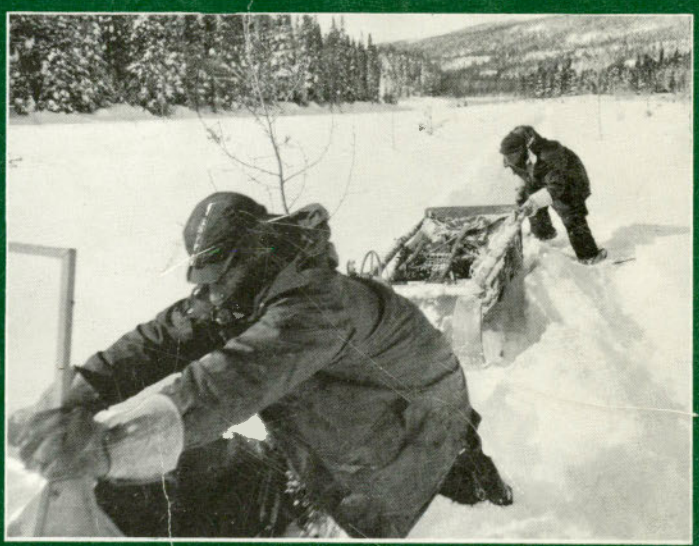
ANNUAL REPORT

MINES AND TECHNICAL SURVEYS

CALENDAR YEAR 1963



Annual Report

Department of Mines and Technical Surveys

Calendar Year
1963

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Ottawa, Canada
1964

To His Excellency General Georges P. Vanier, D.S.O., M.C., C.D., Governor General and Commander-in-Chief of Canada.

MAY IT PLEASE YOUR EXCELLENCY :

The undersigned has the honor to lay before Your Excellency the Annual Report of the Department of Mines and Technical Surveys for the calendar year 1963.

Respectfully submitted,

WILLIAM M. BENIDICKSON,
Minister of Mines and Technical Surveys

The Honorable William M. Benidickson,
Minister of Mines and Technical Surveys, Ottawa.

SIR :

I have the honor to submit the Annual Report of the Department of Mines and Technical Surveys covering the calendar year 1963.

W.E. VAN STEENBURGH
Deputy Minister

MINISTER : The Honorable William M. Benidickson

Deputy Minister : Dr. W.E. van Steenburgh

Assistant Deputy Minister (Research) : J.-P. Drolet

Director, Surveys and Mapping Branch : S.G. Gamble

Director, Marine Sciences Branch : Dr. W.M. Cameron

Director, Geological Survey of Canada : Dr. J.M. Harrison

Director, Mines Branch : Dr. John Convey

Dominion Astronomer : Dr. C.S. Beals

Director, Geographical Branch : Dr. N.L. Nicholson

FRONT COVER :

Departmental activities include skin-diving through the ice for oceanographical research, display sets of Canadian minerals collected and sold by Geological Survey of Canada, and mid-winter topographical surveys in Labrador.

BACK COVER :

This interesting pattern, almost like an air view of a bombed-out city, is a photograph enlarged 1,000 times of a rapidly cooled casting of nodular iron. Nodular iron is important because it has properties superior to those of normal cast iron, the excess carbon forming balls (nodules) rather than flakes when rapidly cooled.

Contents

Introduction 1

Surveys and Mapping Branch 8

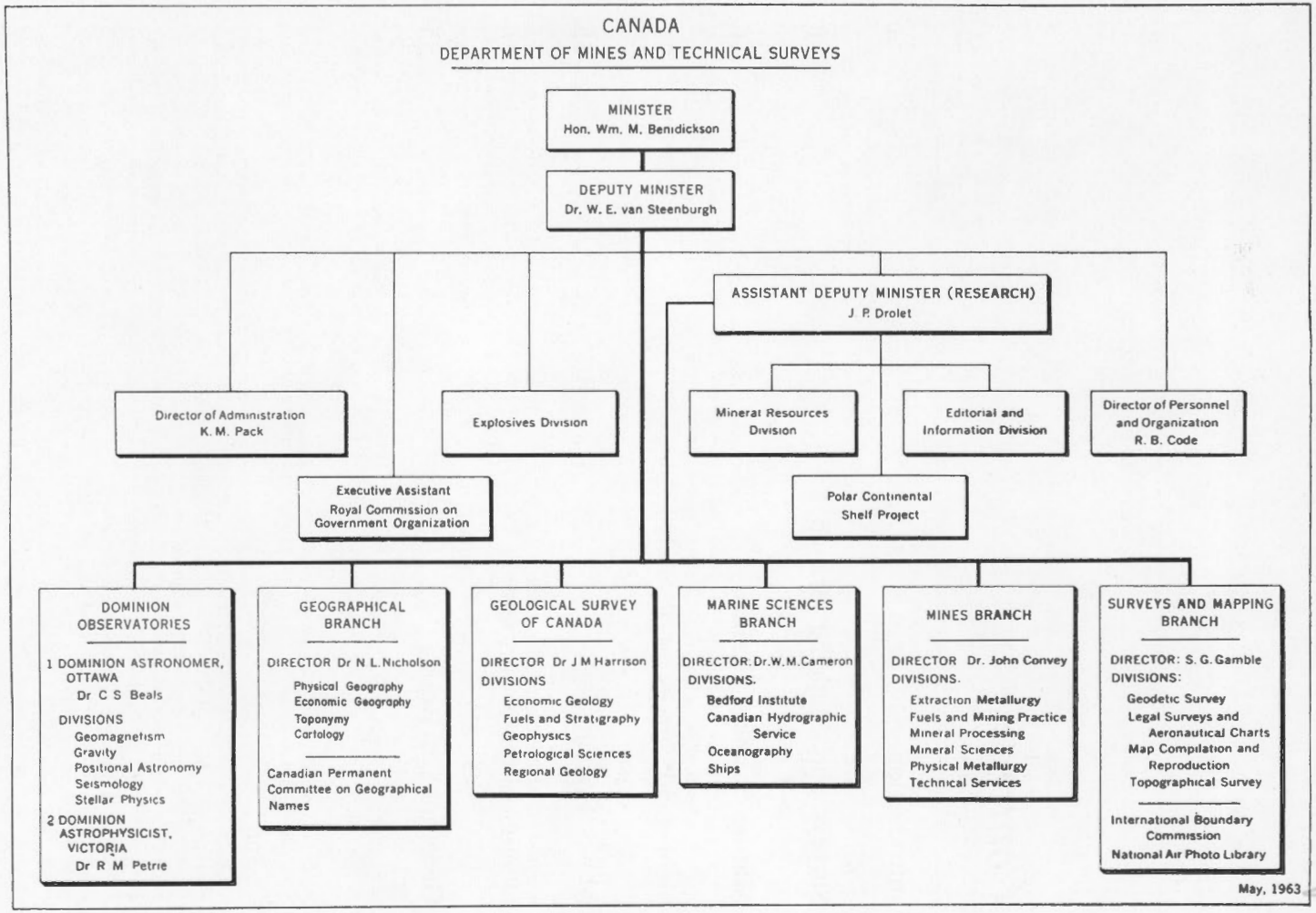
Marine Sciences Branch 16

Geological Survey of Canada 21

Mines Branch 35

Dominion Observatories 46

Geographical Branch 55


CANADA
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Dr. W. E. van Steenburgh
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Editorial and Information Division
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Polar Continental Shelf Project
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Gravity
Positional Astronomy
Seismology
Stellar Physics
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Geodetic Survey
Legal Surveys and Aeronautical Charts
Map Compilation and Reproduction
Topographical Survey
International Boundary Commission
National Air Photo Library
May, 1963

Introduction

For the Department of Mines and Technical Surveys, 1963 was a year of further scientific and technical progress, as well as intensive organizational evaluation and planning to meet the changing research and survey needs of the Canadian economy.

The value of mineral production in Canada rose to almost three billion dollars during the year, a new record, and with this general advance on the economic front went a growing demand for scientific investigations covering all steps in the extraction, use, and marketing of minerals and their derivatives.

Advances and innovations in work methods and instruments characterized surveys and field explorations, and, though many units suffered from shortage of staff, deeper penetration into the field of fundamental research marked laboratory and observatory work.

In the remote Arctic the staff of the Polar Continental Shelf Project carried out its fifth field season and continued to advance on a broad front in the central part of the Queen Elizabeth Islands, covering land, sea, and sea bottom with closely spaced hydrographic, geological, gravimetric, seismic, geomagnetic, glaciological and topographical tests and surveys.

The Surveys and Mapping Branch helped to open new vistas in surveying by cosponsoring a seminar on air-photo interpretation and by placing generally more emphasis on air photography in mapping, with the collaboration of private companies. The aerodist, a new airborne device for electronic distance measurement, was used successfully over land and sea. It has not only enabled surveyors to shorten work in difficult terrain from years to weeks, it has also provided the first absolutely accurate measurements beyond the bounds of sight, such as between Sable Island and the mainland.

In Marine Sciences, oceanographic research continued to expand and strengthen, and new marine investigations were started in the fields of geophysics, sea ice, theoretical studies, and predictions. The new Bedford Institute of Oceanography operated at high pitch and began to attract international interest and acclaim. There was further integration of oceanographic and hydrographic work.

The Geological Survey continued to press its mapping of Canada at reconnaissance scale, 65 per cent of the entire country now having been covered by geological maps at scales no smaller than one inch to eight miles. A notable development in recent years has been special laboratory investigations of fundamental geological processes undertaken by a small but growing staff, along with the development of techniques and equipment.

Among the outstanding activities of the Mines Branch were advanced pilot-plant tests on petroleum refining, with special attention to low-grade oils and tar sands, the use of radiotracers to analyze the processes in copper furnaces, and the successful development of a method to extract enough vanadium from petroleum to supply the entire Canadian demand.

The total solar eclipse over Canada on July 20, 1963, attracted much attention among astronomers here and abroad, and was observed carefully by the Dominion Observatories from an airplane flying along the path of the eclipse. The seismograph array set up at Yellowknife, N.W.T., by the National Defence Department and British scientists in 1962, as a means of studying the earth's structure and detecting atomic tests, was taken over by the Dominion Observatories in 1963.

Scientists from the Geographical Branch continued to study land and ice forms and ancient plant remnants in the Arctic to obtain a better picture of the geographical history of that remote portion of Canada. Geographers also collaborated with the administration of the Agricultural Rehabilitation and Development Act in mapping land use and studying specific socio-economic problems.

There is no mention in this report of the normal ancillary activities — administrative, personnel, and informational work — but it may fairly be said that in many respects they provide the foundation of the scientific and technical tasks carried out by the Department of Mines and Technical Surveys.

POLAR CONTINENTAL SHELF PROJECT

The Polar Continental Shelf Project is a special continuing effort of the Department, devoted primarily to the study of the large continental shelf underlying the Canadian portion of the Arctic Ocean, as well as to the study of the Arctic islands. To carry out its task, the Project relies partly on its own personnel and partly on personnel drawn from the various branches of the Department.

From 1959, the year the Project was started, to 1963 the work has been concentrated between Meighen Island and Brock Island, extending about 200 kilometers both north and south, supplemented by individual studies throughout the Queen Elizabeth Islands.

Field work in 1963 was coordinated mainly from the base of Isachsen on Ellef Ringnes Island. The central section of the continental shelf and adjacent islands was investigated by a party of 79 persons; another 22 persons were employed in the transportation of supplies, and 13 men worked on the construction of camps.

Following are the highlights of the 1963 field season :

Hydrography — For the first time, hydrographers with the Project carried out a standard hydrographic survey entirely by airborne methods. This was done by towing an echo sounder by a helicopter, a technique that had been perfected by field trials in previous years and which, hydrographers hope, will be developed further so that the towed equipment will consist of a single piece rather than two. The area thus surveyed is Hell Gate, between Ellesmere and North Kent islands.

Geology — Geological parties continued to take cores and grab samples of sediments on the sea bottom to study the history of sedimentation. They also explored inshore sediments for imbedded fossils, so as to clarify the biological record of the area. In terrestrial geology, gypsum-anhydrite bodies were studied in several localities.

Gravity — Scientists made regional gravity surveys on several islands of the Queen Elizabeth Archipelago; they also contributed to the geological investigation of gypsum bodies mentioned above, as well as to glaciological studies.

Seismic Surveys — In an interesting survey, seismologists used half-track trucks to travel over sea ice on a 650-kilometer traverse, drilling holes through the ice to lower and set off explosions along the sea bottom. The survey, which took two years, has produced a record of seismic vibrations that tells much about the geology of the earth's crust beneath the Arctic islands.

Geomagnetism — Geomagnetists explored an intriguing magnetic anomaly in a 30,000-square-kilometer region of Prince Patrick and western Melville islands. The absence of short-term fluctuations in the vertical component of the magnetic field seems to be due to a thinning of the crust under the region and the rise of hot mantle material.

Glaciology — Glaciologists studied the processes going on in the icecaps on western Melville Island and on Meighen Island.

Sea-ice Studies — Several years' study of the behavior of sea ice in the Arctic Ocean has now enabled scientists to forecast probable ice conditions in the Arctic shipping routes nine months in advance with fair accuracy. The paths followed by large ice islands continued to draw much interest; some of the islands have been traced right through the island-maze of the archipelago.

Topographical Surveys — Control surveys to calibrate the accuracy of the electronic network were run across the sea ice from Borden Island — a unique experiment not possible over open waters. Control was extended along several islands, partly as a contribution to hydrographic, seismological, and glaciological studies.

Plans for the 1964 field season include a program of geothermal heat-flow measurements on an icecap and the ocean floor, marine biological studies, and a photographic inventory of major glaciers, along with the extension of studies described earlier.

MINERAL RESOURCES DIVISION

Mineral production in Canada in 1963 rose about 4.6 per cent in value to a record $2,976 million from the previous peak of $2,845 million in 1962. The value of output of each of the three sectors of the industry — metals, industrial minerals and mineral fuels — registered modest increases to new highs, with mineral fuels advancing the most. The ten leading minerals, in terms of value of output, accounted for nearly 80 per cent of total output, essentially the same as in 1962. Values were higher for copper, iron ore, zinc, asbestos, oil, natural gas and structural materials; they were lower for gold, nickel and uranium.

Mineral developments in Canada during 1963 continued to be widespread and diversified, a pattern that has been characteristic of the industry for many years. It was not a year of substantial growth in output but rather one of preparation for increased production of many minerals through continued development of large projects and the building of new or expanded facilities at widely scattered locations from coast to coast.

During recent years, the efforts of the Division have been divided about equally between two categories which might be classified broadly under the headings : basic resource-economic research and advisory resource-economic research. First, the Division conducts field and office investigations and research which result in a regular series of mineral resource reports. This work provides an essential base for the second category of responsibilities, that of providing informed assessments and advice to various departments and agencies of government on mineral and related problems.

Basic Resource-Economic Research — The Division's investigations into the molybdenum resources and industry of Canada culminated in the publication of a *Mineral Report on Molybdenum*. Similar investigations into Canadian silver, chromium, iron ore, lead and zinc, copper and petroleum resulted in the publication of reports on these important Canadian resources.

During the year, studies continued on the uranium, nickel, zinc and beryllium resources and industries of Canada. A study made of open-pit mining practice in Canada was completed during the year and sent to the Queen's Printer. As part of the Division's continuing study of mining technology, work commenced on a survey of Canadian underground mine haulage. An interesting study of world iron-ore trade, which has an important bearing on the development of Canadian iron ore, culminated in the release of a graphically illustrated map entitled *Iron Ore Trade — Canada and the World.*

Research continued on the impact of European developments on Canadian minerals; one of the results of this research was the publication of a report entitled *The Canadian Nonferrous Mineral Industry in Relation to the European Economic Community.* The fundamental basis for all these studies is a comprehensive program of field investigations within Canada and, where foreign mineral supply and demand have important implications for Canada, outside Canada.

Advisory Resource-Economic Research — The areas in which the Division staff of 25 mineral specialists provide advice are many and varied, running the entire gamut of minerals in their regional, national and international aspects. Illustrative of special mineral services provided during the year was the third annual study and analysis for the St. Lawrence Seaway Authority of iron-ore, coal and coke, and petroleum traffic in 1962, with forecast to 1970, through the St. Lawrence Seaway. The Division continued to provide analyses and advice on such related matters as roads, docks, airstrips, etc., in relation to mineral resource projects, for other agencies of government. The Division made economic and market analyses of tungsten, vanadium and thorium materials to provide information on which Mines Branch research programs might be based. At the request of the Industrial Development Bank, two resource-engineering-economic studies were made on particular projects for which the Bank had received requests for loans. An analytical report was completed on the suitability of underground mines in Canada as emergency fallout shelters or storage areas, for which investigations had been conducted in 1962 by a senior officer of the Division, assisted by the chairmen of three of the mining engineering departments of Canadian universities.

Information and recommendations were provided to the Department of National Revenue with respect to tax benefits under the Income Tax Act which are applicable to the mineral industry. Reports were prepared on 21 applications for three-year tax exemptions. Four applications for certification as operators of an industrial mineral mine on a non-bedded deposit were processed.

International Activities — Officers of the Division presented briefs at meetings of several international organizations concerned with minerals and mineral trade. Advisory briefs were prepared for other meetings which Division officers did not attend. Meetings in which the Division participated include those of the Organization for Economic Co-operation and Development (OECD); United Nations, Economic Commission for Europe (ECE); International Lead and Zinc Study Group; International Tin Council (ITC); and United Nations *ad hoc* Committee on Tungsten.

Officers prepared technical-economic papers for presentation before technical organization meetings in Canada, the United States and Europe and for publication in journals both in North America and Europe. As an example, the Chief of Division was a delegate and contributor to the United Nations Conference on Science and Technology in Geneva. Also, a senior officer of the Division was a member of a three-man team of experts which, under Colombo Plan auspices, conducted a field investigation on the feasibility of establishing an integrated iron and steel industry in Malaysia.

Wartime Oils Limited — The Division continued to administer the assets of the former Crown company, Wartime Oils Limited. Payments received to March 31, 1963, including repayment of government advances and payment of interest and royalties, totalled $4,126,886.41, which is $69,333.16 more than was advanced by the federal government during 1943-44 to drill and equip the wells.

Foreign Aid Training — The Division, on behalf of the External Aid Office, arranged 21 new technical training programs for foreign trainees. Most of the programs were sponsored under the Colombo Plan. Training took place in the Department of Mines and Technical Surveys with some visits to industry. Fourteen trainees completed studies in 1963 under programs previously arranged. At the end of 1963, five trainees were still on study courses, and 12 programs had been set up awaiting arrival of candidates. Fifty-two foreign students attending Canadian universities under various technical aid programs were given summer employment in the Department in fields related to their academic courses.

Information Activities — The Division has a continuing program of mineral filmstrips. During the year a filmstrip on natural gas was completed in English and French, in cooperation with the National Film Board. This filmstrip received an international award as had an earlier filmstrip on uranium. Work commenced on two filmstrips *(Rocks and Minerals* and *Life in a Mining Community)* designed for the primary school curriculum. Similarly, preparation of a pictorial brochure on mining was begun. The Division's photographic and records library continued to be strengthened. The popular map entitled *Principal Mineral Areas in Canada* received its annual revision, and the series of annual mineral reviews was continued.

The Emergency Gold Mining Assistance Act — The Act was extended on December 12, 1963, for a period of 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 will be 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 Assistant Deputy Minister (Research). Gold mines receiving assistance are visited by inspection engineers from the Division who determine the proper classification of exploration and development expenditures. They review

and report upon the allowance of costs which are in question, mining and milling practices and review production and ore reserve records. The Audit Services Branch, Office of the Comptroller of the Treasury, examines interim applications and carries out the final audit of each applicant's books of account.

The amount of assistance payable to an operator is computed under the current formula 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 per ounce is not eligible for payment of assistance.

There were 42 lode gold mines and 24 placer gold mines in receipt of assistance during 1963. Twelve 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 1963, 252 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	" " "
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 —	12,705,040.68	or 5.22	" " "
1962 —	13,705,090.06	or 5.74	" " "
1963 —	9,307,107.34	or	(not available)

EXPLOSIVES DIVISION

The Explosives Division administers the Explosives Act which controls the authorization, manufacture, sale, storage, and importation of explosives, as well as their transportation by road. Tests of newly introduced explosives are carried

out on behalf of the Explosives Division by the Mines Branch. Inspections are carried out around the country by Division staff supplemented in some cases by the Royal Canadian Mounted Police.

Production of commercial blasting explosives in Canada rose sharply to 210 million pounds from 180 million in 1962. Several new manufacturing techniques were developed. There were 27 licensed explosives factories, four more than the previous year.

The Mines Branch tested 105 samples of explosives, about half of them fireworks. Inspections carried out during the year numbered 2,898, of which 2,237 were of magazines.

According to safety regulations, explosives magazines have to be located in isolated places, and this, unfortunately, often attracts thieves or mischievous youngsters. Especially liable to pilferage are small quantities of explosives permitted to be kept in unlicensed premises, since the proprietors sometimes fail to exercise proper care. During the year, there were 21 thefts from licensed and four reported thefts from unlicensed premises, and stolen explosives amounted to 7,438 detonators and 2,823 pounds of blasting explosives, as well as other material.

Another great danger arises from abandoned or forgotten stores of explosives, which in 1963 amounted to many thousands of pounds.

The total number of accidents involving explosives continued to decline in 1963, which is apparently due at least in good part to the wider use of non-nitroglycerin explosives.

In the use of explosives, there were 39 accidents, in which ten persons were killed and 46 injured. Three of the fatalities occurred on farms. There was one fatal accident in manufacturing. A distressing number of accidents continue to happen to children who find abandoned explosives or fool around with fireworks or attempt to concoct their own explosives. Two young boys were killed and 27 youngsters of widely differing ages were injured in such mishaps.

There were 27 prosecutions under the Explosives Act, 14 of them due to unsafe storage, and 10 to unsafe road transportation.

Surveys and Mapping Branch

The Surveys and Mapping Branch continued its varied program of surveying, mapping and air charting. The Geodetic Survey had 17 parties in the field ranging from the Arctic to primary triangulation for the City of Montreal. The Topographical Survey successfully employed the aerodist, an airborne version of the tellurometer for distance measurements in the James and Hudson bays area and from the mainland to Sable Island. The Legal Surveys and Aeronautical Charts Division introduced a new series of charts for low-level flying and made preparations for the production of a new series of electoral maps. An official ceremony was held at the junction of the boundaries of Manitoba, Saskatchewan, and the Northwest Territories. The Map Compilation and Reproduction Division reported a slight decrease in the production of maps and charts owing to depletion of staff. An increase in receipts of more than 60 per cent from the sale of maps resulted from a price increase initiated January 1, 1963. The National Air Photo Library processed the highest number of requisitions in its history.

During the year the Interdepartmental Committee on Air Surveys obtained for the federal government vertical airphoto coverage of about 80,000 square miles. This coverage consisted of some 50 projects representing more than 100 areas, under contracts with ten companies.

This increasing interest in interpretation prompted the committee to hold a seminar for three days in October 1963 on airphoto interpretation in the development of Canada. About 300 surveyors and other specialists attended.

GEODETIC SURVEY

Seventeen field parties were extending horizontal and vertical control which provides a national framework for mapping, charting and major engineering projects. In addition, a number of small, short-term operations were carried out during the year.

The extension of the network of first-order triangulation was carried on in the Northwest Territories and in six provinces. In the Northwest Territories two large parties extended the western arc from Yellowknife to Coppermine and the eastern arc from Tulemalu Lake to Chesterfield Inlet. In British Columbia a large party completed an arc from Williams Lake to Bella Coola, and the reconnaissance of a small network connecting Vancouver Island to the mainland in the Seymour Narrows area was also completed. In Alberta the reconnaissance of a 16-station network in Calgary was completed.

In Ontario the reconnaissance of a 16-station network in the Hamilton-Toronto area was completed and a number of tellurometer lines were measured to establish a precise aerodist test range in eastern Ontario. In Quebec one large party completed the 26-station network in the Montreal area, and a second large party extended the northern arc from the west end of Lake Minto to within 125 miles of Fort Chimo. A large party in New Brunswick completed the area network in the northern part of the province and about 75 per cent of a small network extending eastward from Bathurst. The reconnaissance of an area network extending from Fredericton to Moncton was completed. In Nova Scotia a small network in northern Cape Breton Island was completed, and 114 existing triangulation stations were inspected.

During the past season, three double parties and a single party extended the precise level net. In addition a small party inspected some 2,200 existing bench marks in Alberta and eastern Ontario, and a number of small, short-term operations were carried out. The double party in British Columbia extended the relevelling of the Prince George-Prince Rupert line to Terrace and ran a new line from Terrace to Kitimat. In Alberta three engineers worked with the Department of Northern Affairs and National Resources during the winter in the establishment of precise level lines along the Peace, Slave and Athabasca rivers near Fort Chipewyan, and during the summer a small party established bench marks along the Athabasca River in preparation of a winter operation. The double party in Manitoba relevelled about 700 miles of existing lines in the southern part of the province and connected a water gauge on Lake of the Woods. The double party in Quebec relevelled 320 miles of existing lines in the Quebec City-Lake St. John-Saguenay River area. The relevelling both in Quebec and in Manitoba was required to improve the level network and to determine the existence and amount of vertical ground movement in these areas. A new water gauge was connected near Montreal and the annual check of the main piers of the Quebec Bridge was made. In Ontario the single party relevelled from Toronto to Hamilton to St. Catharines and established a new line along the Niagara River and the north shore of Lake Erie to Port Colborne. A dense precise network was started in the city of Ottawa.

A new Model 4D geodimeter was obtained this past year, and, after a period of testing, was used to measure 10 lines in New Brunswick and Nova Scotia. Two short base lines to control triangulation were measured in northern Cape Breton Island; the other 8 lines were measured between existing triangulation stations for investigational purposes. Two of these 8 lines were also measured with the Model 2 geodimeter to provide an accuracy check.

Four small parties established precise astronomic stations in the Northwest Territories and British Columbia. Five Laplace stations were established to control triangulation arcs in the Northwest Territories and, in addition, the precise astronomic longitude and latitude of 24 triangulation stations was determined for investigational purposes, at 7 points in the Northwest Territories and 17 points in British Columbia. Some research and development work has been done on new methods of determining local time for longitude observations.

The Survey continued to make increasing use of specialized electronic equipment in the field and laboratory. During the field season three officers and one technician, specially trained in the use and maintenance of electronic equipment, worked with triangulation parties. The development of new electronic equipment for field use continued. The Survey is carrying out the reduction and assessment of a series of aerodist measurements made by the Topographical Survey on the test quadrilateral in eastern Ontario. This test will show the probable accuracy of the aerodist system and indicate if the system is suitable for geodetic work. The laboratory is handling the repair and maintenance of all divisional electronic equipment and also does some work for other divisions of the Branch.

During the year the Survey continued its interest in international geodetic organizations. In August three staff members attended the 13th General Assembly of the International Union of Geodesy and Geophysics at Berkeley, California. Papers were presented on the tellurometer cyclic zero error and ground-swing errors on geodetic lines.

TOPOGRAPHICAL SURVEY

The main concern of the Topographical Survey during 1963 was the map coverage of Canada at the 1:250,000 scale scheduled to be completed by 1967. Slightly more than 100 sheets were compiled by the Branch and the Army Survey Establishment during the year, and most of the remaining 400 sheets in the series are in the process of completion.

Completion of 1:50,000 mapping engaged nearly half of productive capacity but continued to be restricted to the most urgent needs. This work will be further curtailed when a systematic program of revision inaugurated during the year reaches the intended total of 100 sheets per annum.

The last 15 sheets of the 1:25,000 survival mapping project were cleared to the Army Survey Establishment for reproduction.

Field surveys ranged widely across the country and were generally assigned for purposes of securing control for imminent and projected mapping. A new

program of spirit levelling was started in Saskatchewan in cooperation with the provincial government to extend second- and third-order monumented vertical control throughout the developed part of the province. Forty officers of the field staff and six from the office staff took part in field surveys.

Six field officers used the aerodist system to strengthen the horizontal control for 1:50,000 mapping in 36,000 square miles of western Ontario to latitude 50°30′. The line-crossing technique of position fixation was successful for the second year, and a further application of the aerodist system was exploited in fixing ground position in flight, similar to shoran-controlled photography.

The aerodist system, having proved workable under field conditions, was then moved with essentially the same crew to a more difficult assignment: the start of a joint program with the Canadian Hydrographic Service of charting Hudson Bay and James Bay. Nearly all the islands in James Bay were positioned by aerodist, and about one third of James Bay and an equivalent area in Hudson Bay were photographed for shoal areas.

The other major party secured tellurometer traverse control for 1:50,000 mapping for 35,000 square miles in the Nahanni and Redstone river basins west of the Mackenzie River and for 5,000 square miles in northern British Columbia.

A winter survey extended spirit level control from the interior of Labrador to the Atlantic coast despite very bad weather. Further levelling conducted during the summer linked the winter traverse and various other systems to geodetic levels, thus furnishing a good datum for proposed mapping in this region.

Two field parties continued extension of tellurometer traversing in the prairies over 1,500 miles. Surveys for revision of out-dated 1:50,000 maps were carried out in the vicinity of Montreal and in central Nova Scotia. New control networks by tellurometer and geodimeter traverse and by spirit levelling were established for 1:25,000 mapping at Glace Bay, Sydney, Sorel, Three Rivers, Wallaceburg, Sudbury, North Bay, and Moose Jaw.

Interest is growing in the establishment, for municipal use, of high-order monumented control systems to which all local surveys may be referred. These surveys are made at the request and with the assistance of municipal officials, and in 1963 were conducted in Toronto, Calgary, Moose Jaw, and Whitehorse.

Special surveys made during the year included the fixing of a position on Sable Island by aerodist measurements from geodetic stations on the mainland, detailed surveys along Lake St. Pierre for the St. Lawrence Ship Channel project, and tying of municipal control network to newly established geodetic positions in Montreal.

Desirable backlogs of work have been built up in nearly all sections of compilation and editing.

In April, the compilation of 1:250,000 maps from larger-scale mapping was transferred from the Map Compilation and Reproduction Division to the Topographical Survey.

Special mapping projects, numbering 20, were undertaken for the Departments of Agriculture, Citizenship and Immigration, Northern Affairs and National Resources, Public Works, Transport, Defence Research Board, Polar Continental Shelf Project, and the governments of Alberta and Saskatchewan.

Preparation of specifications and inspection for payment approval of mapping under contract to private companies for the Colombo and Special Commonwealth African Assistance Programs continued to occupy the attention of two senior officers. A six-month study of aerodist and tellurometer equipment and operation in South Africa has proved valuable in getting the aerodist system adapted to Canadian field conditions. The Moore Plotter has been developed to the stage of being in production on 1:250,000 mapping.

The principal items of technical equipment purchased during the year were the remaining parts of the three-channel aerodist system, four Wild T-2 and one Wild T-3 theodolites for field use, and one Wild B-8 precision plotter and two pantographs to complement plotting equipment.

Advance information prints of new maps continued to be much in demand, but total distribution was somewhat less because of the improved schedule of publication at the 1:50,000 scale. The demand for this detailed mapping for forest protection, water-power investigations and communications far exceeded present capacity to produce, and new work was avidly seized as soon as it became available.

LEGAL SURVEYS AND AERONAUTICAL CHARTS

The need of other federal departments for legal surveys in Indian Reserves, national parks and territorial lands, and the interest in Indian lands by private and provincial agencies continued unabated in 1963. The demand for new series of aeronautical charts and air information publications continued. Because of the anticipated amendments to the Representation Act, activity in the electoral maps function increased. The French edition of the *Manual of Instructions for the Survey of Canada Lands* was published, and new methods to produce the Polaris and Sun Tables were developed.

Four interprovincial and territorial boundary commissions were active in 1963. The atlas for the northern boundary of British Columbia and the report and atlas for the northern boundary of Saskatchewan were completed. Work continued on the reports and atlases for the northern boundary of Manitoba and the Manitoba-Saskatchewan boundary.

During the year a ceremonial visit was made to the corner where the boundary between Manitoba and Saskatchewan meets the Northwest Territories boundary by the Ministers of the Manitoba Department of Mines and Natural Resources, the Saskatchewan Department of Natural Resources and the Federal Department of Mines and Technical Surveys, the Director of the Surveys and Mapping Branch, and the respective boundary commissioners.

Seventeen field parties carried out legal surveys in public lands of Canada for other federal departments. In addition, instructions were issued to private surveyors for 158 legal surveys for private and provincial agencies. Surveys for other federal departments were undertaken in 52 Indian Reserves, in three national parks, one being a survey of 52 miles of the Prince Albert National Park boundary, and of three historic sites. In the Yukon Territory surveys were made at Dawson, Whitehorse and Watson Lake as well as 52 miscellaneous lot and parcel surveys in various locations. In the Northwest Territories small subdivisions and individual lots were surveyed at Fort Norman, Fort Franklin, Arctic Red River, Fort Good Hope, Fort McPherson, Inuvik, Tuktoyaktuk and Coppermine.

In aeronautical charting, a new series of charts for low-level flying was introduced. In addition, three new publications were compiled. In most of the series of charts and publications improvements in production techniques and in presentation of information were made, one of which was the use of the art of vignetting to depict controlled airspace on visual aeronautical charts, thus significantly improving their legibility.

Survey documents recorded in the Canada Lands Surveys Records numbered 403 plans and 70 field books, and about 18,000 document extracts, publications, and astronomical field tables were dispatched. The Board of Examiners for Dominion Land Surveyors held eight meetings, and 47 candidates wrote examinations. Of these, seven qualified for certificate of preliminary examination and seven for a commission.

MAP COMPILATION AND REPRODUCTION

The production of maps and charts in 1963 showed a decrease from the previous year owing to depleted staff.

Special attention was given to the hill shading of low-level pilotage charts for the Royal Canadian Air Force. One series was completed during the year, and a second series was started and scheduled for completion in 1964.

Conversion of the 221 eight-mile maps to a scale of 1:500,000 continued, and 128 were completed. Of the 1:250,000 map series, 53 per cent were published, as well as 25 per cent of the 1:50,000 map series.

Maps received from the Topographical Survey for reproduction number 268, a big increase from the 197 received in 1962.

Maps and charts printed numbered 4,450, compared with 4,303 in 1962. Of these, 2,049 were done on the large offset presses, slightly less than in the preceding year, while the output of the multilith presses of 2,401 was greater than that of 1962.

The distribution of maps amounted to 1,081,598 copies, compared with 1,093,578 in 1962, a decline of one per cent. The map depot increased its stock of maps and charts from 10,151,257 to 10,715,038.

Among major map compilation projects were a new edition of the map of the world, a revision of the Canadian Polar Plotting Chart base, and the start

of a program of mapping at 1:1,000,000 to International Map of the World specifications.

Information booths on mapping were set up at the National Sportmen's Show in Toronto and the Central Canada Exhibition in Ottawa.

Map requests during 1963 numbered 45,910, about 5,000 more than in 1962. Revenue from sales was $217,607, up from $132,499 in the previous year.

During the year a total of 36 research and development projects were carried out to improve map production. Two new pieces of equipment put into production were a Duplication Scribe and a Dilar 1.

INTERNATIONAL BOUNDARY COMMISSION

The Commissioners for Canada and the United States made a joint inspection of various points on the international boundary along the provinces of New Brunswick, Quebec, Ontario, and Manitoba. They also inspected the work of two United States parties and two Canadian parties carrying out maintenance operations along the boundary.

A Canadian party working along the New Brunswick-Maine and the Quebec-Maine boundaries applied chemicals to retard growth, on 100 miles of 20-foot boundary vista. The Commission eventually expects to maintain much of the boundary vistas through the use of chemicals.

A second Canadian party was engaged on the Manitoba-North Dakota boundary, where 40 miles of 20-foot boundary vista were recleared and chemically treated through the Turtle and Pembina mountains. A number of boundary monuments found disturbed by construction work along the Manitoba boundary were relocated.

Tests were again carried out on the control of vista growths through the use of chemicals applied by helicopter. These tests were applied on mountainous sections of the British Columbia-Washington boundary, where ground operations are difficult.

Inspections of reference monuments along the St. Clair and St. Lawrence rivers, and position checks of boundary buoys in Lake Erie, were also carried out during the season.

In all, 220 miles of boundary and 440 monuments were inspected, 40 miles of boundary vista were recleared, 160 miles chemically treated to retard growth, and 12 monuments repaired or relocated during the 1963 field season.

NATIONAL AIR PHOTO LIBRARY

During this year, 4,903 requisitions for photographic work, the highest annual total in the Library's history, were prepared and forwarded to the Photographic Establishment of the R.C.A.F. These requisitions covered 266,253 reprints from federal government air survey negatives (contact prints, enlargements, multiplex diapositives, mosaics, lantern slides, etc.).

The revenue from photographic requirements ordered through the Library amounted to approximately $160,000.

The Library received 26,701 new photos, bringing the total of the Library collections to 2,967,000.

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

The unfailing cooperation of the R.C.A.F. Photographic Establishment fully complemented the efforts of the N.A.P.L. to maintain the best possible service to the public.

The third edition of the Air Photo Coverage Map of Canada (1962) was made available for distribution in April, and the Mosaic Coverage Map was corrected to June 1963. Copies are supplied, free of charge, on request. A brochure, presenting a brief outline of the history and function of the Library, and containing information regarding requests and photographic material, first published by the Queen's Printer in December 1962, required a second printing in April. Approximately 10,000 copies of this brochure have been distributed to the public, either by mail or through various government agencies.

An article concerning the National Air Photo Library in a national farm magazine brought approximately 200 requests for air photos, from readers in all parts of Canada.

In May, 40,958 index cards and 4,835 index maps were photographed on 16 mm and 35 mm film, respectively, by the Public Archives, to be stored for safe-keeping.

In the latter part of the year, favorable consideration was given to the collection of satellite photography; discussions regarding the method to be adopted and the organization of this project were postponed until the new year.

In October, the N.A.P.L. contributed a display panel in connection with the Seminar on Air Photo Interpretation, held in Camsell Hall, Ottawa.

The Library was asked by the Department of Transport to assist in the selection of photos to be used in the construction of two wall murals in the new Edmonton International Airport.

Welcomed to the Library were visitors from England, the United Nations, Southern Rhodesia, the U.S.A., Netherlands, Sweden, Morocco, Australia, New Zealand, Austria, U.S.S.R., Poland, and Tunisia. Constant use has been made of the offices and facilities by representatives of government and civilian organizations to examine the Library photos.

Marine Sciences Branch

The year 1963 was a period of marked adjustment in the marine investigations carried on by the Department. Oceanographic research continued to expand and strengthen as a result of the momentum which had been generated the previous year. On the other hand, the Canadian Hydrographic Service, because of personnel losses which could not be made good and the initiation of a long-overdue rotation for field staff, was obliged to reduce its program substantially. Even under these conditions, the closer integration of the hydrographic and oceanographic activities continued, and a more intensive utilization of the larger vessels over a longer season was initiated.

Because the following pages report separately on the activities of three functional divisions, the closer coordination and integration developing between these specialties are not clearly evident. The year is not far off when such arbitrary divisions will no longer be appropriate and when there will emerge a summary of the complete and balanced marine research toward which the Branch continues to develop.

HYDROGRAPHY

A total of 20 operational units were at work in 1963, including nine departmental ships, one chartered ship and seven launch parties. Three Department of Transport icebreakers also carried hydrographic personnel for northern survey work.

The C.S.S. *Baffin* party, in a joint project with a Topographical Survey unit, established the accurate position of Sable Island. This position was used in the second major project of the Baffin cruise involving the use and evaluation of the new Decca Lambda electronic equipment. Accurate fixing was achieved at ranges up to 400 miles from the slave stations, while an area of 4,000 square miles was sounded in the "Tail of the Bank" area, south of Newfoundland.

C.S.S. *Acadia* in her fiftieth year of service, carried out a number of projects in Nova Scotia and Newfoundland. The results of one of her surveys enabled the National Research Council to construct a model of Codroy Harbour for erosion study.

C.S.S. *Kapuskasing* completed an offshore survey of the Nova Scotia Shelf with the use of two-range Decca equipment. This party also completed a large-scale survey in Miramichi Bay for the Department of Public Works and obtained extensive data for calibration of the Nova Scotia Decca Navigation chain.

C.S.S. *Maxwell* carried out a large-scale survey of Dingwall Harbour, N.S., before completing a standard survey of Baie Comeau, Quebec, and various minor projects in the Gulf of St. Lawrence. The launch parties *Anderson* and *Eider* continued charting in the Cape Sable area and the eastern shore of Nova Scotia respectively. *Eider* also made a reconnaissance survey in the Bras d'Or Lakes. The new Decca Hi-Fix electronic system was used successfully by the *Anderson* party which has been severely handicapped in the past by the poor visibility for which Cape Sable is notorious.

Extraordinary ice conditions in northern waters completely disrupted schedules of the Eastern Arctic Patrol ships, forcing cancellation of all major projects assigned to the hydrographers on board.

Operational strength on inland waters was reduced to one ship and four launch parties. As in the previous year, C.S.S. *Cartier* was assigned to field training and completed surveys in the Kingston area and in the lower St. Lawrence. C.S.L. *Petrel* completed a number of projects between Quebec City and Prescott, Ontario, while C.S.L. *Cygnet* continued the survey of the Ottawa River.

C.S.L. *Rae* continued surveying in the Mackenzie River-Great Slave Lake area.

In addition to four minor projects in Georgian Bay, the C.S.L. *Bayfield* party extended the survey of the inshore small-boat route along the northeastern shore of the bay. This survey has attracted much interest, and already orders have been received for the charts covering the first section of this project. Scheduled for 1964 publication, they will be presented in folding strip chart form, the first of its kind produced by the Department. A preliminary survey of the Muskoka

Lakes was initiated. Here, again, public demand is exceedingly great, and there is very little doubt that the charts will be highly popular and will fill a great need.

On the Pacific Coast, C.S.S. *Wm. J. Stewart* continued surveys in Hecate Strait and in the Vancouver area, while C.S.S. *Marabell* worked on a number of projects from Vancouver to Observatory Inlet, north of Prince Rupert. C.S.S. *Parry* completed a survey of Kyuquot on Vancouver Island before carrying out a brief inspection survey. The C.S.L. *Owl* party continued to work in the Gulf Islands area of the Strait of Georgia.

C.S.S. *Richardson,* built specifically for work in the Western Arctic, completed surveys between Herschel Island and Prince Albert Sound. Also operating in this area, a party surveyed from C.C.G.S. *Camsell* during the course of the ship's escort duties from the Amundsen Gulf to Spence Bay.

TIDES, WATER LEVELS AND CURRENTS

The collection, processing and dissemination of data continued to improve. The Department's computer was further employed in analyses and prediction. A wide variety of tidal and water level information has been made readily available on microfilm. Several new gauging stations were established, new equipment evaluated and tests conducted on ship-to-shore data transmission. A small arctic edition of tide tables covering seven ports was introduced. This will be expanded to a complete arctic edition, including ten reference ports and all secondary ports. The new annual publication *Water Levels* was also introduced. This contains the daily and monthly mean water levels recorded at all stations.

M.V. *Theta* was chartered for current studies on the East Coast, including a survey in the Pointe Des Monts area. This was an extension of the previous season's work in the Gaspé Passage and was related in particular to the Gaspé Current. During August and September, the currents over a cross-section of Belle Isle Strait were measured by means of E.M.F. cables laid across the strait. Extensive oceanographic observations were taken during the course of both projects.

On the West Coast C.S.S. *Parry* and C.N.A.V. *Whitethroat* completed a number of current surveys including one in the Strait of Georgia in the vicinity of Nanaimo.

CHARTS AND PUBLICATIONS

Demands for standard navigational charts and various special types of charts continue to outpace the productive capacity of the Hydrographic Service. However, a significant increase in chart coverage was achieved with the publication of 58 new charts, bringing the total number of catalogued charts to 930. Distribution also reached a new peak. 1963 figures show a distribution of over 170,000 standard charts and a total, including various special charts produced, of more than 217,000.

A new edition of *Great Lakes Pilot,* Vol. 1, was published in addition to supplements for nine other pilots.

OCEANOGRAPHY

Oceanographic research during the year has been characterized by vigorous expansion and the formation of new marine investigations in geophysics, sea ice, theoretical studies and environmental prediction. Recognition of the achievements to this end came from the 1963 meeting of the Scientific Committee on Oceanic Research, SCOR, and visits of several world-famous oceanographic vessels to the Bedford Institute of Oceanography.

Significant results can be reported in the first year of operation of the Bedford Institute of Oceanography; seven major oceanographic cruises were undertaken, covering diversified studies in the Gulf of St. Lawrence, the Scotian Shelf, North Atlantic Ocean, Baffin Bay and the Canadian Archipelago. Oceanographers from the Institute, in cooperation with other federal agencies and universities, played an important role in conducting a multiple-ship oceanographic study of Greenland waters for the International Commission of the Northwest Atlantic Fisheries. Studies of the structure and mixing of the Deep Slope Water and Slope Water Current off the East Coast of Canada have continued.

In cooperation with scientists of the Fisheries Research Board, Atlantic Oceanographic Group, joint investigations were carried out in the Gulf of St. Lawrence on the Gaspé Current and transport through Belle Isle Strait. The Gulf of St. Lawrence program was completed in the late fall with a special oceanographic cruise that was required for the annual winter ice outlook and seasonal forecast of ice conditions by Sea Ice Central, Department of Transport, Halifax, N.S.

In conjunction with the physical oceanographic studies, considerable support is provided by chemical oceanographers for analyses of nutrient, oxygen and pH concentrations in oceanic and coastal waters. Other programs are under development for the investigation of concentrations of fallout fission products, their transport and mixing rates in the oceans.

The marine geophysics group, although organized only by mid-year, completed two extensive cruises and contributed to four other field projects. During one cruise to the Arctic, 6,000 line-miles of magnetic data and 465 line-miles of seismic profiling were collected. Valuable experience was gained in operating geophysical equipment under arctic conditions and in ice-infested waters. An acoustic study of a section across Baffin Bay to Thule revealed a relatively smooth sub-bottom without indication of a median ridge.

The reconnaissance and exploratory nature of arctic oceanography is gradually being superseded by detailed studies of the dynamics and current structures in restricted regions. A preliminary study of the heat budget was undertaken near Tuktoyaktuk, N.W.T., which allowed a quantitative assessment of the sensible heat available. Work of this nature is being continued by a recently organized

arctic land-based oceanographic group which intends to study ice formation, thermal properties of sea ice, and energy exchange between the frozen sea and the atmosphere. A National Research Council study of the operation of an air-bubbler system as a means of preventing damage from ice continued to be supported by field studies.

Theoretical and environmental groups have been engaged in wave-hindcasting analyses, tidal theories, time-dependent motions of the oceans, and environmental conditions. Preliminary hindcasting results showed that waves in the Gulf of St. Lawrence are about one and a half times as high as those in Lake Superior and are much longer owing to the intrusion of ocean swells; also high waves are 2 to 5 times as frequent in the Gulf as in Lake Superior.

A study of the diurnal and semidiurnal tides in the area bounded by the Labrador Sea, Davis Strait and Baffin Bay has shown that almost a complete reflection of the diurnal and semidiurnal waves occurs at the head of Baffin Bay. One- and two-dimensional schematizations of the area have led to accurate positioning of points of amphidromy, the effect of Coriolis acceleration and degeneracy of the diurnal point of amphidromy.

Source data for all current oceanographic observations on the east coast and in the Arctic were transferred to punch cards, and a start has been made on west coast data. Card-to-magnetic-tape programs have been developed for high-speed sorting, and a geographic file is being set up for environmental studies and rapid retrieval of data on request. New ways of processing and automatic handling of corrections continue to be developed by the Canadian Oceanographic Data Centre.

Nine of the Branch's staff were given educational leave to carry out post-graduate studies.

SHIPS

C.S.S. *Hudson* joined the Marine Sciences fleet in December, increasing the strength to 11 ships, and more than 50 launches. The *Hudson* is 293 feet long, has a beam of 50 feet and displaces 4,800 tons. Designed to operate world-wide and under any climatic conditions, she is equipped with the latest navigational and hydrographic instruments and complete oceanographic laboratories.

Design work was completed for two new tidal and current survey ships, one for each coast. Plan specifications are now being checked and construction is scheduled to commence on these vessels in 1964. Designed primarily for tidal surveys but with considerable oceanographic capability, these ships will be 211 feet long with a beam of 40 feet.

Preliminary work is being undertaken on the $50 million replacement and expansion program, which will extend over the next 7 to 10 years.

Geological Survey of Canada

The Geological Survey each year places about 100 field parties throughout the country to obtain basic data on the geology of Canada. Most of these parties operate only during the summer, owing to climatic difficulties, but a few are active during other times of the year. Supporting these field projects are the many laboratories at Survey headquarters, to which the field officers can send rock and mineral samples for various tests and analyses. In recent years a small but increasing number of the Survey staff has been undertaking special laboratory investigations of problems pertaining to fundamental geological processes, and the development of techniques and equipment with which to tackle these problems. The information obtained from these many field and laboratory investigations appears on maps and in reports issued from time to time by the Survey, and in many instances helps guide those engaged in the search for and development of Canada's metallic and non-metallic mineral deposits, fuels, water supplies, and construction materials.

In 1963 the Survey had 105 parties in the field, an increase of 11 over 1962. Of these, 32 conducted systematic bedrock mapping, much of it reconnaissance mapping of remote or little-known areas; 19 mapped surficial deposits or investigated groundwater and engineering geology problems; 15 investigated stratigraphic and palaeontological problems; 16 examined mineral deposits or studied granitic, ultrabasic, and basic or other rocks, 12 undertook geophysical investigations; and 11 tackled problems of a geochemical, structural, marine-geology, or other nature.

Field work was completed (or nearly so) on 45 of the 105 field projects, covering many thousand square miles. Three parties alone completed reconnaissance-bedrock and surficial-geology mapping of approximately 115,500 square miles of Canada's northland.

Sixteen of the field parties used helicopters or fixed-wing aircraft as operational support, by means of which much larger areas can be examined more efficiently each summer than was heretofore possible. Such operations rapidly bring closer the completion of basic reconnaissance geological mapping in Canada. Many other parties used aircraft from time to time for supplies, camp moves, and related services. At the end of 1963 the Geological Survey had published geological maps on about 65 per cent of Canada on a scale of 1 inch to 8 miles or in more detail, and the present rate of coverage is about 4 per cent per year. Only in Ontario does the Geological Survey now have less than 50 per cent coverage, and some of the outstanding 53 per cent is covered by Ontario Department of Mines maps.

The joint federal-provincial program which was inaugurated in 1961 to complete the aeromagnetic survey of most of the Canadian Shield and some adjoining areas by about 1973, was carried out on schedule during 1963, with large areas being flown in northern Alberta, Saskatchewan, and Manitoba, as well as a large area immediately north of the east end of Great Slave Lake, another north from Lake Huron, and yet another north from Quebec City. Collectively these totalled 329,593 line-miles flown during the year. Some of the resulting aeromagnetic maps were issued in 1963; the remainder will be issued at frequent intervals during 1964.

Grants by the Geological Survey to Canadian universities were initiated in 1951 to stimulate and support geological research in these institutions. These grants are awarded mainly to support projects involving studies of rocks, minerals, and fossils directed towards the solution of specific geological problems, rather than for experimental projects involving the simulation of geological processes in the laboratory. In 1963, 47 grants totalling $75,000 were awarded to 14 universities in support of 22 new and 25 continuing studies. For the past two years applications for Geological Survey grants have been almost double the $75,000 available.

Since 1956 National Research Council postdoctorate fellowships have been awarded, tenable at the Geological Survey. Some 17 men have held these fellowships since then. The fellowships allow the recipients to undertake basic research of their own choosing for one or two years, when their scientific interest

and enthusiasm is at its peak. From 55 applications, the Survey in 1963 selected three fellows, one from Japan, one from British Columbia, and one from England. Fellowships for three others already at the Survey were extended in 1964.

Preparation of a tectonic map of Canada for publication by the Survey on the scale of 1:5,000,000 continued during the year, and a copy of the completed manuscript map will be exhibited at the International Geological Congress in 1964. This map will serve as Canada's contribution toward the preparation of a world tectonic map, to be compiled and published by that Congress.

The Geological Survey maintains offices in Yellowknife, Whitehorse, Vancouver, and Calgary, to act as a source of geological information for the public through sale of departmental publications, library and laboratory facilities, and advisory services. In 1963, the Yellowknife office sold 900 publications and 35 rock and mineral kits, and the resident geologist and his assistant visited 30 mining properties in addition to conducting specific geological studies. The Whitehorse office had 2,035 visitors during the year and sold and distributed 4,147 topographic and 2,492 geological publications. The resident geologist visited all operating lode mines and most of the important lode prospects and placer operations during the year, and carried out various other duties and services on behalf of other governmental departments and the public. The Vancouver office had its busiest year on record, with 10,015 visitors registered, 28,161 publications distributed, and 1,217 collections of rocks and minerals sold. The two staff geologists carried out several short-term field projects during the year, mainly at the request of other government departments.

The Geological Survey library added 25,521 periodicals, books, pamphlets, and government publications in 1963, received almost 3,000 maps and charts, and recorded 45,000 loans. A complete set of reference books and many serial publications were ordered for the Calgary office library.

The Survey's publication distribution office in Ottawa received 19,923 requests for publications and information, a decrease of about 4,000 from the previous year, and sent out 318,305 publications consisting of 206,430 maps, 83,687 reports, and 28,188 miscellaneous items. During the year the Survey published 10 *Memoirs*, 15 *Bulletins*, 1 *Economic Geology Series* report, 46 *Paper Series* reports, 22 final multicolored maps, 35 preliminary maps, and 577 aeromagnetic maps.

The Photographic Section of the Survey in 1963 made 19,468 contact prints, 24,245 enlargements, 558 photomicrographs, 253 lantern slides, 607 color transparencies, 342 color prints, and processed 4,500 feet of 35-mm magnetometer film and 420 feet of 70-mm magnetometer film, all as service work for the professional staff of the Branch.

The Lapidary Section prepared 6,340 thin sections and 150 polished sections from specimens submitted by staff geologists.

In 1963, 122 technical officers and 181 student assistants were employed for field work in various parts of Canada and for laboratory and related office duties.

Survey drafting personnel prepared 28 multicolored geological maps, 63 preliminary geological maps, 81 aeromagnetic maps, 6 index maps, and 339 figure illustrations for publication during the year. Work was in progress on a corresponding number of maps and figures.

Many of the Survey's technical personnel published scientific papers in geological periodicals, attended and presented papers at scientific meetings in various parts of Canada, the United States, and Europe, and visited Canadian and foreign laboratories during the year. A staff geologist was appointed British Commonwealth Liaison Officer in London, England, for the two-year period 1963-65.

REGIONAL GEOLOGY

The Regional Geology Division is responsible for geological mapping and related research in the Appalachians, much of the Cordillera, and in the Canadian Shield, thereby including all parts of Canada underlain by folded rocks except the Arctic Islands north and west of Baffin Island. Twenty-eight field parties were active in the following parts of Canada during 1963 : Northwest Territories and Yukon (7 parties); British Columbia (7 parties); Manitoba, Ontario, and Quebec-Labrador (7 parties); New Brunswick, Nova Scotia, and Newfoundland (7 parties). Most of these conducted reconnaissance mapping of the rocks and structures in large areas for publication on a scale of 1 inch to 4 or 8 miles. The rest conducted semi-detailed mapping of much smaller areas for publication on a scale of 1 inch to 1 mile. One additional party undertook specialized studies in several parts of the Canadian Shield from Quebec to the Northwest Territories. The field work on each project generally takes between one year and three years to complete, and is supplemented by extensive laboratory studies of representative rock and mineral specimens collected during the field seasons. The results ultimately appear in maps and memoirs published by the Geological Survey.

In the Appalachian region much of the primary mapping is now completed, and future mapping will be mainly related to one or more research problems. In New Brunswick one party completed reconnaissance mapping of Restigouche map-area, and another completed detailed mapping of Upsalquitch Forks map-area. In Nova Scotia a party commenced structural studies and detailed bedrock mapping of the Cobequid Mountains region, while a second party completed detailed bedrock mapping in Lochaber map-area. In Newfoundland parties completed reconnaissance mapping of Belleoram and Botwood map-areas, and a third party commenced reconnaissance studies of the Port aux Basques area.

In the eastern part of the Canadian Shield, including Baffin Island, the present status of geological mapping is still chiefly in reconnaissance stages. One party completed 4-mile mapping and structural studies in Opocopa Lake map-area near the southern end of the Quebec-Labrador iron ranges, while a second party completed 4-mile mapping of granite and associated rocks in the Michikamau Lake region of Labrador, east of the Labrador Trough. Five staff geologists completed mapping of approximately 48,000 square miles of northwestern Quebec for publication on a scale of 1 inch to 8 miles, winding up Operation Leaf River, a

helicopter-supported project begun in 1961. Four other staff geologists began and completed reconnaissance mapping (for publication on a scale of 1 inch to 8 miles) of that part of Baffin Island west of longitude 80°. This was Operation Admiralty, and was supported by two helicopters and one Piper Super Cub aircraft, enabling an area of about 55,000 square miles of little-known country to be examined. A party completed detailed studies of the Huronian sediments near Sault Ste. Marie, Ontario, and two parties commenced detailed studies of the complex structures and metamorphosed Grenville rocks near Ottawa (one in Carleton Place map-area, the other in Tichborne map-area). One staff geologist continued detailed studies of diabase dykes throughout the Canadian Shield as part of a basic research project on the age and structural history of the ancient rocks in this vast region.

In the western part of the Canadian Shield, which is arbitrarily selected as that area west of the Ontario-Manitoba boundary, six staff geologists were engaged in the mapping of areas in which puzzling geological phenomena had previously been known. Three of these carried out the following reconnaissance mapping: in the Upper Nelson River area, Manitoba; in the Beechey Lake area, District of Mackenzie; in the Kognak River area, District of Keewatin. A fourth party began a study of the Dubawnt Group of rocks in the western part of District of Keewatin, another party studied detailed structures and regional correlations in Grant Lake area, District of Mackenzie, and the sixth party completed detailed studies of the many rock types in Benjamin Lake map-area, an area containing many small sulphide showings.

Primary mapping and geological research in the folded sedimentary rocks and igneous rocks west of the Great Plains, which form the Cordilleran physiographic province, are conducted by Survey personnel stationed both in Ottawa and in Vancouver. Four parties shared two helicopters, employing techniques first proven satisfactory in 1960, in conducting reconnaissance mapping in the Windermere, Big Bend, Adams Lake, Canor River, Taseko Lakes, and Bonaparte River map-areas. These areas all lie west of the Rocky Mountain Trench in southern British Columbia and are potential mineral areas. Another party commenced a long-range reconnaissance study of the formidable Coast Ranges, examining accessible areas of the coast. About half of Alberni map-area was mapped for publication at 1 inch to 4 miles; and one-third of the Greenwood map-area, a copper-bearing region along the United States border, for 1-inch-to-1-mile publication. Near the north end of the Cordillera, two staff geologists with assistants and two aircraft conducted Operation Nahanni, mapping some 12,500 square miles in Logan and Mackenzie mountains in Yukon Territory and the adjoining District of Mackenzie, for publication on a scale of 1 inch to 4 miles. The area contains extensive sequences of sedimentary rocks, and several showings of copper and iron minerals.

As the field season during which mapping can be conducted is limited by the Canadian climate to the months between May and October, personnel of the Regional Geology Division use the winter to examine and analyze the data and specimens collected during the summer, to compile geological maps and reports,

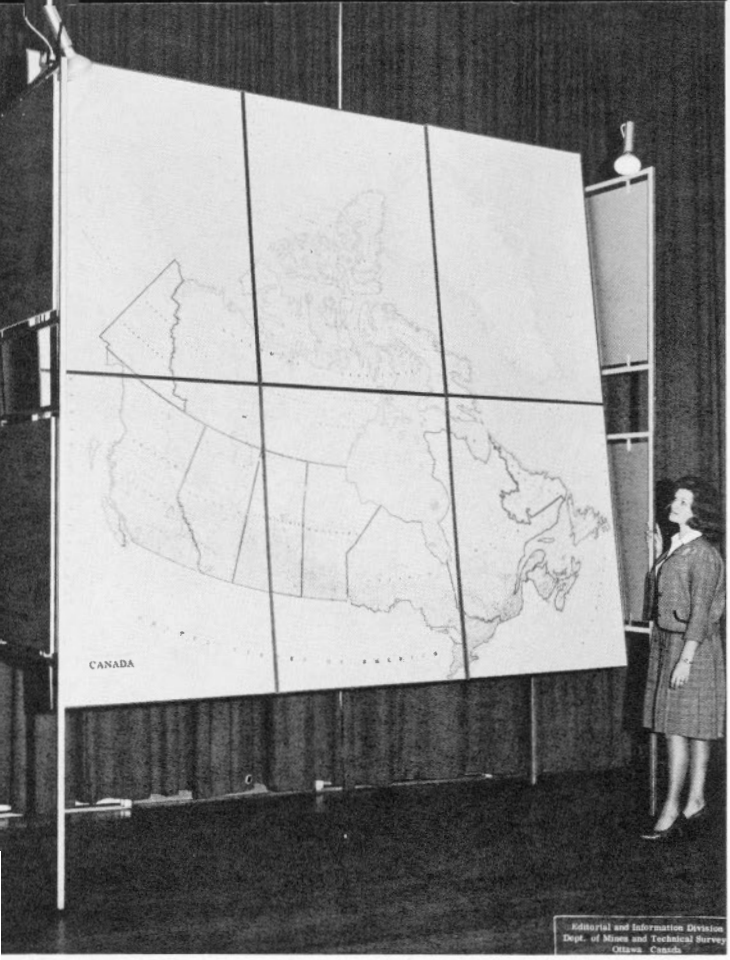
to prepare and present papers and talks to technical organizations, and in some instances to participate in special field trips in various parts of Canada and elsewhere in the world. These men are the 'general practitioners' of the Geological Survey, being required to recognize and interpret evidence from the many phases of geology, and to publish reports dealing with subjects ranging from stratigraphy and structure to economic geology and glacial geology. Many of these men are conducting reconnaissance studies as did their forefathers, for such studies logically precede all detailed geological investigations. Most of these reconnaissance studies are expected to be completed within the next decade or so. An increasing proportion of the staff is now conducting investigations of specific geological problems. As the area of particular concern to the Regional Geology Division covers more than two-thirds of Canada, progress is necessarily fairly slow, although the extensive use of helicopters and fixed-wing aircraft in recent years has greatly speeded up the rate of completion of field mapping projects.

FUELS AND STRATIGRAPHY

Many Survey geologists are gathering basic data and information necessary in the exploration for and development of oil, gas, and coal resources. They are chiefly stratigraphers and palaeontologists, who are mapping the surface and subsurface distribution of the sedimentary rocks in Canada, their succession, structure, age, correlation, and the fossils and fuel resources they may contain. Samples from wells drilled in the western provinces and the Yukon and Northwest Territories are kept in Calgary. These collections are available to visiting geologists to study. During the year more than 200,000 samples from about 1,100 wells were processed.

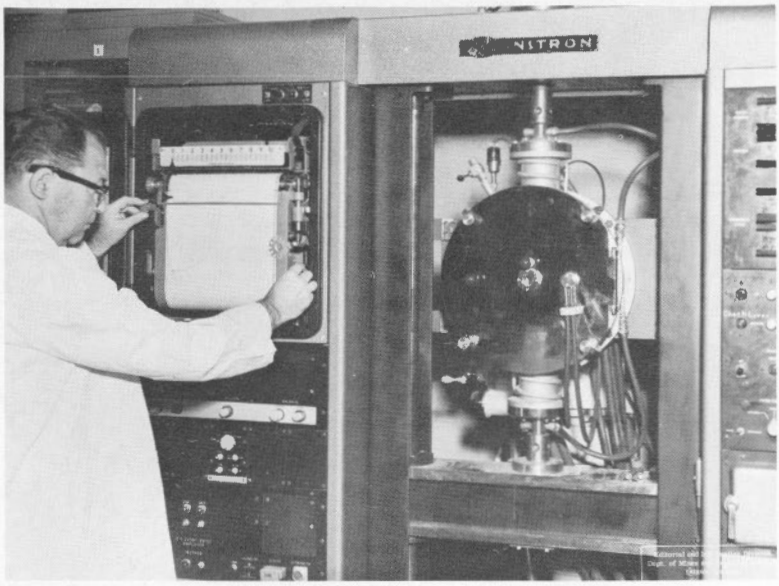
Eight staff geologists undertook field work related to petroleum research. Reconnaissance geology studies were begun in an area in northeastern British Columbia that included the northern Rocky Mountains, South Liard Plateau, and Interior Plains. This helicopter-supported project is expected to take three years to complete, and is known as Operation Liard. Stratigraphic mapping of the Burnt Timber area in the Alberta Foothills was completed for publication at a scale of 1 inch to 1 mile. Special investigations of the stratigraphy and sedimentology of Cambrian, Upper Devonian, Mississippian, and Triassic rocks in the Rocky Mountains and Foothills of Alberta, and of the Upper Devonian of Hay River region, Dictrict of Mackenzie, were also conducted during the field seasons. At the same time, laboratory investigations were conducted on various aspects of subsurface rocks in southwestern Ontario, Quebec, the Maritime Provinces, and northeastern British Columbia, and compilation and appraisal of information and statistics pertaining to the oil, gas, and coal industries of Canada continued.

Survey palaeontologists prepared 171 reports on 2,706 lots of fossils, which had been submitted by Survey geologists and persons in other government departments, in industry, and at universities. Some 954 fossil types were added to the Survey's Type Collection, 439 of which are described in Survey bulletins,

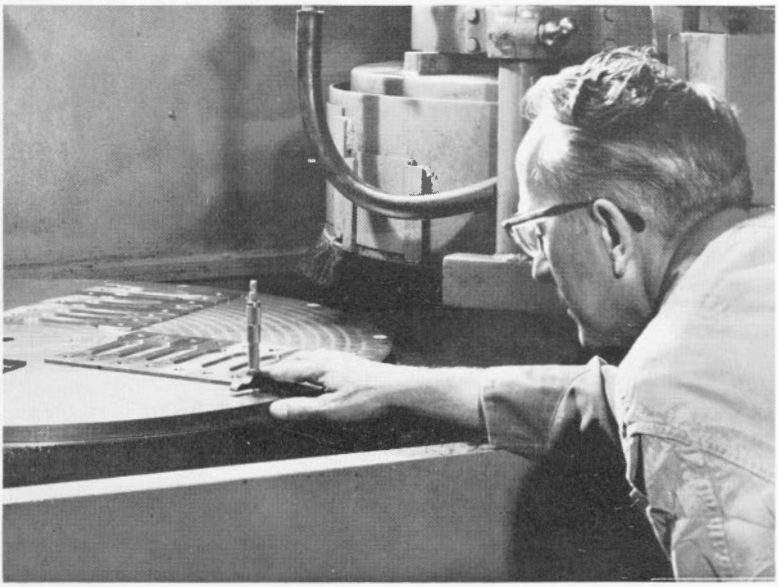


Largest available map of Canada was put on sale by Surveys and Mapping Branch in both English and French in 1963.

Departmental employee demonstrates electronic data-processing unit used to compute tide predictions for northern Canadian waters.



Mines Branch technician uses polarograph for determining metal content in ores and process solutions.

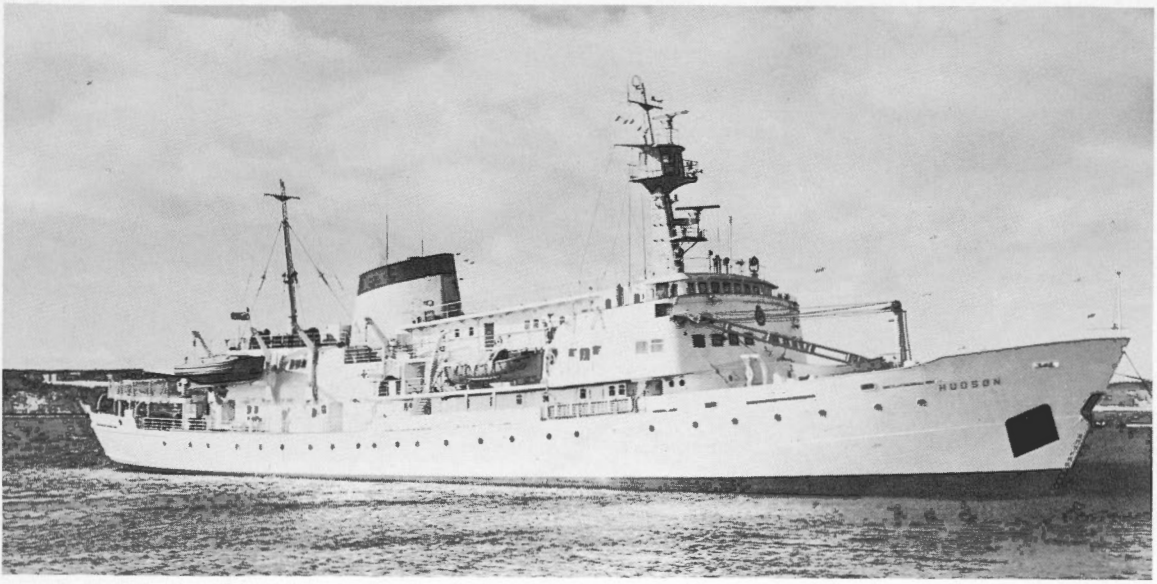


High-tensile steel is being tested by abrasive machining in Mines Branch technical services shop.

Graph shows tensile strength of metal being studied in Mines Branch laboratory.

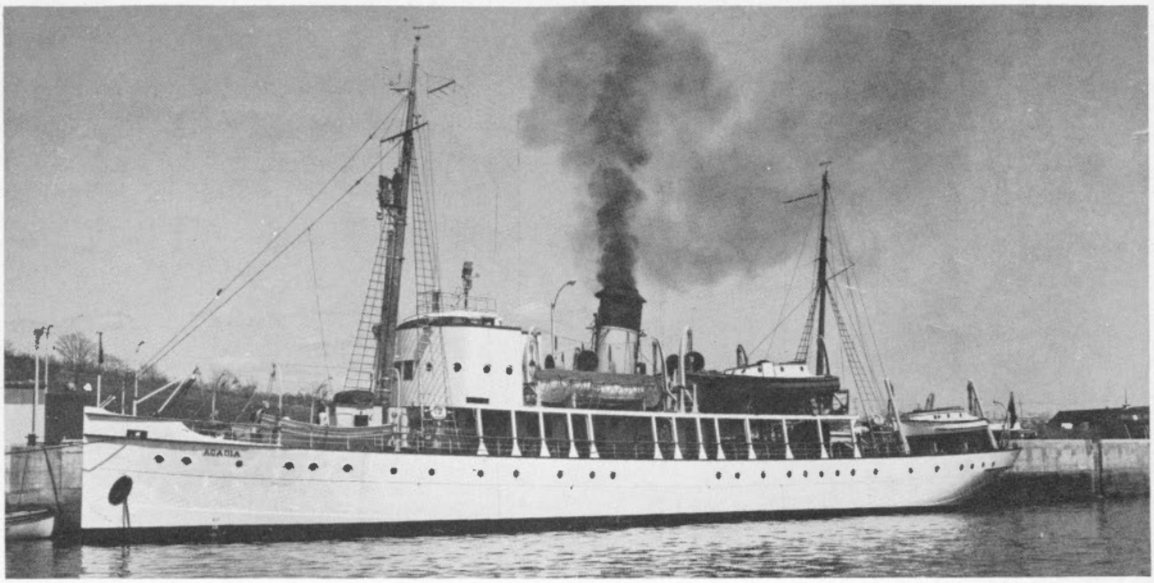
Dr. Yves Fortier, new Director of the Geological Survey, received the Massey medal for outstanding scientific contributions to the geology and geography of Canada.

Topographical Survey party extended spirit level control across Labrador in epic winter treck.



Most important recent addition to Department's marine sciences fleet is the C.S.S. **Hudson,** recently commissioned for hydrographic and oceanographic service in the Arctic and Atlantic oceans. The ship is a floating laboratory equipped with elaborate gear. It has a cruising range of 15,000 miles.

Young visitors have a look at some of the meteorites in the collection of the Department. The Geological Survey of Canada is anxious to obtain further specimens, and pays up to $100 for genuine meteorites.

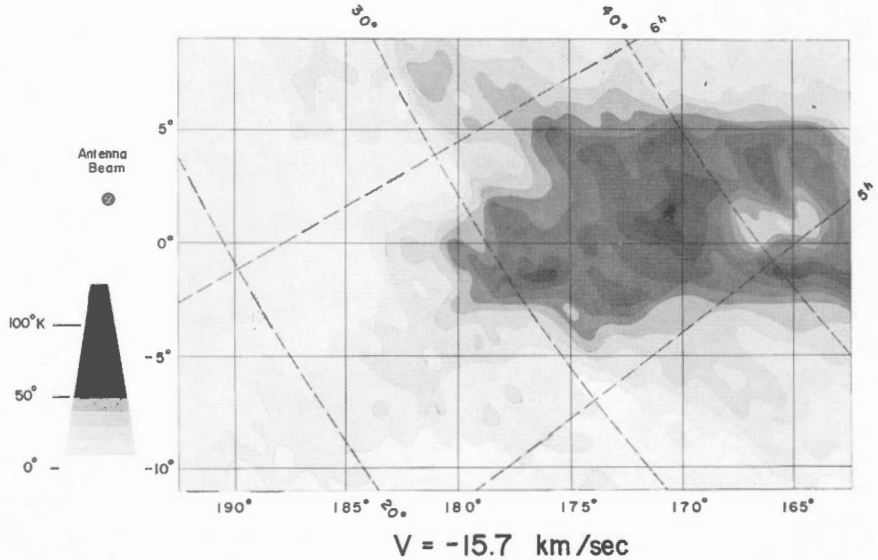


C.S.S. **Acadia** observed her 50th anniversary this year. The ship, one of the Marine Sciences Branch fleet, has been doing hydrographic surveying in Canadian Atlantic waters for half a century and is still going strong. The **Acadia** is one of the few steamships left in North America.

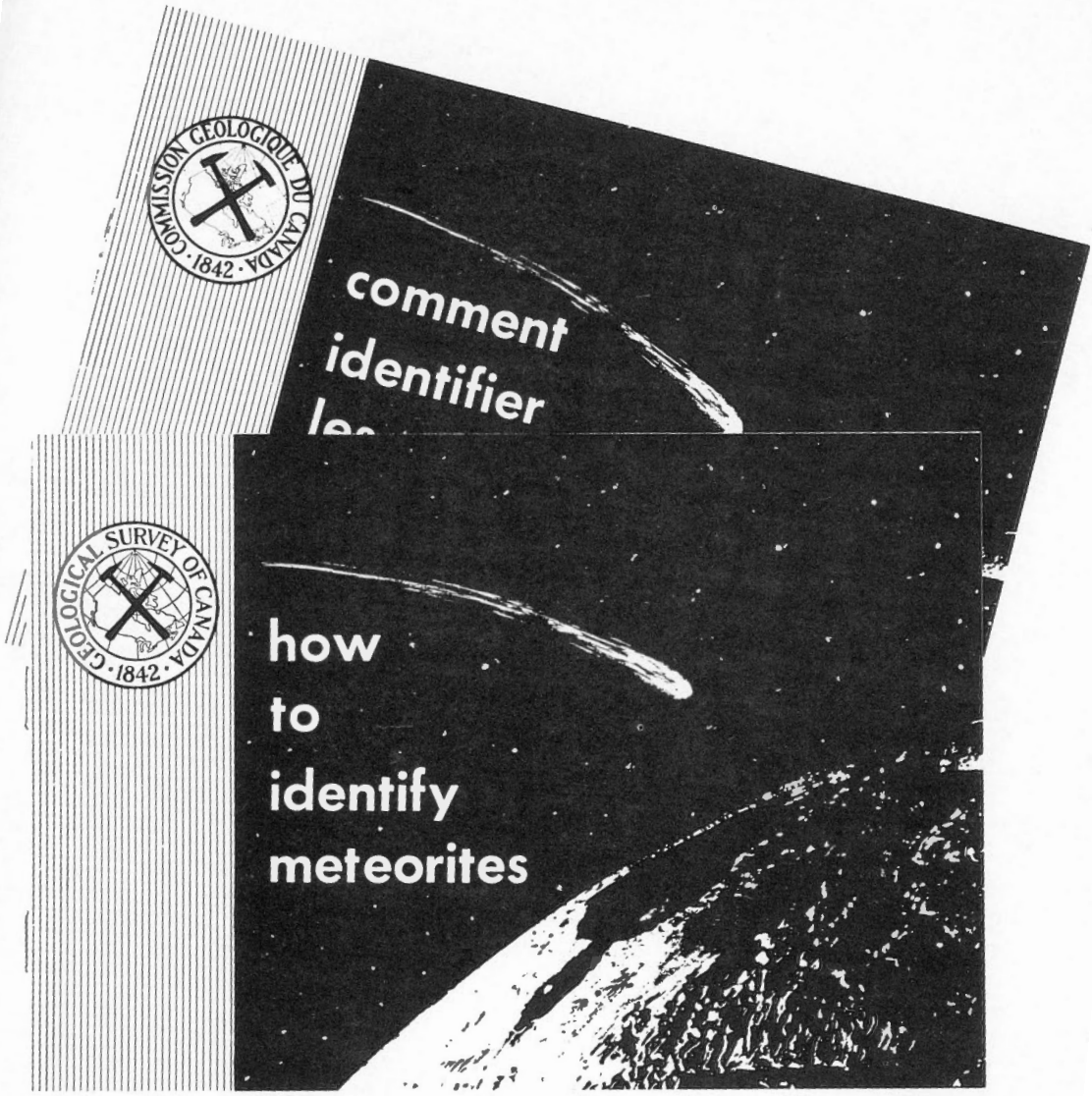
Geological Survey staff member prepares series of mineral sets for sale to the public Both sets of rocks and of minerals are sold by the Survey at $2 each, to amateur geologists, prospectors, educational institutions, and others.

Survey monument dating from 1762 located recently by departmental survey team near Caughnawaga, Quebec.

Camp of seismic survey team, attached to Polar Continental Shelf Project, on King Christian Island in the Queen Elizabeth Islands.



Cosmic gas cloud charted by radio telescope at the Dominion Radio Astrophysical Observatory. The cloud, which is extremely cold and rarefied, is moving away from the solar system at a speed of 36,000 miles per hour.



Eight-page illustrated booklet distributed by Geological Survey, helps Canadians, particularly those living in rural areas, to identify meteorites.

the remaining 515 in an assortment of outside journals. Special studies were commenced or continued on corals; Silurian trilobites from the Arctic Islands; microfossils from the Aklavik Range in northwestern District of Mackenzie and from southern Ontario; graptolites from Gaspé, Quebec; Cretaceous fossil plants from western Canada; and on Ordovician, Silurian, Devonian, and Triassic fossils from western and Arctic Canada. More than 5,000 fossil specimens underwent special laboratory preparations, including sectioning, preparation of casts and moulds, cataloguing, and filing.

Reconnaissance mapping of post-Precambrian rocks of Axel Heiberg and northwestern Ellesmere Islands was completed, with the aid of a Piper Super Cub aircraft, and studies of the stratigraphy and structure of the Bathurst Island Group on Bathurst Island were started.

Coal research under way at the Survey involves studies of microscopic properties, which may provide information valuable for coal utilization and for an understanding of the regional stratigraphy. These studies are chiefly on coals from Nova Scotia and British Columbia.

ECONOMIC GEOLOGY

Personnel in the Economic Geology Division are actively studying metallogenic, geochemical, hydrogeological, and geological engineering problems, and the surficial geology of Canada. Efforts are directed towards obtaining basic information of value towards the exploration and development of our country's resources, with studies providing descriptive data, identifying the natural systems, and understanding the geological processes, past and present.

Metallogenic studies are being made to identify the major times and places of ore formation and the related geological history of the enclosing rocks. The Survey has recently published several metallogenic maps stemming from such studies. Present studies are being carried out in the Appalachian region of eastern Canada, and in the Timmins-Chibougamau mineralized region of northern Ontario and Quebec. Detailed studies on the geological occurrences and modes of formation of tin, vanadium, nickel, and iron in various parts of Canada are currently under way, and studies of heavy minerals in stream sediments have been made both in northwestern Canada and in Nova Scotia, which may provide information helpful to the mining world. A report on the copper deposits of northern British Columbia and Yukon is now in preparation for publication, and investigations of Canadian beryllium occurrences are well advanced.

Both the metallogenists and the geochemists at the Survey are concerned with developing techniques for mineral exploration. Research in geochemistry and geochemical prospecting during the year included geochemical surveys of reef-bearing carbonate sediments in western Canada, geochemical studies in the Kirkland Lake gold belt of Ontario, of the Crow Lake granitic dome in Frontenac county, Ontario, and of the massive sulphide deposits of the Bathurst-Newcastle district in New Brunswick. In addition geological investigations were made on the Manicouagan and Holleford crater-like features. A mobile spectrochemical

laboratory for biogeochemical studies was designed and built and will be ready for field duties in 1964. Laboratory research in the chemistry of ore genesis, isotope geochemistry, radiochemistry, analytical chemistry, geochemical prospecting, statistical geochemistry, and sedimentary geochemistry continued during the year. It included: pilot experiments in the Survey's greenhouse involving the addition of small amounts of radioactive Cobalt-60 to soils in which have been planted small birch trees, to gain information on treating soils with trace elements; progress on the development of a method for determining cadmium in geological materials by neutron activation analysis, and of gold in certain glacial deposits; continuation of studies on the absorption of trace elements by rock-forming minerals; studies of the solubility of sodic feldspar (albite), one of the chief rock-forming minerals; and work on methods of using a direct-reading spectrometer to determine a suite of trace elements in geological materials. In the analytical laboratories procedures were devised for determining small amounts of zinc, nickel, and cobalt in the presence of larger amounts of copper; for determining minute amounts of silver in rocks; and studies continued on various trace elements in marine organisms, in cooperation with the Fisheries Research Board.

The study of groundwater traces the path of water down through the geological materials, determines how and at what rate it may be chemically affected, sums up the water budget to ascertain the availability and quality of water supply, and distinguishes between replaceable meteorological waters and irreplaceable original groundwater. The hydrogeologist must work closely with the chemical and physical geologists, with meteorologists, agricultural scientists, and surface-water hydraulic engineers, to provide information on the country's water resources. As many engineering geology problems result from troubles with groundwater, their solution depends on many of the theories and techniques developed by hydrogeological research. During 1963, the Survey continued studies of the movement of groundwater within typical drainage basins in Saskatchewan and Manitoba, from recharge to discharge areas. Other groundwater studies were conducted in the Moncton, New Brunswick, area, near Truro, Nova Scotia, on Prince Edward Island, and technical assistance was provided on groundwater aspects of the Greater Winnipeg Floodway. A laboratory has been established for analogue studies of groundwater problems. Engineering projects included the study of potential dam-sites in Yukon, and landslide studies in the three Prairie provinces; advice was also provided by Survey engineering geologists to the St. Lawrence Seaway Authority on problems pertaining to the Welland Canal.

Surficial geology deals with unconsolidated deposits formed during Pleistocene (or glacial) and Recent times. Such deposits form the foundations beneath many engineering structures, the parent materials of agricultural and forest soils, the source of gravels and sands for construction purposes, and the reservoirs of much of the country's groundwater supplies. Ten Survey field parties were engaged in operations pertaining to surficial deposits during the 1963 field season. Two were attached to aircraft-supported mapping parties in the Arctic, one on

Bathurst Island, the other in northern Baffin Island. Another made a reconnaissance examination of the area between Granby and Rivière du Loup, Quebec, outlining a major glacial moraine system containing extensive gravel deposits, and adding much to our knowledge of ice recession in eastern Canada. Another party tested a newly developed technique of ore-mineral tracing in glacial deposits in the Kirkland Lake area, with moderate success. The results suggested the existence of a previously unknown gold-bearing orebody in addition to showing marked gold concentrations in the glacial deposits around known orebodies. Additional glacial studies were conducted in New Quebec, on Prince Edward Island, in southern Alberta, southern Manitoba, and in southeastern Ontario. Drilling through the ice of Lake Ontario and two nearby lakes during the winter yielded samples of lake sediments and glacial deposits, the study of which is expected to yield useful information on the geological history of the Lake Ontario basin. Studies of airborne pollen in the Ottawa area and in parts of the Arctic are under way to aid in recognition of pollen species in glacial deposits as a means of recognizing former climates in Canada. In the laboratories studies are going on to improve the classification and precision of nomenclature of clastic sediments as an aid in correlation problems and in basic research concerning the behavior of sediments. Studies of fossil woods, seeds, and leaves, which form part of the specialized field of palynology, are being undertaken to provide basic information that may permit stratigraphic correlations in many parts of Canada of wide varieties of glacial deposits.

PETROLOGICAL SCIENCES

Much of the work of the Petrological Sciences Division is carried out in the laboratory, including complete and partial chemical analyses of rocks and minerals; isotopic analyses for age determinations of minerals and rocks; identification of unknown minerals; studies of variations in mineral compositions, structures, and related properties; preparation of rock and mineral sets for sale to the public; and maintenance of a National Mineral Collection, and petrographical and meteorite collections. Intensive field studies are under way at the same time on granitic rocks in British Columbia and ultrabasic rocks in the Northwest Territories, British Columbia, Manitoba, and Quebec, projects aimed at establishing basic data on the modes of occurrence and formation of these important but controversial rock types. Much laboratory work is a service to field geologists in other parts of the Survey, but some basic petrological research is always being done by the laboratory personnel. The demand for services increases annually, and has taxed most of the laboratories to their maximum, with extensive backlogs of requests for analyses, etc. Laboratory personnel are regularly improving their methods of operation, with an increasing use of automation and streamlining of operational flowsheets, resulting in a sharply increased production per man-hour during the past few years.

The Analytical Chemistry laboratories installed a new vacuum X-ray multichannel spectrometer during the year, thereby permitting the change from rapid

chemical methods to an X-ray fluorescence method for the determination of eight of the main elements (Si, Al, Fe, Ca, Mg, K, Mn, and Ti) in rocks and minerals. The instrument was set up and tested during the early months of the year, and although numerous unpredicted operational difficulties were encountered, it appeared to be operating satisfactorily at the end of the year and is expected to yield accurate and speedy analyses in the future. Laboratory personnel tested and adopted a new chemical procedure for thorium determination, developed an ion-exchange separation technique combined with X-ray fluorescence analysis for the determination of rare earths in certain minerals, completed an investigation with the collaboration of several instrument manufacturers into the application of infrared spectroscopy in mineralogical analysis, set up an apparatus that will permit the determination of water and carbon dioxide in minute amounts of sample, and adopted for routine analyses a method for the determination of ferrous iron that is faster and less difficult to do than the classical method.

The Analytical Chemistry laboratories also prepared lead, thorium, and uranium extractions from zircon grains for determining the ages of the zircons and enclosing rocks, extracted lead from 57 sulphide samples for isotope determinations, undertook a complete analysis on a small sample of xanthophyllite for basic mineralogical purposes, completed a series of accurate chromite analyses, undertook analyses of two meteorites, and adopted a new procedure for the determination of fluorine in silicates. Some 75 synthetic standards were prepared for the determination of trace elements in granites and a variety of sulphate minerals, and preliminary work was done for the synthesis of standards for a wide range of sulphides. The laboratory has undertaken a long-range program to widen its analytical procedures to include more sensitive methods for the many types of samples received, aiming at the retention of good precision and accuracy but speed-up in production. The laboratories completed 1,198 chemical and X-ray fluorescence analyses and 2,432 spectrographic analyses, an increase of about 15 per cent over 1962. Because the number of samples submitted for analyses increased approximately 80 per cent over 1962, a substantial backlog of specimens remained at the end of the year.

The Isotope and Nuclear Geology laboratories continued their program of potassium-argon age determinations on micas and whole rock samples, and undertook the preparation of material for rubidium-strontium age determinations and for uranium and thorium analyses for zircon age determinations. During the year, 197 potassium-argon ages were calculated from analyzed specimens, bringing to 844 the number of such ages determined by the Survey since the inception of its age-determination program in 1959. Most of the 197 ages calculated in 1963 were obtained from mica concentrates, but 46 whole rock samples, mostly selected from diabase dykes, were dated, and the results proved sufficiently encouraging to process a greater proportion of samples of whole rocks in the future. Use of whole-rock samples would expand the scope of the age-determination technique to permit use of some rock types that do not contain sufficient mica for recovery and analysis. No new rubidium-strontium ages were

obtained during the year, as the solid-source mass spectrometer was assigned to the determination of the relative isotopic abundances of lead in a suite of galenas and other sulphides. The number of lead analyses completed was 214. Special techniques were developed to make these analyses, for many of the sulphide specimens contained smaller amounts of lead than were required by normal analytical methods. Facilities were readied for age-determination work on zircon grains based on uranium-lead and thorium-lead ratios, which will permit comparison with some of the potassium-argon ages, and will also permit dating some rocks not otherwise datable because they do not contain sufficient potassium. The laboratory placed its third mass spectrometer (and second gas-source instrument) into service during the year; it is a unit embodying many special features, some of which were designed and fabricated by Survey technicians. The sensitivity of this instrument will facilitate the determination of younger potassium-argon ages on rocks and minerals than was formerly possible. A fourth mass spectrometer (and second solid-source sample instrument) was constructed and was awaiting testing at the end of the year, before being used for rubidium and strontium analyses.

The Radiocarbon-dating laboratory completed 87 measurements during the year, thirteen of which were on tree rings and tree leaves to determine variations in carbon-14 content of modern plants as a guide to the interpretation of dates provided on older materials. A second 5-litre proportional counter was designed and fabricated, and has undergone preliminary tests. This instrument may permit dating of older carbon-bearing material than the two older instruments already in use in the Radiocarbon laboratory.

The Mineralogy laboratories contain equipment for sample preparation, mineral separation, and preparation of mineral and rock sets; X-ray diffraction instruments; X-ray spectrographic instruments; and a new electron probe micro-analysis instrument. These are used to provide mineral identifications and analyses for Survey personnel, for examination of specimens submitted for potassium-argon dating, and for primary research in the field of mineralogy. During the year the output of these laboratories increased slightly over that for 1962. A method for rapid determination of rubidium and strontium contents in rocks and micas was developed as a requisite for the rubidium-strontium age-determination program. Some 3,189 mineral identifications were made by X-ray diffraction, and 917 samples were received for X-ray spectrochemical analysis, on which a total of 2,264 quantitative determinations were made for Survey geologists during the year. The Sample-preparation and Mineral-separating laboratory produced 4,180 mineral concentrates (2,504 in 1962), involving separations of some 25 species of minerals. During 1963 a total of 7,039 collections of minerals and rocks, containing 246,431 specimens, were distributed to the ten provinces and the territories of Canada. Some 1,153 samples received from the public for identification were examined during the year and the results returned in 283 letters.

The systematic reference series of the National Mineral Collection showed continued growth and service. During 1963 it was augmented by 497 specimens,

including 180 by exchange and 52 as gifts. Of these, 265 were new mineral species, increasing the total representation of species and chemically distinct varieties of minerals in the Survey's collection to 1,184. The use of this collection as a source of research material shows a marked increase in the interest of the public and Survey personnel. The economic collection was enriched by a gift of 504 samples from the Mineral Resources Division of the Department, and by several trays of specimens from mining properties in Canada, receipt of which is most appreciated.

The Survey maintains a Microscope laboratory, a rock-specimen preparation room, and a storage area for its collection of representative rock specimens and thin sections from many parts of Canada, and its meteorite collection. Survey personnel have already access to these facilities. Petrographic studies on Canadian meteorites are currently under way, and a catalogue of the Survey's collection was published early in the year. A pamphlet *How to Identify Meteorites* published during the summer by the Survey was taken up so quickly by the public that it was out of print within four months, and a new supply was on order at the end of the year.

The Survey's systematic study of granitic rocks in southern British Columbia continued during the year, as part of a program aimed at a better understanding of the origin of these common rocks. The areas under study were selected because of the contrasting structural and metamorphic terrains they contain, well exposed within a single mountain belt. Some of the field studies were completed during the year, and will be followed by extensive laboratory investigations. Results obtained from these studies should provide valuable basic data and interpretations for similar studies of granites in other parts of Canada and the world.

As part of the Upper Mantle Project — a three-year international program started in 1962 by the Geological Survey in collaboration with many other scientific organizations throughout the world to study the upper layers of the earth — the Survey conducted its first major diamond-drilling program, with the drilling of three holes, to depths of 4,000, 3,593, and 2,496 feet, into selected parts of the Muskox Ultrabasic Intrusion in northern District of Mackenzie. About 650 samples are presently being examined for major and trace elements. Present studies are expected to provide basic petrological and mineralogical data on the silicate and sulphide minerals in the intrusion, as well as certain geophysical properties of the body. A comprehensive study of sulphur isotopic variation in sulphides from the intrusion was begun, 157 samples having been selected for mass-spectrometric analysis. Some 86 analyses were completed during the year. Preliminary results show a moderate spread in the ratios of the two sulphur isotopes present in the sulphide minerals, more so than has been found in sulphide specimens from meteorites, suggesting that the parent materials were not similar.

Initial petrological studies of the Mount Albert Intrusion in Gaspé, Quebec, were completed, and plans prepared for the drilling of a deep hole into this ultrabasic rock, which is thought to comprise material from a near-surface layer of the earth's crust.

GEOPHYSICS

Personnel of the Geophysics Division of the Geological Survey conduct and interpret geophysical surveys as an aid to the understanding of the geology of Canada, and in addition carry out research into the development of new geophysical methods and instruments to help geological investigations and prospecting.

Field activities by the Survey's geophysical staff consisted of the following: (1) an investigation of the Coulonge River Basin in southwestern Quebec to evaluate the extent to which aerial photos (including color photos) and aeromagnetic data could be used to facilitate and expedite geological mapping; (2) seismic surveys along part of Hudson Bay, of the Chignecto Isthmus, Nova Scotia, in the Kirkland and Larder Lakes region of Ontario and Quebec, in the Beauceville area, southern Quebec, and of the Athabasca Formation in northern Saskatchewan, which were conducted mainly to establish the existence of buried channels, and depths to Precambrian or other bedrock surfaces; (3) palaeomagnetic studies of the Muskox Intrusion and associated rocks in northern District of Mackenzie, as a means of determining their age relationships and cooling histories; (4) a resistivity survey in southern Manitoba to delineate near-surface groundwater-bearing zones; (5) a sea-magnetometer survey off Newfoundland and Nova Scotia; and (6) a micromagnetic survey near Nakina in northwestern Ontario to investigate known magnetic anomalies in some Precambrian iron-formations.

Geophysicists from the Survey coordinated the federal-provincial aeromagnetic survey program, which was commenced in 1962, with contracts awarded to private companies for aeromagnetic flights and map compilations in parts of northern Alberta, Saskatchewan, Manitoba, and areas north of Great Slave Lake, Sault Ste. Marie, and Quebec City. During the year Survey personnel checked approximately 540 one-mile aeromagnetic map compilations resulting from this program, and compiled more than 200 map-sheets from aeromagnetic surveys flown by the Survey. Staff members also planned and conducted a week-long seminar on aeromagnetic interpretation for 24 representatives from provincial mines departments.

The hammer seismic survey of the Chignecto Isthmus region between Nova Scotia and New Brunswick has outlined the bedrock surface and preglacial channels with maximum depths of 20 feet below sea level, but no continuous channel across the Isthmus. A hammer seismic survey in the Moncton, New Brunswick, area was completed and the resultant contoured map showing the bedrock surface reveals several buried depressional features, which may be of assistance in groundwater studies. Hammer seismic surveys in the Kirkland Lake, Ontario, and Beauceville, Quebec, areas measured overburden thicknesses and outlined buried bedrock channels, which may be of assistance in locating placer gold deposits.

Several staff geophysicists are engaged in the development and field-testing of geophysical instruments that can be used as aids in geological mapping.

Work is under way on low-frequency induced polarization equipment, with a field model to be used for obtaining data on depths to horizontal layers and to detect sink holes and aquifers beneath the surface, the laboratory model to be used for studying membrane polarization in rocks and soils that contain clay minerals. A transmitter has been designed and built to produce and receive electrical pulses for scale-model simulation. Modifications were made to telemetering equipment used with the airborne magnetometer to permit speedy installation in or removal from the Cessna-180 aircraft. Modifications were also made to other equipment on the aircraft for more efficient operation. Design and construction of a lightweight magnetometer without electron tubes were under way at the end of the year.

Laboratory studies on the palaeomagnetic properties of rocks continued, with measurements and stability tests completed on 533 samples from Newfoundland and adjoining parts of Labrador. The laborious task of processing the magnetometer data and statistical analyses was eliminated with the preparation in 1963 of computer programs, which permit the task to be performed electronically. Two magnetometers, which were constructed in previous years, were calibrated during 1963, and their limitations established.

The design and construction of a portable three-channel gamma-ray spectrometer for the determination of uranium, thorium, and potassium content of rocks *in situ* was completed, and the instrument received initial field testing in Preissac township, Quebec. It is now undergoing calibration.

Basic studies were made on the characteristics of electromagnetic wave propagation through a medium exhibiting induced electrical polarization, and theoretical investigations were made on the development of new methods and on the evaluation of existing methods for quantitative interpretation of aeromagnetic data.

MARINE GEOLOGY

Personnel of the Marine Geology unit were transferred from Survey headquarters in Ottawa early in 1963 to the new Bedford Institute of Oceanography in Dartmouth, Nova Scotia. There, four new laboratories were set up to permit analytical work in sedimentology, micropalaeontology, X-ray spectrography and diffraction, and organic geochemistry. During the summer studies were undertaken on Arctic bottom sediments in Prince Gustaf Adolf Sea and along the shores of East Bay, Mackenzie King Island; on bottom sediments and soundings on the continental shelf west of Queen Elizabeth Islands and between Greenland and Ellesmere Island; on bottom sediments and microfauna in St. Margarets and Mahone bays, southeastern Nova Scotia; on organic matter in recent sediments off Halifax, Nova Scotia; and on the foraminifera content of sediments on the Magdalen Shelf in the Gulf of St. Lawrence and off Halifax. These studies result from the increasing awareness of the need for more scientific information on our country's coastal waters.

Mines Branch

The Mines Branch during 1963 continued its intensive search for better and broader uses of Canadian metals, minerals, and fuels. It collaborated with private industry in the solution of processing problems, mine safety, and the assessment of raw materials for commercial purposes. Branch specialists also carried out numerous analyses and tests on behalf of other government agencies, notably National Defence, and participated in the work of international bodies, both to exchange scientific information and to set testing and other standards. Among the interesting and important projects were the continuing search for non-nuclear uses for uranium, especially as an additive to steel, petroleum hydrogenation at high pressures, radiotracer applications in copper refining, novel methods for producing electronic ceramics, and the separation of metallic components of complex ores in concentrate mills.

PHYSICAL METALLURGY

The Physical Metallurgy laboratories continued to work on problems applying directly to Canada's mining, metallurgical, and metal-working industries. In addition, they continued to undertake fundamental studies and applied research, much of it on behalf of other government agencies. In the execution of this latter task, some 90 reports were issued during the year.

The staff also maintained scientific exchanges with professional societies and laboratories around the world.

Investigational services rendered by the Branch included some 118 laboratory examinations and metallurgical studies of a wide range of materials, from boiler tubes, aircraft and military equipment parts, to bird bands and Indian copper artifacts. Cases in which advice or recommendations were provided to the Department of National Defence numbered 56 during the past year — 17 for the Navy, 29 for the Army, and 10 for the Air Force. Other government agencies made 135 requests for technical assistance on physical metallurgy questions, and private industry accounted for another 139 requests.

Among the more important studies were the resolution of the cracking and warping of a cast steel mould at a large producer of aluminum ingots, and the investigation of eyebolts on emergency parachutes. Several investigations dealt with ferrous and non-ferrous equipment suspected of helping to cause gas explosions and fires as well as premature failure of boiler tubing, ship propellers, and aircraft engine exhausts. The Branch conducted numerous investigations of faulty or improper welding, with appropriate recommendations.

The Branch carries out the certification of industrial radiographers on behalf of the Canadian Government Specifications Board, and in examinations held across Canada it certified 123 candidates as junior radiographers and 40 as senior radiographers.

The Branch also undertook a considerable number of gas analyses, establishing the proportion of "parts per million" of such gases as hydrogen, oxygen, and nitrogen in certain steels and refractory metals. Such analyses are important in the evaluation of quality control in production and in refining techniques.

The Bank of Canada was advised on improved methods of banknote production, to prevent counterfeiting, and some novel proposals of the Branch were well received.

In the field of fundamental and applied research, the Branch experimented with the production of new and improved alloys, particularly steels. It studied niobium-bearing steels with high tensile strength, good toughness, and weldability, with encouraging results. Promise was also shown by the low-temperature properties of low-carbon steels containing niobium. In an attempt to develop non-nuclear uses for uranium, Branch scientists carried on intensive investigations of the effects of uranium additions to a wide range of steels. Some beneficial effects have been discovered, but further studies are necessary.

Uranium additions to non-ferrous alloys are also being studied, and it has been found that the hot-rolling characteristics of lead-contaminated brass, for example, can be markedly improved by small additions of uranium.

The Branch completed a long-term project on the aging of aluminum alloyed with 10 per cent magnesium, and scientists advance the theory of a two-stage aging process as the explanation of observed effects on mechanical properties.

Further work on magnesium-base alloys containing zinc, silver, and zirconium has produced a casting alloy which, after being treated with heat, develops unusually attractive tensile properties coupled with good elongation, the combination of which is much superior to the qualities of any current commercial product.

Studies of alpha-beta titanium alloys have been directed to the determination of the constitution of the titanium-rich corner of the titanium-aluminum-molybdenum system. This work was almost completed during the year.

Strong, tough, dense alloys with metallurgically controllable hardness are much sought after for military purposes. Uranium alloys may play an important role in this respect, and the Branch has started an extensive binary and ternary alloy investigation to help evaluate the mechanical and physical properties of uranium alloys.

The Branch also continued to study the effects of vacuum deoxidation and degassing of carbon steels melted in acid furnace linings, and started a program to study the vacuum-degassing and -casting of high-strength alloy and stainless steels.

Casting research included studies of segregation and its effect on the tensile and fatigue properties of carbon and carbon-manganese steels. This work was based on the influence of uranium-rich segregates in uranium-treated steels. Studies of the erratic mechanical properties of aluminum alloyed with 10 per cent magnesium showed the cause to be layer porosity in the gauge length of test-bar castings.

Welding research concentrated on the welding of structural steels during extremely cold weather, such as that found in the Arctic.

Studies of corrosion prevention included the influence of alloy additions to galvanizing baths; the effect of steel-base material on the quality of galvanized coatings; studies of the behavior of steels containing small quantities of uranium in water solutions; and the corrosion of various zirconium-base alloys in high-pressure steam.

Research on mechanical properties was concerned chiefly with fatigue caused by cyclic stress and atmospheric conditions. The researchers were using electron microscopy in this work, whose practical value has been shown by the development of an improved, fatigue-resistant push-on rock drill bit.

In the field of melting and solidification, studies were undertaken on the effect of temperature and composition on the density, viscosity, and surface tension of zinc and some of its alloys, and on the application of radio isotope tracer methods in the study of inverse segregation.

The Branch studied dislocations and lattice structure in strained crystals, and applied transmission electron microscopy of thin metal foils to the study of transformations in iron and steel, single crystals of fatigued copper, and fatigued aluminum alloy. Evaluation of the technique of crystal orientation by ion bombardment was completed for face-centred and body-centred crystal structures.

FUELS AND MINING PRACTICE

The Branch continued to devote much attention to the conversion of low-grade Canadian fuels into marketable commodities. To forestall waste in attempted extraction and refinement of petroleum from Alberta's vast deposits of tar sand, Branch scientists in 1963 concentrated their efforts on the hydrogenation, catalytic cracking, and distillation of low-grade oils and tar sands.

Hydrogenation research centres on the construction of a combined liquid- and vapor-phase pilot plant operating at pressures up to 10,000 pounds per square inch, commonly known as the "Combi Process". The assembly of this plant began in summer, and the design and manufacture of the vessel supports, valve and instrument racks were completed. All major pieces of equipment were assembled. In addition to the complete processing of heavy crude oils to finished products, the plant will be used as a cost indicator and a training ground for chemical and mechanical engineers. For this purpose the pilot plant simulates as closely as possible the conditions expected in large commercial operations.

During the year preliminary autoclave experiments were made to develop a Canadian substitute for the liquid-phase "iron grude" catalyst used in Germany in the "Combi" process.

To study catalytic cracking, the Branch is building a plant that is capable of operating at pressures up to 1,000 pounds per square inch, thus permitting the hydrogenation and cracking of feed stocks too heavy for conventional plants. The plant is near completion.

Distillation, which is used both to obtain primary petroleum products and before and after thermal and catalytic conversion, was studied through the inert gas stripping method of topping heavy crude oils and bitumen containing appreciable quantities of water and mineral matter. Branch scientists managed to develop an integrated control system ensuring safety and freedom from contamination, which is being evaluated.

The Branch is also carrying out fundamental studies on the chemistry of catalysts. The first project was an investigation of the porosity of catalyst supports such as alumina and silica gels, with a view to creating catalysts with large arterial pores for the transport of the reactants and products to and from the active surface. This would eliminate certain undesirable catalytic side effects and lead to greater efficiency. Progress has been such that Branch specialists can now prepare many common catalysts and catalyst supports with any desired pore volume or surface distribution.

Progress has also been made in an investigation of the acidity on the surface of catalysts, which is generally related to a tendency of forming coke. Much

time and effort were devoted to better measuring techniques, but it is already apparent that highly acidic catalysts are undesirable if the feed contains much material deficient in hydrogen and high in molecular weight. Future work will attempt to establish the degree of surface acidity desirable.

The Branch continued to evaluate Canadian and other peat moss resources and to assist the peat producers.

As a part of research on cleaning fine materials, Branch technicians at the Edmonton laboratory built a multiple water cyclone capable of handling four to ten tons dry feed per hour, to deal with effluent materials.

In coal research, much attention was devoted to the production of more and better coke needed by the Canadian steel industry. Both laboratory bench-scale and technical-scale tests in the Branch's movable-wall oven were used to evaluate coals for coke making. Technical assistance was also given to Canadian coke plants and coal mines producing coking coals. The Branch is also installing equipment for the new method of using petrographic control as a means of predicting coke quality from small samples of coal.

A working model of a high-frequency oscillating grate stoker was built to provide criteria for the design of a full-size stoker, a step toward development of a packaged boiler unit using cheap coals.

The Branch continued research sponsored by the Navy to overcome slag deposition on superheated tubes of marine furnaces.

A combustion research rig for the study of pulverized coal or residual oil in turbulent diffusion flames under slagging conditions, completed by Branch personnel after two years of work, has given a very satisfactory performance. The rig was run with Saskatchewan lignite. Further tests are scheduled.

During the year, underground studies were conducted by the staff of the Branch in cooperation with seven mines — three coal mines, one gold mine, one salt mine, and two iron-ore mines. Advisory service in rock mechanics and interpretation of results were given to five other mines.

Cooperative programs on slope stability were undertaken at three open-pit mines. The Branch also conducted various laboratory studies on mine safety, such as evaluation of pre-stress retention of rock bolts in plastic grouts, long-term behavior of photoelastic coatings, development of a portable sound-velocity apparatus to outline the fracture zone around mine openings, and the development of a reliable rock-bolt dynamometer. A dust chamber for the evaluation of dust-sampling instruments was constructed and calibrated.

The analytical laboratories analyzed 1,100 samples of solid, liquid, and gaseous fuels, including 144 mine-air samples.

The explosives research laboratory examined 105 explosives, blasting accessories, and fireworks. A fundamental study was started on the blasting effects of explosives on rock properties.

The electric certification laboratory completed 69 investigations of equipment during the year, and progress was made on several research projects on

explosive gas atmospheres. Included in these were stress effects on metal plates and bolts from static and dynamic pressures, propagation of flame through tubes containing pre-compressed flammable gas-air mixtures, and measurement of inductance of iron-cored coils.

The Branch assisted in the Second Canadian Rock Mechanics Symposium at Queen's University and made grants-in-aid in mining research to five Canadian universities. It also continued to take part in the work of the Canadian Standards Association and the Canadian National Committee of the International Electrotechnical Commission aimed at greater safety in the field of explosives.

MINERAL SCIENCES

In its research on rare and unusual minerals, the Branch completed mineralogical and chemical studies of niobium-bearing perovskite from Oka, Que., leading to a new scheme of classification. Further work on the beryllium-niobium-barium complex at Seal Lake, Labrador, led to the determination of eight minerals.

The laboratories undertook numerous ore microscopy investigations on ores of iron, tin, molybdenum, copper, zinc, nickel, gold, silver, etc., to provide information on the value and best treatment of these minerals. During the year, the Branch issued 66 reports on mineralogical investigations.

Staff members visited various mineral areas in Canada to examine and collect specimens.

In response to rising demands, the analytical chemistry laboratories devised new and improved methods in such fields as the determination of iron, copper, and nickel in refractory metals for military use; nickel in brasses and bronzes; a rapid method for zinc in concentrates; various X-ray spectrographic procedures; emission spectrographic determination of trace impurities in rock salt.

The platinum-group metals project embracing platinum, palladium, rhodium, iridium, and ruthenium has reached the point where Branch specialists can determine accurately any of the metals with relatively inexpensive equipment. There are indications that a sixth metal, osmium, can be included in the scheme.

Cooperative projects on chemical standards were undertaken with the International Standards Organization on light alloys; the American Society for Testing and Materials on stainless steels, fluorspar, and iron ores; the U.S. National Bureau of Standards on major constituents and minor impurities in copper-based alloys. Collaborative work was also done with two iron-ore producers on the analysis of iron ore and pellets for laboratory reference standards.

In support of internal and other programs, 22,891 chemical determinations were made on 7,016 samples. There were also 8,376 spectrochemical determinations on 873 samples. These samples included ores, concentrates, minerals, metals, alloys, and other materials.

In physics and radiotracer research, the Branch continued surface chemical studies of mineral particles in relation to flotation processes, adding to its information on control factors.

The project on surface exchange between silver solutions and various crystallographic faces of the metal itself was completed, and the investigations were extended to nickel systems.

Branch scientists continued to study the semi-conductor properties of bismuth telluride as an aid to the use of mineral derivatives in secondary industry. They synthesized single crystals and used them to study the diffusion of contacting metals such as gold, silver, and tin. They also concluded a joint investigation with the Geological Survey on the absorption and scattering of gamma rays emanating from rocks and minerals.

Activities in the development of equipment and apparatus concerned development of prototypes. Branch staff completed the development work on the conductometric monitor for acid and alkaline bleach solutions and on the cyanide-strength monitor. Both are now being used by private industry.

Other equipment being developed includes a gamma gauge for the measurement and control of pulp density; a photoelectric slime-level indicator; an automatic scanner for dust-particle counting; and an ore-sorting device.

An important project in radiotracer applications was the tracer experiment at a copper refinery, aimed at determining how much of the copper present in the converter slag that is returned to the reverberatory furnace is actually recovered in the matte. By addition of about one gram of copper-64 per ladle of slag it was possible to trace the distribution of the "ladle copper" in about 1,600 tons of furnace burden. This is the first time in the long history of copper metallurgy that such information was obtained.

Studies continued in the uses of neutron activation analysis.

In physical chemistry work, stress continued to be placed on the interaction between materials at high temperatures. A new project, the detailed investigation of oxide systems of tantalum, iron, and manganese, has yielded much valuable information on the compounds and solid solutions that are stable under defined oxygen pressures.

Another new project almost completed during the year was the phase-equilibrium system of gold-bismuth-tellurium. This work tied in with semi-conductor studies.

The Branch completed the investigation of complex systems relating to the chemistry of constitution of magnesite clinkers used in refractory materials, and almost completed similar work on systems of niobium pentoxide and other oxides.

The electronic ceramics program concerned itself with the division in sintering studies of high-purity co-precipitated oxides of lead, zirconia and titania, and a phase-equilibrium investigation of this three-oxide system; the latter program was completed.

X-ray crystallography work, much of it on single-crystal material, concerned the examination of many unusual minerals. Polycrystalline materials from the phase-equilibrium program also presented many problems.

Supporting investigations on behalf of other government agencies and private industry fully engaged the attention of specialists working on X-ray diffraction, differential thermal analysis, and thermogravimetric analysis. Investigations were made of corrosion products, sulphate and carbonate decomposition products, uranium compounds, non-metallic inclusions in metals, ash residues, and minerals.

EXTRACTION METALLURGY

Research in extraction metallurgy continued to concentrate on hydrometallurgy and pyrometallurgy, with some attention also to the prevention of metal corrosion.

For several years, the Branch has been studying the cyanide process for extracting gold from ore, one of the most important hydrometallurgical processes. Together with the gold mines, it has formed the Canadian Gold Metallurgists Committee, under whose auspices a meeting of gold-mill operators was held in early 1963 at Ottawa.

As part of the gold extraction program, Branch specialists installed automatic controls on a pilot-plant grinding unit, and results have been promising enough for them to plan the installation of similar equipment at an operating gold mine. Automatic control of lime additions to the cyanide leaching circuit to maintain the alkalinity at precise levels was studied for two months at another gold mine with a device developed by the Mines Branch. The results of this test showed that the savings from such close control would pay for the cost of the equipment in a few months.

At the suggestion of the Gold Metallurgists Committee, laboratory studies were made to develop standard metallurgical tests so that test data would be directly comparable throughout the industry. Branch scientists also continued research on the dissolving of gold in sodium cyanide solution, and found that the deleterious effects of sulphur compounds on the dissolving of gold leaf also applied to the dissolution of gold from ore. A decomposition study of sulphide minerals in cyanide-lime solutions showed that vigorous agitation and high aeration rates lead to increased formation of soluble sulphur compounds.

Over the past few years the Mines Branch has been carrying out a study of ceramics production for electronic uses as an outlet for metallurgical products. These ceramics, produced from mixed oxides of lead, zirconium, and titanium, must meet rigid standards of purity, uniformity, and composition. The normal commercial practice of mixing the various oxides in the required proportions does not lend itself to easy repetition, and Branch specialists have developed novel and precise chemical processing techniques for the production of a mixed oxide primary material. The operation is now carried out in a pilot plant, and the electronic characteristics of the ceramics produced in it are being investigated.

All the vanadium consumed by Canadian industry, about 330,000 pounds per year, has to be imported, and the discovery that certain imported Venezuelan crude oils contained appreciable proportions of the rare metal led the Mines

Branch to seek a method of extracting it. Research has now reached the stage where a pilot plant is being planned, and a Canadian oil refinery has announced its intention to build a commercial vanadium extraction plant when process studies are complete.

The Branch continued to participate in the work of the Uranium Producers Metallurgical Committee, and helped to lay plans for a joint project to study the beneficiation of uranium ores in a continuous flotation pilot plant in the Mines Branch laboratories. Bacterial decomposition of sulphide-bearing uranium ore in place has assumed economic importance in the Elliot Lake mines, and the Branch has started studies to increase and use these bacterial actions. The first phases of the work have been carried out with the aid of the Department of Agriculture.

Some companies wish to produce pig iron by electric smelting even though the cost of power is relatively high. The Branch experimented with pre-heating and pre-reduction of the pelletized charge by hot reducing gases in order to lower power consumption. The study was carried out in an eight-foot-high shaft furnace in which the descending pellets are heated by ascending reducing gases, and a larger plant is being planned.

Preference of pelletized iron ore is growing among blast furnace operators, and since the pelletizing process is not fully understood the Mines Branch started a study of it. It published a survey of relevant literature and carried out research with ground silica which showed a definite relationship between the moisture content which gives pellets their strength and the specific area of the silica.

In research on electroplating, it was found that cadmium plating baths are stable and the anode and cathode current efficiencies are higher when the hydroxide normality in the bath is equal to the cyanide normality. Baths of this type contain considerably more hydroxide than do baths recommended by previous investigators and now used by the industry.

It has long been realized that chromium-plated steel is not as resistant to corrosion as ought to be expected, and Mines Branch laboratories experimented with various chromium bath compositions, cathode potentials, and cathode current densities and studied the resulting chromium plate by electronic and optical means. Much remains to be learned about the electroplating reactions.

In basic research studies, that of thermal stability of metal sulphates, which had already dealt with ferric sulphate, aluminum sulphate, and zinc sulphate, was extended to sulphates of copper and cobalt. Both these latter metals are economically important for Canada, and understanding of sulphate and oxide formation helps in their processing.

Hydrocyclones are being used increasingly in the mineral industry for such operations as thickening, dewatering, and classification, since their large throughput and lack of moving parts make them attractive to production engineers. But in spite of much work with hydrocyclones their operating principles are not fully understood, and the laboratory study has been continued. It seems possible to arrive at a single equation linking the density and viscosity of the slurry that is being

treated with the pressure applied and the throughput, for a given hydrocyclone. This appears to be an important step forward.

MINERAL PROCESSING

During 1963, both personnel and facilities for mineral processing were engaged to capacity.

The Metallic Minerals laboratories carried out 34 investigations, most of them complex, on metallic ores, mill products, and other metallic minerals. The size of samples ranged from a few hundred pounds to carloads.

A milling process was developed for a complex Quebec ore to produce separate magnetite and ilmenite concentrates for pig-iron and titanium smelting and a by-product phosphate concentrate. The feasibility of the process was tested in a pilot plant operating at one ton per hour. A sample of iron ore from the Yukon was concentrated by a gravity process in the plant. A process was developed for concentrating a molybdenite ore from Quebec, and the results encouraged the company concerned to design a mill processing 1,200 tons per day, scheduled for production in 1964.

The laboratories developed treatments for several new properties across Canada, including base-metal, gold, silver, and iron-ore properties.

Investigation of industrial problems included recovery of metals and concentrates from slags and furnace residues; re-treatment of waste mill products; and improvement of processing, such as grinding, sizing, and concentration.

In applied research, progress was made on production of highly pure iron oxide concentrates and reduction of phosphorus content in iron ores. A patent was obtained for a method of roasting antimonial gold ores.

The completion of a metallic minerals research laboratory aided fundamental research on flotation. Projects included the behavior of slime particles in flotation and the adsorption of cationic collectors in flotation of iron ores.

The staff of the Branch provided advice on mineral processing to several government agencies and private concerns, as well as laboratory space for visiting specialists.

The number of samples received by the industrial minerals laboratories in 1963 was over 600, a heavy load for both personnel and equipment. Lack of personnel in general delayed progress on several studies.

Four major investigations in the ceramic laboratories dealt with the processing of structural clay products, aiming at reducing permeability in vitrified pipe, improving plasticity, and extruding properties of raw materials and overcoming efflorescence in fired products.

In the whiteware field, the Branch is studying glaze crazing in wall tile, glaze defects in sanitary ware, and the physical properties of electrical porcelain.

The mineral processing staff continued to gather information on thermal properties of ceramics, and collaborated with other institutions in improving thermal

conductivity measurement of commercial refractories and special dense ceramic products of high performance.

As part of the long-term search for ceramic raw materials, staff members studied clays from Ontario, Prince Edward Island, and Manitoba.

The Branch continued to devote much effort to the development of piezoelectric compounds for the Defence Research Board, giving special attention to mixed-oxide preparation. Staff members also participated in research on thermal piercing and spalling of rocks to solve an unusual problem in an underground opening at a military installation.

In the field of construction materials, the Branch helped Quebec Hydro to evaluate the durability of concrete for the Manicouagan development in northern Quebec. The construction materials laboratories also participated in a study by RILEM, an international association for testing of construction materials, aimed at accelerating the determination of concrete strength. Studies were also completed on potential raw materials for lightweight aggregates and on new sources of building stones from Ontario and Quebec.

In the non-metallic field, the evaluation of minerals from different localities as potential raw materials for industry continued intensively. One of the major investigations was that of the physical properties of bentonites. The staff collaborated with private companies in search for better means of measuring length and texture of asbestos fibres.

As part of the search for Canadian sources of good silica, beach sands from Prince Edward Island were processed in the laboratory of the Atlantic Development Board.

The Branch's industrial minerals mill processed 27 samples and carried out an intensive investigation of the concentration of magnesite from a deposit in northern Ontario. Applied research continued on beneficiation of clay, recovery of weakly magnetic minerals, and separation of minerals mechanically by color sorting.

The industrial waters laboratories analyzed 3,300 samples, many of them requiring analysis for heavy metals. The long-term survey of chemical quality in surface waters in western Canada for the International Joint Commission continued.

The Branch continued to assist the Department of National Defence in solving problems of water supply and treatment. Boiler water treatment control continued at 30 military heating plants; 15 Department of Public Works heating plants in Ottawa have also been included in that program.

The Branch increased its assistance to the Federal Department of Fisheries and to the provincial department of New Brunswick by collaborating in a study of stream pollution by mine waste.

The broad survey on water quality in the upper Great Lakes, Hudson Bay and Labrador basins was completed. Other areas surveyed included the Athabasca River and the eastern Rockies, the latter being studied in cooperation with the Department of Forestry.

The mineral processing staff continued to share in work of various national and international economic and research organizations.

Dominion Observatories

The Dominion Observatories comprise the following six units, each of which has a considerable degree of autonomy within the organization: the Dominion Astrophysical Observatory, Victoria, B.C., which operates as a separate scientific institution and is generally regarded as an independent research institute by scientists outside of Canada; the Division of Positional Astronomy at Ottawa; the Division of Stellar Physics with headquarters at Ottawa but which operates a semi-independent radio observatory at Penticton, B.C.; the Division of Seismology whose research activities are centred at Ottawa but which carries out seismological field work and operates sixteen seismological observing stations in various parts of Canada, one of which, at Victoria, is a modest centre of seismological research; the Division of Geomagnetism with research headquarters at Ottawa but which has an extensive field program and operates seven magnetic observatories in northern and southern Canada, three of which carry out on their own sites, some operations of a research character; the Division of Gravity centred at Ottawa but carrying out field operations in all parts of Canada. Details of the scientific activities of these units follow.

POSITIONAL ASTRONOMY

Hipparchus, during the second century B.C., made a map of the positions of the "fixed" stars, and found that the whole dome of the heavens had shifted compared to an earlier map. So the motion called precession was discovered. Not, however, till 1718, nearly 19 centuries later, was it shown by Edmond Halley that individual stars had changed in relative position compared to the ancient map of Hipparchus.

The study of stellar motions has occupied the attention of astronomers in the two and a half centuries since Halley. Positional astronomy may be described as that branch of the science which is concerned with the measurement of the exact positions of stars, and the deduction of the exact proper motion of individual stars. Proper motion (angular displacement across the line of sight), when combined with radial motion (displacement towards or away from the earth) gives the true space motion of a star. It has been found that certain stars within our galaxy are travelling as a group and this information is important in the study of stellar evolution.

Stellar motions are measured in speeds of several miles per second. Yet the great distance of even the nearest star makes the detection of these motions difficult. Great assistance in the detection of small changes is afforded in the development of modern precise timekeepers, improved photographic techniques and electro-mechanical engineering. Many such improvements have been incorporated in the new mirror transit telescope which was developed at the observatory, and which now replaces the former meridian circle telescope.

In this new instrument two telescopes, fixed horizontally in a north-south line, are directed towards a centrally located flat mirror of high quality. The light of a star as it crosses the meridian is reflected by the mirror into one or other of the telescopes, a south star into the south telescope and vice versa. A camera records the star at several precise moments during its passage up to and away from the meridian, together with the reference mark fixed in the telescope. At the same time a photographic record is made of the exact angle of tilt of the mirror. During 1963 it was necessary to have the declination circle, which indicates the tilt of the mirror, re-graduated, thus delaying full operation of the telescope by a full year. However, many exposures have been made which indicate that the mirror transit telescope is capable of much greater precision than the former meridian circle telescope. It is none the less a prototype, a pioneer in telescope design, and modifications must be effected when the design is faulty.

A new two-coordinate measuring engine, designed to measure the mirror transit star exposures and to transfer the results directly onto punch cards for electronic data processing, was fabricated in the observatory workshop. It is now in regular operation.

The photographic zenith tube (PZT) is a telescope designed especially to measure the daily rotation of the earth. It is fixed in a vertical direction, and as the earth rotates, a narrow band of stars is brought into view. Again the measure-

ments are placed directly on punch cards for data processing. The two products of the PZT observations are universal time (UT) and variation of latitude. The former is combined with results from other observatories at the Bureau International de l'Heure (BIH) to establish the time of an average world clock. Latitude observations are in like manner contributed to the office of the International Polar Motion Service (IPMS) to determine the exact position of the axis of rotation of the earth. PZT observations were secured on 211 nights during 1963.

One rotation of the earth as indicated by the sun is a solar day. Mean solar time is the basis of Universal Time (UT), and is the ultimate scale against which our ordinary domestic clocks are set. Modern quartz oscillators when combined with atomic frequency resonators provide a means of adjusting observatory clocks to the average rate indicated by UT, and maintaining this rate precisely for many months. The atomic clock is so steady that small variations in earth rotation are readily detected. When the difference amounts to a tenth of a second, national time services, by international agreement, adjust their clocks simultaneously. One such adjustment was made November 1, 1963 at 0000 hours UT, when all the clocks were put back one tenth of a second.

CHU, the Dominion Observatory radio timer service, operates continuously on three frequencies : 3330 kc, 7335 kc and 14670 kc. Not only has the time been referred to an atomic standard, but the carrier frequencies have also been maintained with the same precision. CHU may thus be considered a standard of time and frequency.

The unit of time, the second, is now defined as a fraction of the solar year, and is determined by lunar observations, the time so measured being called Ephemeris Time (ET). The present moon camera program, which began in 1958 during the International Geophysical Year, was suspended in September 1963. An analysis of the Ottawa observations secured during the final two years indicates that UT has lost about 35 seconds on ET since the beginning of the century. During this interval the earth has rotated a little slower on its axis than it did during the 19th century.

No observations of artificial earth satellites were made from the Dominion Observatory in 1963. However, liaison was established with the R.C.A.F. satellite station at Cold Lake, Alberta. Two Schmidt-type cameras are at an advanced stage of construction, and will be used for satellite photography in 1964.

The search for a good site for astronomical work in Canada was pursued. A location in the Gatineau Park north of Ottawa has for the past two years been equipped with a barograph, two thermographs and a rain gauge. During the year a sunshine recorder and a 12-inch Tinsley reflecting telescope were installed. A visit to British Columbia was made to compare the seeing in the dry belt of the Okanagan Valley with the seeing in Gatineau Park.

The total solar eclipse of July 20, 1963, attracted much international attention. The remarkable view of a total solar eclipse, seen from an altitude of 30,000 feet over Great Slave Lake was one of the outstanding events of the year.

STELLAR PHYSICS

One of the major programs being undertaken at the Dominion Radio Astrophysical Observatory, near Penticton, B.C., is a detailed comparison of emission from the sky at two widely separated radio frequencies. This study is expected to contribute greatly to an understanding of the physical processes involved in the production of radio energy both by our galaxy and by external radio galaxies.

A considerable portion of the high-frequency part of the study was completed during 1963. The high-frequency survey is being carried out with the 84-foot parabolic radio telescope operating at a frequency of 1420 Mc/s.

A second telescope, which will operate at a frequency of 22 Mc/s, consists of aerials supported on poles arranged in the form of a large "T". The long crossbar of the "T" measures approximately 4/5 of a mile and the collecting area about 16 acres. Completion of this telescope is being rushed to take advantage of the low level of interference from terrestrial transmitters expected during 1964 and 1965 when sunspot activity will be at a minimum.

Development was completed of a multi-channel receiver for observations at the hydrogen-line frequency. This receiver, based on the interference principle, effectively receives on ten adjacent frequency bands simultaneously. It was used successfully in studies of hydrogen emission from external galaxies.

Successful observations of the solar corona were made during the total eclipse of July 20, 1963. The equipment was carried aboard an R.C.A.F. Yukon aircraft which intercepted the eclipse shadow at 30,000 feet over Great Slave Lake. Observations were made of the white-light emission of the corona and of the green emission line which is a prominent feature in the spectrum of the corona. Preliminary considerations showed that it should be possible to use modern photoelectric equipment to map the intensity of the green-line emission to greater distances from the limb of the sun than had been previously achieved by photographic techniques. These intensity measurements can be used to determine the distribution of temperature and electron density through the corona, quantities which are vital to the understanding of its physical nature. These experiments must be repeated for many eclipses in order to study the change in coronal radiation during a complete sunspot cycle.

All the objectives set for the coronal green-line experiment were successfully achieved during the eclipse flight. Where the green-line emission was strongest, it could be traced to a height of about 1,000,000 miles above the solar surface, or nearly twice the maximum height observed with earlier photographic methods.

The Solar Flare Patrol continued its routine daily observations of the solar chromosphere. This program of time-lapse photography of the sun viewed through a narrow-band optical filter is conducted in cooperation with the National Aeronautics and Space Administration and the National Bureau of Standards in the United States.

The observation of meteors by photographic methods continued at the meteor observatories in Alberta. Three new spectrographs have been installed to

study the light persisting in the sky for several seconds after the passage of some meteors. Mechanical improvements were made to the Super-Schmidt telescopes which photograph meteor positions with high accuracy.

A geophysical study of West Hawk Lake, Manitoba, published during the year lends support to the hypothesis that this resort lake is an ancient meteorite crater.

A program to determine the diameter of the planet Pluto, which is poorly known, was begun during the year. The program requires international cooperation among various observatories.

GEOMAGNETISM

Every ten years, the Division of Geomagnetism publishes a new set of charts showing the orientation and intensity of the earth's magnetic field over all of Canada and neighboring ocean areas. The charts must be revised periodically, not only as more accurate and better distributed observations become available, but because the geomagnetic field is everywhere gradually changing, and magnetic maps become obsolete in five or ten years. A new edition of charts showing the magnetic field as of January 1965 is in preparation for distribution before that date.

The Dominion Observatory's magnetic charts are based on measurements at some 15,000 points, the great majority of the observations being made in the air with the three-component airborne magnetometer. In November 1963, a survey of 38,000 miles was carried out with this instrument in a chartered DC-6 aircraft. The area covered extended north from the mainland of North America to the north pole, east to the Greenwich meridian and west to the international date-line, including northern Greenland, and Queen Elizabeth Islands, and a large part of the Arctic Ocean.

To make use of the observations of earlier surveys in the preparation of the maps for 1965, maps showing the rate of change of the geomagnetic field at five-year intervals since 1950 have been prepared. These are based on measurements made on the ground at about 100 "repeat stations" distributed uniformly over the country, which are visited regularly. During 1963, 21 such stations were reoccupied, mainly in Quebec, Ontario and Manitoba. In addition to its practical importance in the construction of magnetic charts, the study of the slow changes in the magnetic field has a great theoretical interest. These effects originate deep within the earth in its liquid core, and provide one of the most useful tools for the investigation of that inaccessible region.

Studies of the more rapid changes in the geomagnetic field were carried out at the seven permanent magnetic observatories at Alert, Mould Bay, Resolute and Baker Lake, all in the Northwest Territories, and Agincourt, Ontario, Meanook, Alberta, and Victoria, British Columbia. At these stations are recorded, 24 hours per day, the variations and disturbances in the magnetic field which originate from streams of charged particles emitted by the sun. Because of their location close to the auroral zone and the north magnetic pole, the Canadian observatories play an important part in the world-wide investigation of geomagnetic disturbance.

Temporary magnetic observatories were operated in 1963 for periods of about one week at many locations in the northern Arctic islands, for the investigation of local anomalies in the variations of the geomagnetic field. Four scientific papers have been published attributing the observed effects to large bodies of unusually high electrical conductivity, buried many miles underground. Later in the year, the temporary observatories were operated along the southern coast of Hudson Bay, in a preliminary study of the propagation of magnetic disturbances along lines of force between Canada and observatories in the Antarctic. A temporary observatory was also set up near Thetford Mines, Quebec, to study possible geomagnetic effects of the solar eclipse of July 20.

GRAVITY

Measurements of gravity and the interpretation of gravity anomalies as applied to problems of structural geology and geodesy continue to be the major activities of the Gravity Division. The growing importance of gravity data is emphasized by the ever increasing number of requests for gravity maps and reports from the exploration and mining industries and from earth scientists generally. During the year under review, approximately 500 requests for data were handled by the division.

Regional gravity mapping continued in southern Canada and in the Arctic with the use of helicopter and fixed-wing aircraft for transportation. A major survey covered all of the Ontario portion of the Hudson and James Bay lowlands, and the Precambrian areas currently being studied in detail as part of the "Roads to Resources Program". About 5,000 field observations necessary to compile 12 map sheets in the 1:500,000 Gravity Map Series were completed. The gravity anomaly maps, when issued, will be useful to the mining exploration industry in obtaining the regional structure in areas of local interest; and also to geologists and geophysicists for tectonic studies of the Superior Province of the Canadian Shield and its extension beneath the Palaeozoic cover of the lowland areas.

During the past year an extensive study of the Timmins-Kirkland Lake-Noranda mining areas was initiated by additional gravity observations to increase the station density fourfold. A detailed gravity anomaly map of the entire area has been compiled.

Gravity studies of the continental shelves and coastal waters of Canada continued. Approximately 400 stations were established in that part of the Lower Gulf of St. Lawrence having water depths of 150 fathoms or less. Off the coast of Nova Scotia the underwater gravimeter was used to establish a standardization range for testing shipborne gravimeters. Later in the year, in cooperation with the Marine Sciences Branch, performance tests of an Askania gravimeter, a LaCoste and Romberg gravimeter and a stabilized platform were conducted over this range.

In the Polar Continental Shelf Project, approximately 600 gravity measurements were made on the ice of the Arctic Ocean and Prince Gustaf Adolf Sea, and on Devon and Melville islands. The gravity results indicate the configuration of the potential petroleum-bearing Sverdrup basin and areas of basement uplift.

As a contribution 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, two long-range geodetic gravimeters were used to connect the continents of North and South America and Europe. In cooperation with the Institute of Geodesy of Buenos Aires, preliminary gravimeter work was carried out to establish a standardization line over the latitude range of Argentina.

The program of observing gravity at bench marks throughout Canada continued. Observations were carried out in the three prairie provinces and in British Columbia.

Digital computer programs have been developed for processing and analyzing gravity data.

Field investigations were made of six craters of possible meteoritic origin in Ontario, Quebec, and Saskatchewan. All evidence strongly supports impact origin for all of these circular structures. An important addition to the methods of investigation was begun late in the year with the establishment of a laboratory for the examination of rock deformation.

Research and development of a vibration gravimeter for the measurement of rock density in bore holes, and a new pendulum apparatus for gravity control measurements were continued.

SEISMOLOGY

In 1958 the Department began a program to expand and modernize the seismological network of Canada. During 1963 instruments were installed at Port Hardy, B.C., Coppermine and Frobisher, N.W.T. This brings the number of stations operated by the Department to 16; in addition three stations are operated by private organizations. During 1963 vaults were completed at Yellowknife, N.W.T., Flin Flon, Manitoba, and St. John's, Newfoundland. Instruments will be installed in these stations early in 1964.

The only major Canadian earthquake in 1963 occurred in Baffin Bay on September 4. It had a magnitude of about 6½. A number of small shocks occurred near Deep River. All Canadian earthquakes are listed in an annual publication released to insurance companies and other interested people.

Like other branches of science, seismology is feeling the impact of modern high-speed computers. A device has been developed for the digitizing of earthquake records onto punch cards and the analysis of the data by the departmental 1620 computer. It is expected that the study of surface waves and their use in defining earth structure, the analysis of the spectra of seismic waves and of background noise, and the study of the mechanism of earthquakes will all be reduced to a semi-automatic status by these new devices.

In 1962 a crossed array of seismographs was set up at Yellowknife, N.W.T., in cooperation with the Department of National Defence and United Kingdom scientists. This array aims at establishing a criterion for distinguishing between nuclear blasts and earthquakes. In 1963 this Department was directed by the

Cabinet to assume responsibility for the array and to use it as a major research facility. Plans are now well advanced for the establishment of the necessary analysis centre in Ottawa. Aside from the importance of the array in policing any atomic test-ban treaty it provides an important tool for the study of the earth's structure.

During the summer departmental seismologists joined with others from Canada and the United States in an important study of the crust in the vicinity of Lake Superior. More than 80 shots were fired in the lake and these were recorded by teams of seismologists in both countries. When the analysis of the records has been completed it should greatly increase knowledge of the structure of the earth's crust in a continental region. Seismic field work was also carried out by the Polar Continental Shelf Project in the Queen Elizabeth Islands.

A section for the measurement of heat flow is set up within this Division. During 1963 it completed the setting up of laboratory and rock-cutting and polishing equipment and drilled holes at Halifax, N.S., Penticton, B.C., and London, Ont., for measurement of thermal gradients. It also began a campaign for the measurement of heat flow in holes drilled for commercial purposes.

DOMINION ASTROPHYSICAL OBSERVATORY

The Observatory's work, generally speaking, is to contribute to our knowledge of the nature of stars and other heavenly bodies and the numbers, distances, and motions of the stars, through detailed studies of the radiation of selected stars and measurement of speeds, distances, brightnesses, and masses, of scores, or even hundreds, of stars. The original information consists of observations made with spectroscopes attached to the 72-inch and 48-inch telescopes of the Observatory; the photographs so made are then analyzed for the study of stellar bodies. The 48-inch telescope, put into operation in 1962, has made possible the accurate measurement of the brightnesses and colors of stars and it has permitted observation of the atmospheres of the planets Venus, Mars, and Jupiter, thus contributing knowledge urgently needed in the planning of space research.

In 1963 observations were made on 165 nights with the 72-inch telescope and on 162 nights with the 48-inch telescope, giving in all some 2,400 photographs of the analyzed light of stars and planets. Accurate measures were made of colors and brightnesses of 150 stars. The primary equipment of the Observatory was increased in 1963 by the gift of a 16-inch telescope and dome by Mr. R.S. Evans of Victoria, B.C. Special equipment is being constructed for this telescope to relieve some of the pressure on the larger instruments.

A nova or "new star" flared into prominence in February, 1963. Spectroscopic observations showed the explosive nature of the outburst. A large program, undertaken as part of an international project, contributed several thousand measures of stellar radiation of use in the determination of the abundances of chemical elements in the stars. A close watch was kept on a number of stars which undergo rapid and violent surface-atmospheric changes.

Several hundred determinations of the line-of-sight speeds of stars were made.

Spectroscopic studies of the atmospheres of the planets Venus, Mars and Jupiter have given new information as to the water-vapor content of the Martian atmosphere; they have also given further definite evidence of the presence of ammonia in the spectrum of Jupiter.

Special equipment continues to be designed and fabricated in the Observatory's shop; such equipment cannot be purchased and must be designed to meet the research requirements. During the year a semi-automatic machine of improved design for the measurement of stellar speeds was put into operation and special cameras were built and installed for use with the 48-inch telescope.

The Observatory organized several field expeditions to inquire into astronomical and meteorological conditions at several points in British Columbia. The information derived from these surveys will be of value in planning future expansion of Canada's astronomical facilities.

Staff members attended eight Canadian and international scientific meetings.

Some 21,000 persons visited the Observatory and approximately 3,750 attended 34 public observation periods. Staff members gave a total of 18 lectures to service and educational organizations in British Columbia and adjacent territories. Astronomical information was supplied to airport and meteorological authorities.

Geographical Branch

Studies of the natural landscape of Canada and man's impact on it are the main preoccupations of the Geographical Branch. Being a fairly small organization, the Branch is selective in its studies, and only certain special aspects of research received attention in 1963, such as rural and urban land-use mapping, geomorphology, and glaciology. The prime objective was to move towards the completion of a series of specialized research projects and to train and discipline a more highly skilled nucleus of research staff as the basis for progressive expansion.

A total of 38 geographers were in the field : 21 in the far north, two in New Brunswick, two in Quebec, five in Ontario, four in Saskatchewan, and four in British Columbia.

The Branch continued to maintain contact with international organizations and developed coordinated research programs at the national level with the administration of the Agricultural Rehabilitation and Development Act and the Federal Emergency Measures Organization. From this new research, programs in rural and economic geography are being built up.

PHYSICAL GEOGRAPHY

Terrain analysis and glaciological studies continued in various parts of the Canadian north, the main emphasis again being placed on the long-range program for northern Baffin Island where 18 geographers and assistants were located. The Barnes Icecap crest station was occupied between late April and late August, and studies of the icecap regime were carried out. Before the start of the runoff the party used motor toboggans for long traverses, and it was finally evacuated by helicopter. Further work on the marginal moraines with ice centres was undertaken, and two large ice samples were obtained for carbon-14 dating. The party made reconnaissance glaciological surveys in the mountain and fiord district of the east coast of the island with light aircraft support.

Geomorphological and hydrological studies along the icecap perimeter were intensified. The runoff of the Lewis River was gauged by a conductivity method, and silt-content analyses were made. Geographers studied lichen at 200 locations to help them in the evaluation of glacier fluctuation over the past 2,000 years. This was aided by collaboration with botanists at Queen's University. Precise measurements were made of former marine submergence along the west and north coasts of Baffin Island, and the direction and distance of glacio-isostatic tilt were computed for Grant-Suttie Bay. Radiocarbon dating and pollen analysis of an important peat deposit have yielded preliminary indications of a warm, ice-free period 24,000 to 28,000 years ago. For the first time a field geomorphological laboratory was operated at the Flitaway Lake base camp.

Detailed surface mapping in the Milne Inlet vicinity was made preparatory to the construction of a geomorphological map. Such a map should prove invaluable for road planning and construction in the area between high-grade iron-ore deposits on the plateau and the head of the inlet.

Systematical aerial mapping of sea ice in the Queen Elizabeth Islands was carried out as a contribution to the Polar Continental Shelf Project. The survey involved over 200 flying hours, and preliminary results indicate wide variability in ice distribution and the feasibility of long-range ice forecasting. It was the third successive summer survey.

Two geographers worked in the Mackenzie Delta and repeated Alexander Mackenzie's canoe journey down the great river. Studies of the heat budget of the river, ground-ice sheets and delta channel form were initiated, and a manuscript analyzing Mackenzie's voyage was completed as a contribution to historical geography.

A program of detailed geomorphological mapping was initiated in the dry regions of southwestern Saskatchewan. Mapping of land forms, degree of slope and surface conditions at a field scale of 1:25,000 is being done on an experimental basis and should prove of value to land-capability assessment and land management in problem areas. A program of mapping Prairie land forms was continued.

The long-term project for study of periglacial problems was continued and included the collection of extensive data on geographical distribution, geometry and structure of the various forms.

Office work included the publication of the first major results of the Baffin Island project, including two colored maps of glacial features.

The data-processing section began tabulation of all new field data on punched cards for processing by computer. Various statistical analyses of break-up and freeze-up data were completed, and it seems likely that it will soon be possible to predict dates of break-up and freeze-up. A monograph on the Mackenzie Delta area was published as Memoir 8.

ECONOMIC GEOGRAPHY

Land-use surveys and urban studies constituted the main activities during 1963. Much of the work was carried out in cooperation with the administration of the Agricultural Rehabilitation and Development Act and E.M.O. respectively.

Field work was carried out in Ontario, eastern Quebec, New Brunswick, Saskatchewan, and British Columbia.

The first monograph based on the land-use mapping program was published; it was a comprehensive study of the land use in Prince Edward Island. A study of the origin and destination of commodities passing through the port of Saint John was completed for National Harbors Board.

By the end of the field season the first phase of the land-use mapping program had been completed. To date 28 multi-colored maps at scales ranging from 1:50,000 to 1:1,000,000 have been published, and 16 more are being printed. Future development will be closely tied to Agricultural Rehabilitation and Development Act requirements, emphasis being placed on land-capability analysis and the investigation of specific socio-economic problems, as well as the completion of maps of present land use for all of southern Canada.

Reports were completed on 28 settlements in the Northwest Territories. Yukon, and northern Quebec, for the planning and construction of new settlements.

In collaboration with the Federal Emergency Measures Organization the Branch started the mapping of urban land use and physical characteristics of the 16 largest Canadian cities on a scale of 1:25,000.

TOPONYMY

The Toponymy Division is responsible for the investigation and research into the origin, usage, and propriety of all geographical names in Canada and advises the members of the Canadian Permanent Committee on Geographical Names on nomenclature problems. During 1963, geographers investigated 19,528 names, and nearly 2,000 new names were officially approved. They answered over 800 queries. The *Gazetteer of Ontario* was published early in the year and

preparation began of the *Gazetteer of Newfoundland*. A bi-annual supplement to the *Gazetteer of Canada* series was inaugurated. A booklet was published outlining the functions and responsibilities of the Permanent Committee.

CARTOLOGY

Research and production of a population map of southern Ontario at a scale of 1:1,000,000 continued. Preliminary plans for a new desk atlas of Canada were completed and presented as a possible contribution to Centennial celebrations. Land-use maps were published at various scales: five of Ontario and six of southwestern British Columbia at 1:50,000, two of Prince Edward Island at 1:126,720, and one of the Hanna-Kindersley area of Saskatchewan-Alberta at 1:500,000.

Two color maps of glacial features in the terrain-analysis series were printed, and one in black and white was sent to the printer. Maps and graphs drafted for all Branch publications and outside agencies numbered 208.

A total of 20,031 new maps were acquired from 32 countries, bringing the total collection to 200,300. The exhibit "Lunar Cartography" was sent to Laval, McGill, and Ottawa universities, and to the Hull High School Board. More than 20,000 persons visited the exhibit.

Two geographers attended the International Commission meeting on Economic Regionalization in Poland. Representatives also attended the 23rd annual meeting of the American Congress of Surveying and Mapping and the 29th annual meeting of the American Society of Photogrammetry in Washington. During the year, 23 research papers and two monographs were published. Twelve new positions were added to the Branch.