In the laboratory, installation of new equipment was essentially completed with the addition of mineral-separation, diffractometer, and photomicrographic units. Field investigations were carried out at Pilot and Nicholson Lake in the Northwest Territories, and diamond-drilling programs at the Deep Bay crater in northern Saskatchewan and at West Hawk Lake in Manitoba.

The Branch continued its work of previous years to maintain gravity standards in Canada and to contribute to the international program of establishing a world network of first-order gravity-control stations, as recommended by the International Union of Geodesy and Geophysics. A series of precise measurements were made at nine control points extending over the latitude range of Canada between Montreal, Que., and Alert, N.W.T. Long-range gravity ties were made to connect this line of control stations with the European Gravity Control Network.

Research in the development of gravity-measuring devices continued. A program to measure the gravitational effect of earth tides has been initiated as a contribution to the Upper Mantle Project.

DOMINION ASTROPHYSICAL OBSERVATORY

The studies of the Observatory continued in 1965 with some shift of emphasis as projects were completed, and new work begun, on current astronomical problems. The work, generally speaking, is undertaken to advance our knowledge and understanding of the physical nature of heavenly bodies, their origin and evolution, and of the natural laws prevailing outside the earth. The Observatory's chief role in this task is to make observations of the distances, motions and masses of stars, of the chemical and physical properties of the atmospheres of stars and planets, and of the material between the stars. Original observations are made mainly with spectroscopes attached to the 72-inch and 48-inch reflecting telescopes.

Observations were made on 175 nights with the 72-inch telescope and on 168 nights with the 48-inch telescope, resulting in a total of 1,910 photographs of stellar and planetary spectra. These photographs are subjected to measurement by special instruments and devices to yield the data of interest. Much of this equipment is unique and is designed and built in the Observatory shops, as are improved optical and mechanical auxiliaries to the telescopes.

During the year new data were acquired on the chemical composition of stellar material as revealed by spectroscopic studies. Anomalous abundances of several elements, e.g., hydrogen, carbon, lithium, strontium, etc., were found to exist in certain stars. These results are believed to have a connection with the evolutionary processes. Studies were made of the optical properties of the dust and gas in interstellar space, giving some information on the composition of the material. Sizes and masses of some stars were determined through observation and analysis of their orbital motions.

A group of rapidly varying high-temperature stars was observed intensively, and a long accumulation of such observation was analyzed. These objects were shown to have a special significance in the study of stellar evolution, because of their short periods of variation.

Distances to some 700 distant high-temperature stars were determined as the result of a long program of observation. These data together with star velocities formed the basis of a determination of the rotation of our galaxy and the distribution of stars in the sun's neighbourhood.

Some 26,000 persons visited the Observatory, 3,768 persons attended 36 public observation periods and 34 educational and study groups were given special tours of the Observatory. Astronomical information was supplied to meteorological and airport authorities, and a large volume of enquiries from business firms, the public, and the news services was received and answered

Geographical Branch

The work of the Geographical Branch has two objectives: systematic research in geography, and specific research aimed directly at serving present national needs and future national development. The first objective is typified by the geomorphological and glaciological studies being carried out in the Canadian Arctic and by the theoretical studies being made in the field of economic geography. Examples of the second objective are the many projects undertaken at the request, and with the cooperation, of such government agencies as the Agricultural Rehabilitation and Development Act (ARDA), the Emergency Measures Organization (EMO), the Atlantic Development Board (ADB) and the St. Lawrence Seaway Authority.

In recognition of the need for a national approach to the direction of geographical research in Canada, and in order to make the best use of available geographical talent and facilities, the National Advisory Committee on Geographical Research, for which plans had been made in 1964, was formally established by Order-in-Council on 14 April 1965 (P.C. 1965-693). On 5 November 1965 it held its first meeting which was addressed by the Assistant Deputy Minister of the Department of Mines and Technical Surveys. The membership of the committee, which may be expanded as need arises, will represent not only the geography faculties of Canadian universities but also government departments whose needs and interests are related to geographical research and to agencies and commercial concerns outside the federal government. Grants-in-aid to the value of $25,000 will be awarded in 1966 on the recommendation of this committee for the purpose of promoting geographic research in Canada.

Considerable reorganization was effected during 1965 in the Administration Section of the Branch in order that it might serve more adequately the demands resulting from actual and projected increases in staff and from expanded research.

The Geographical Bulletin, the major publication of the Branch, was put on a quarterly basis and its format completely reorganized. A small scientific editing group was attached to the Administration Section to facilitate the handling of papers for the Bulletin, and an editorial board was established to which material may be referred before publication. The board will consist of 12 senior scientists from universities and government agencies in Canada, United States and the United Kingdom, each a recognized authority in his field.

The book and map libraries were amalgamated at the administrative level. In view of the increasing emphasis now being placed on the Canadian aspect of the work being done, the large collection of foreign topographic maps formerly collected by the Branch was transferred to the Public Archives of Canada. All Canadian maps and foreign special maps have been retained.

The Data Analysis and Computer Programming Section was formally established within the Administration Section to serve the growing needs of economic and physical geographical research.

The research program in glaciology and geomorphology, planned as part of Canada's contribution to the International Hydrological Decade, was actively carried forward by field parties during the summer. However, with the establishment of the

Water Research Branch in 1965, part of the glaciological program and personnel of the Geographical Branch will be transferred to it early in 1966. Excepted from this transfer will be the considerable glaciological program already under way in the Arctic.

In addition to maintaining close liaison with the university geography faculties in Canada throughout the year, the Branch employed some sixty graduate and undergraduate geography students during the summer in field and office projects. Eight faculty members from geography departments in Canada, England and Holland were temporarily taken on strength for work on short-term research programs. Three special projects requested by the Emergency Measures Organization (EMO) were contracted to faculty members in Canadian universities.

PHYSICAL GEOGRAPHY

The 1965 research was the most extensive this division has yet undertaken, with major field projects under way in Baffin Island, the Cordilleran region of southern British Columbia and Alberta, the Cypress Hills area of Alberta, and in the Mackenzie Delta.

Baffin Island

This was the fifth consecutive summer in which field work was carried out on Baffin Island by the Branch. A wooden building was erected at Inugsuin Fiord to serve as a permanent field base, providing office, storage and accommodation. The 1965 Baffin Island team totalled 28 geographers and assistants.

Mass balance studies of the Barnes Ice Cap were continued and were also expanded to include work on the southern lobe. Hydrological and geomorphological studies of a glacial meltwater stream were continued for the third summer at Lewis River. A detailed mass balance study of a small mountain glacier near the Inugsuin base camp was initiated as part of the Branch contribution to the International Hydrological Decade. Geomorphological observations were made along Clyde Fiord, the Clyde River valley and in the vicinity of Generator Lake. Two field parties carried out extensive studies of late-glacial moraines and marine features on the west coast of Baffin Island, and three parties made similar studies on the east coast. In the former area, emphasis was on the glacial geomorphology of the outer coast with particular stress on the old deposits of the area. Shells from some of the beds studied have been dated as more than 50,000 years old.

Cordilleran Region

The second part of the Branch contribution to the International Hydrological Decade is being undertaken in this area of southern British Columbia and Alberta. Permanent huts were erected at three glaciers to facilitate future work, and a field party of seven geographers and assistants began detailed mass-balance studies on three small glaciers and collected additional data on one other. All these glaciers lie along a profile extending from the maritime slopes of the Coast Mountains in British Columbia to the arid eastern flanks of the Rocky Mountains in Alberta. Detailed studies of accumulation and ablation have been completed for the three glaciers and will be related to discharge measurements being made for the relevant meltwater streams and to meteorological records made on the glacier as well as those available from the Meteorological Service, Department of Transport. Sediment transportation of these meltwater streams is also being studied. Plans for future operations include studies of the glacial geomorphological processes evident in each area.

Cypress Hills, Alta.

This new research project places particular emphasis at present on the study of late-glacial deposits in this area of southeastern Alberta and on their periglacial features. Observations were also made of the summit surface of the hills, with special reference to the soil types and their distribution. Reconnaissance was completed for a study to be initiated in 1966 on the microclimatology of the area, and future plans include research into both the economic and historical geography of the region. The 1965 party totalled nine geographers and assistants.

Mackenzie River and Delta

Observations of the pattern of ice break-up were again made on the Mackenzie River in May and June, and detailed studies of geomorphological features and processes evident on the islands along the northern fringe of the delta were continued.

Channels of the Arctic Archipelago

Mapping of types and distribution of sea ice in the channels of the Queen Elizabeth Islands was continued in cooperation with the Polar Continental Shelf Project.

Headquarters Projects

Several studies not involving field work were carried out in Ottawa. These include, (1) a study of the heat budget of part of the St. Lawrence Seaway, undertaken in cooperation with the St. Lawrence Seaway Authority; (2) the compilation and publication of a map of glacier distribution in southern British Columbia and Alberta.

In addition, the following studies, involving computer programming or the use of the facilities of the newly expanded Geographical Branch geomorphological laboratory, were completed: (1) a study of till-fabric data; (2) a study of tide-gauge data; (3) an analysis of run-off in the Canadian drainage basins; (4) a study of the distribution of cirques and cirque glaciers in Labrador.

ECONOMIC GEOGRAPHY

ARDA Projects

Land-use surveys, initiated in 1963 at the request of the Agricultural Rehabilitation and Development Act (ARDA) and carried out in close cooperation with its administration, continued during 1965. The project is now two-thirds completed, and forms part of activities of the Economic Geography Division. Under existing arrangements, manuscript land-use maps of six provinces (Ontario, Quebec and the Maritime Provinces) are being compiled by the Branch on a scale of 1 :50,000. For the three western provinces a similar survey is being undertaken by the geography departments of the universities of Saskatchewan and Alberta, Spartan Air Services and the British Columbia Department of Agriculture, with the Geographical Branch acting as general coordinator of the project. In all cases the mapping is based on air-photo interpretation supplemented by checking in the field.

In eastern Nova Scotia a land-use project—involving research on farm consolidation, woodlot development, shoreline studies and tourist and recreational possibilities—is being conducted by the Branch at the request of ARDA.

The economic survey of the forestry and fishery resources of the west coast of the Great Northern Peninsula of Newfoundland, initiated in 1964, was completed during 1965.

Prairie Railway Rationalization Impact Study

This project, initiated in 1964 to examine on a theoretical basis the economic and social effects which might result from the abandonment of selected rail lines, continued

to make progress during 1965 and drew support not only from the three originally interested federal departments but also from an ever-widening field of users and of contributors of the information. These now include: the federal Departments of Agriculture, Transport, Industry, Trade and Commerce; certain provincial planning agencies; the Prairie grain companies; the railway companies and the economics and geography departments of practically every Canadian university. Eighteen of the proposed 100 maps have been completed and the data gathered are being subjected to computer analysis to provide answers to the wide range of queries and problems which may result from the rationalization program.

EMO Project

The study of the physical characteristics and land-use practices in 14 major Canadian cities, initiated in 1963 at the request of the Emergency Measures Organization (EMO), continued in 1965. Work on the Vancouver section was completed and the maps published (see Regional Geography), compilation of the field-work data already gathered for the map series of Toronto and Montreal continued, and the surveys of Windsor and Ottawa, the fourth and fifth cities in the program, were completed. Information is being compiled for reproduction on maps on a scale of 1:25,000. Maps and data are made available to all agencies to whom they may be of value and have already been used by planning and research agencies at the provincial, municipal and urban levels in those cities for which survey work is already completed.

Other Projects

Further programs continued during the year include: (1) a study, which has received support from the National Harbours Board, on the origin and destination of foreign freight routed through Halifax, N.S., and St. John, N.B.; (2) a study of the pattern of migration from the farms in the Prairie Provinces; (3) a study of land-use patterns in the Niagara Peninsula; (4) a study, made at the request of the Atlantic Development Board, of trade centres and trade areas in the Atlantic Provinces; (5) the preparation of a resources map of the Atlantic Provinces at the request of the Atlantic Provinces Economic Council.

In cooperation with the Department of Industry a computer mapping program has been initiated by which industrial statistics will be projected directly onto base maps and from which analyses of the industrial structure of Canada can be made.

Two land-use studies for which the field work has been completed and manuscripts are nearing completion deal with the rural area covered by Renfrew County, Ontario, and the urban-rural complex of the Ottawa region.

TOPONYMY DIVISION

The Toponymy Division, which is responsible for investigation of the origin, usage and propriety of all geographical names in Canada, maintains name records and advises the Canadian Permanent Committee on Geographical Names on matters of nomenclature. It is also responsible for advising on geographical terminology and for the production and maintenance of the Gazetteer of Canada.

During 1965, the Division investigated nearly 24,000 names, of which 2,500 new names were officially approved. The nomenclature was verified for 370 map-sheets, and more than 580 inquiries concerning geographical names or terms from members of the Committee, the mapping agencies, other government departments and the general public were answered. Progress continued on the Gazetteer of Newfoundland. The New Brunswick and Alberta Gazetteers were reprinted. A revision of the Gazetteer of British Columbia was almost completed by the end of the year and, in collaboration

with the province, considerable progress was made on the Gazetteer of Quebec. Supplements to the Gazetteer of Canada were issued at regular intervals. A report on the names of Renfrew County, Ontario, was completed and field work conducted elsewhere in eastern Ontario.

The Canadian Permanent Committee on Geographical Names at its meeting in Ottawa in October was addressed by the executive secretary of the United States Board on Geographic Names. During the year, the Committee approved the naming of features for Sir Winston Churchill, President John F. Kennedy, General William Booth (founder of the Salvation Army), and Superintendent Henry A. Larsen, RCMP.

REGIONAL GEOGRAPHY

The name of this division was changed in 1965 from Cartography Division to Division of Regional Geography in order to give recognition to the amount of geographical research involved in its present major project, the compilation and publication of the 1967 Atlas of Canada, and in future projects of regional geography. The division comprises two sections: the Research Section and the Cartographic Section, the latter responsible for all cartography originating in the Branch.

Atlas of Canada

Base maps for the atlas were prepared, manuscripts for about one-third of the atlas maps were compiled, and arrangements were made for the collection of most of the data still required.

Urban Characteristics of Major Canadian Cities

This project is being handled by the Branch on contract from the Emergency Measures Organization, and collection of the material required for the maps is being handled by the Division of Economic Geography. The Vancouver section of the project, which comprises 32 maps, was completed in 1965 with the printing of the final 23 multicolour maps on a scale of 1:25,000. Compilation was begun on material collected for the 62 maps which will comprise the Toronto series.

Prairie Railway Rationalization Program

This project calls for about 100 maps in colour, of which 18 were compiled and printed in 1965, while the remainder were in various stages of compilation and reproduction.

Varied Projects

During 1965 a total of 44 multicolour maps were completed, printing of these maps being done by the Surveys and Mapping Branch.