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ANNUAL REPORT

MINES AND TECHNICAL SURVEYS

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GEOLOGICAL SURVEY

CALENDAR YEAR 1964

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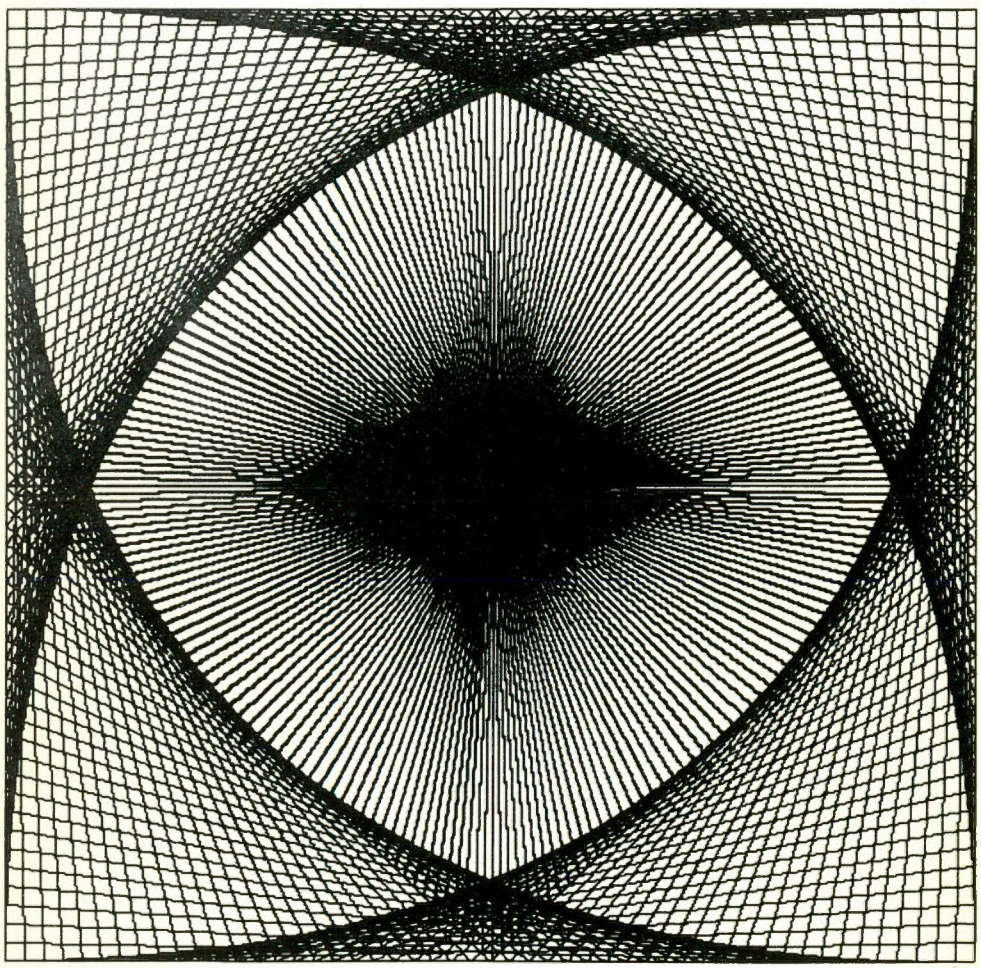
The department is making increasing use of computer systems to speed up tedious research calculations. Pictured is an experimental diagram using a Cal Comp plotter with a wet pen; probably a standard program was used to draw a regular curve, to which was added a variable, in steps, of a series of curves, resulting in this interesting and balanced configuration.



ANNUAL REPORT——————

——— CALENDAR YEAR 1964

Department of Mines and Technical Surveys
Ottawa

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1965

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Deputy Minister: Dr. W. E. van Steenburgh

Assistant Deputy Minister (Research): Dr. J. M. Harrison

Assistant Deputy Minister (Mines): J. P. Drolet

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Director, Geological Survey of Canada: Dr. Y. O. Fortier

Director, Mines Branch: Dr. John Convey

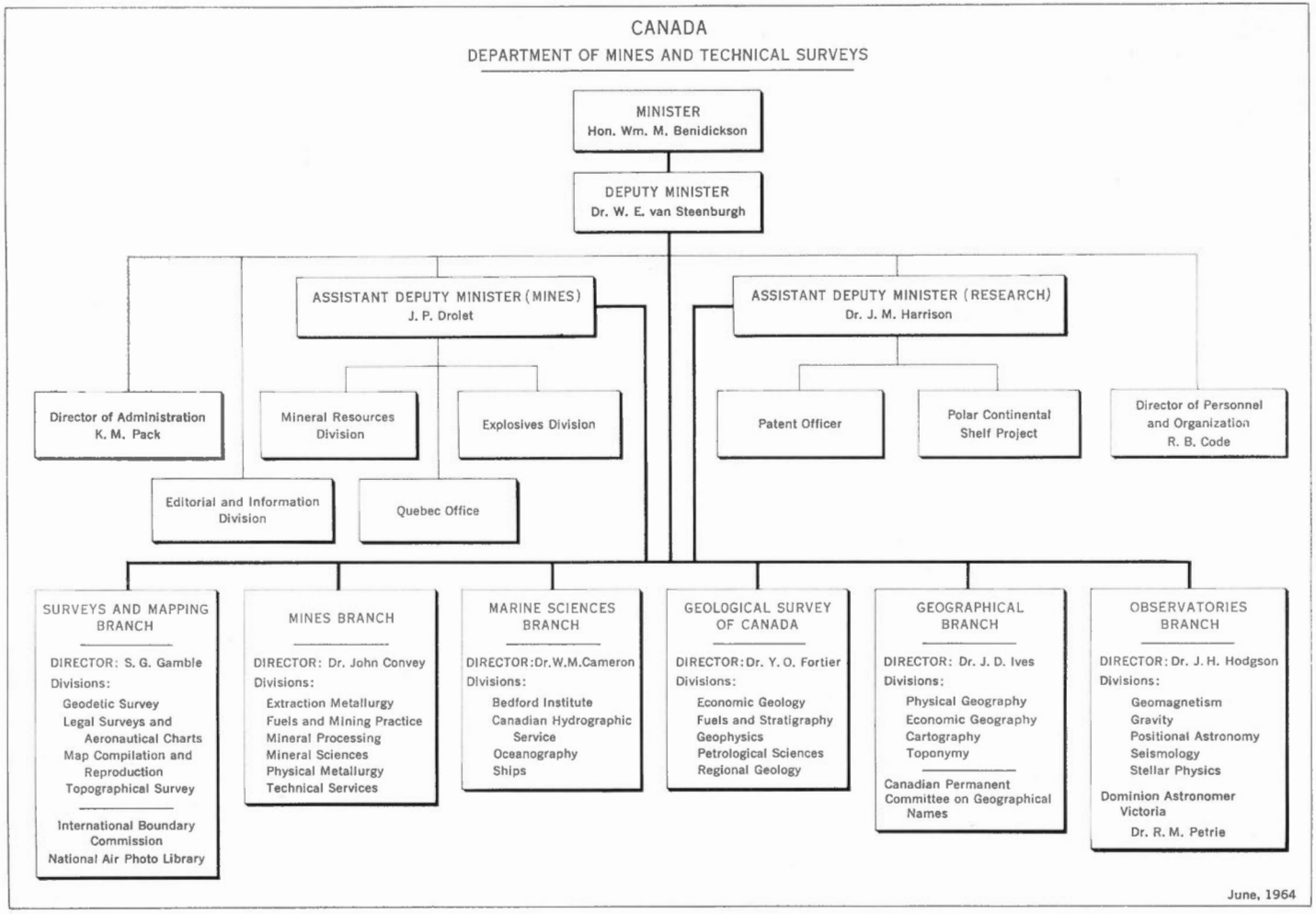
Director, Observatories Branch: Dr. J. H. Hodgson

Director, Geographical Branch: Dr. J. D. Ives

COVER:

Air view of the Mines Branch buildings, showing the cross-town, limited-access Queensway, beyond which is depicted part of the city, the Peace Tower and a suggestion of the Gatineau Hills beyond the Ottawa River.

Contents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Dr. R. M. Petrie
June, 1964

Introduction

In 1964, the Department of Mines and Technical Surveys continued to survey and investigate Canadian terrain and waters; and, through intense research, to further the development and processing of the country's mineral resources. Its work took many forms, covered many regions — near and far — and embraced many disciplines. But in the realm of mining and the earth sciences, in particular, the Department continued to shoulder an ever-growing share of Canada's scientific responsibilities.

In 1964 the Department fulfilled its tasks with a vigor matching that of the country's economy: the value of Canada's mineral production rose to $3.4 billion, a new record. In fact new highs were recorded in each of the industry's three sectors — metallics, industrial minerals, and mineral fuels.

But the work of the Department's six branches was of significance not only to mining but to many other aspects of Canadian endeavour. Of the many projects underway in 1964, several deserve special notice:

The urban control surveys of the Surveys and Mapping Branch, carried out by geodesists and topographers, went into their third year. Confined to densely settled areas these surveys provide a network of precisely positioned points in and around municipalities, to serve as a basis for municipal mapping and public works. The use of the aerodist, an airborne device for measuring great distances, was further refined and extended by the Branch.

A new multicolored map of the world published by the Surveys and Mapping Branch became a "best-seller." The first printing of 6,000 copies was sold out in ten weeks, and a second, larger printing was put on the market before the end of the year.

The CSS *Hudson*, the latest and largest addition to the fleet of research ships of the Marine Sciences Branch, was commissioned in 1964. On her first season's cruise, ship-borne geophysicists discovered an unusual gravity anomaly off Cape Breton Island while carrying out one of the projects concerning the geology of the Atlantic shelf. The 20-mile-wide anomaly, called Orpheus Anomaly, may have important economic as well as scientific implications. Meanwhile, the Canadian Hydrographic Service continued the formidable task of charting Canadian waterways both inland and coastal.

To carry out its field studies, the Geological Survey of Canada sent out 107 scientific parties, about half of whom concentrated on reconnaissance mapping and the remainder studied specific geological regions.

In the Canadian Shield, five geologists and auxiliary personnel, supported by helicopter, carried out Operation Wager, the last of a series of operations to establish the fundamental geological framework of the barren ground of the western part of the Shield. The largest geological survey in the eastern Shield was the Grenville Project, in which new, rapid reconnaissance methods were tested and successfully applied in an exceedingly complex terrain. A large helicopter-supported field project in the Yukon, Operation Keno, was carried out to provide new geochemical data to stimulate prospecting, and also to evaluate and further develop both heavy mineral and geochemical exploration techniques. In the federal-provincial aeromagnetic survey program, the first set of three-year aeromagnetic contracts was completed.

In 1964 the G.S.C's ground water research constituted an important contribution to the

world-wide study of water resources known as the International Hydrologic Decade. No less important were the projects undertaken as part of the International Upper Mantle Project.

The Mines Branch intensified its work in mining practice and rock mechanics, which received further impetus from the opening of a field laboratory at Elliot Lake, Ontario. In uranium extraction, the novel bacterial leaching process was tested further, with highly promising results. To find better ways of producing marketable petroleum products from low-grade Canadian oils, the Branch continued its research in hydrogenation, catalytic cracking, and distillation, and completed a new pilot plant designed to operate at extremely high pressure.

In the extraction of gold, the Mines Branch developed a device for automatically determining and controlling the cyanide content of mill solutions. The Branch is testing the device in a Western Quebec gold mine. Experiments on the pelletizing of iron-ore concentrates continued.

One of the most noteworthy developments in world astronomy is the plan for the construction of a new observatory in southern British Columbia to be known as the Queen Elizabeth II Observatory. Its telescope will have a reflecting mirror approximately 150 inches in diameter, and thus recapture for Canada the advanced position it once enjoyed in astronomic research. At Penticton, B.C., the site of the Dominion Radio Astrophysical Observatory, personnel from the Observatories Branch and from Cambridge University jointly constructed an aerial array designed to receive and to analyze radio signals from distant galaxies. The number of seismic stations operated by the Branch in Canada increased to 19, the planned network being two-thirds complete. Gravity-mapping of Canada continued at a vigorous rate with the aid of planes and helicopters, and is expected to be completed by 1972.

The Geographical Branch co-ordinated land-use surveys intended to cover the whole of southern Canada as part of the Canada Land Inventory sponsored by the administration of the Agricultural Rehabilitation and Development Act. The Branch itself is producing the maps for the six eastern provinces and is co-ordinating the work of other agencies in the West. Systematic aerial mapping of sea-ice distribution continued in the Gulf of St. Lawrence during the winter, and in the Queen Elizabeth Islands during summer, together taking up 308 flying hours.

The work of the Polar Continental Shelf Project suffered somewhat because of unusually unfavourable weather and heavy ice in and about the Queen Elizabeth Islands, but it carried out a wide range of research on land and at sea. In 1964 parties totalling 91 persons were investigating the central section of the Arctic continental shelf and the adjacent islands and straits.

The Mineral Resources Division, in keeping its finger on the economic pulse of the mineral industry, undertook investigations covering all aspects of mineral development, production, consumption and marketing — domestic and foreign. The resulting information took the form of numerous published reports and provided a basis for the Division's role as adviser to government on matters of mineral policy, legislation, etc. Not the least of the Division's responsibilities in 1964 was the administration of the Emergency Gold Mining Assistance Act.

The total number of permanent employees of the Department on December 31, 1964, was 3,149, an increase from the preceding year.

In April 1964, the functions of the Air Photo Production Unit, previously under the jurisdiction of the RCAF, were transferred to the Department.

The Department continued to develop its committee appraisal system for determining salary changes and promotions. The work of re-slotting scientific officers in the new "research scientist" began. The departmental training program was enlarged and improved. And personnel research was carried out in such matters as job attitudes, group communications and employee evaluation.

POLAR CONTINENTAL SHELF PROJECT

The Polar Continental Shelf Project is a co-operative research venture in which not only various Branches of the Department but also other federal government agencies and universities are taking part. The pooling of men and material was made necessary by the extreme remoteness, the great extent, and the harsh climate of the area to be studied. The field survey and research of the Project will eventually cover all the Canadian sector of the Arctic continental shelf of North America, those parts of the Arctic Ocean basin that are of interest to Canadian investigators and which can be reached with available logistics resources, and all parts of the Arctic Archipelago not investigated by other agencies in the fields of interest covered by the Project.

Some of the research contributions to the Project will be found described in more detail in the reports of the various Branches.

From 1959 to 1963 work was concentrated in the region between Meighen Island and Brock Island, extending about 200 kilometers out to sea and the same distance back into the archipelago; but individual programs of survey and research have been carried out throughout all the Queen Elizabeth Islands, and extended to Banks Island in the southwest and northern Greenland in the northeast.

In 1964, field work was co-ordinated mainly from Mould Bay, on Prince Patrick Island. Parties totalling 91 persons were investigating the central section of the Arctic continental shelf and the adjacent islands and straits. A further 54 persons were employed in supporting roles connected with transport.

Operations during the past season could not be carried out on the same scale as in previous years because of remarkably heavy sea ice offshore from Prince Patrick Island in the spring, which frustrated the oceanic program, and because of unusually long periods of bad weather over the archipelago in middle and late summer, resulting in fewer "flyable" days than in any field season since 1959.

As a contribution of the regional aeromagnetic mapping of Canada by the Geological Survey, a survey of the total-intensity magnetic field was made along 53,000 kilometers of flight path, covering an area of approximately 110,000 square kilometers of the continental shelf. The program in submarine geology, designed to provide information on sediments, yielded cores and bottom samples as well as data on sea-bottom morphology around several islands. The bathymetric survey of the continental shelf and slope as well as the straits between the various islands was continued, with sounding through ice over an area of about 30,000 square kilometers northwest and southeast of Brock Island, Ballantyne Strait, and north Prince Patrick Island. The standard hydrographic survey of Cardigan Strait and approaches also continued, with helicopter-towed equipment.

The four icecaps on Melville Island were further surveyed and measurements were carried out on ice formation and thawing. The regional gravity survey was continued to cover the continental shelf and slope. In heat-flow research, equipment was built and tested for measuring the flow of geothermal heat from ocean floors, and three successful measurements were made in the west end of M'Clure Strait.

A party was established off the outer edge of the continental shelf northwest from central Prince Patrick Island to collect deep-water fishes from the Arctic Ocean basin, and studies were made of marine algae beneath and within the pack ice.

Scientists again followed the migration of "ice islands" to learn more about the ice movement and forecasting. It has proved possible to follow the movement of the same ice throughout the season and from year to year.

Seismic refraction traverses were run from Brock Island northwest over the continental shelf, and southeast into the area of Ballantyne and Hazen straits. In the field of geodetic and topographic surveys, preliminary surveys were carried out in the Robeson Channel for a future precise survey to determine the relative movement of the Greenland and Ellesmere crustal blocks.

MINERAL RESOURCES DIVISION

The work of the Mineral Resources Division concerns mineral resources, economics, legislation and taxation rather than basic or applied laboratory research.

Commodity officers of the Division conduct field and office investigations that are part of detailed mineral-economic research on a wide range of commodities. Field and office investigations cover all aspects of the mineral field from resources through mining, milling, concentration, beneficiation, smelting, refining, uses and consumption, both domestic and foreign. This work is essential as a base for the Division's advisory service to various government departments and agencies on mineral policy. It also provides a base for the preparation of numerous reports on Canada's mineral industry for public distribution.

Illustrative of the Division's work in research was the publication in 1964 of eight reports in the *Mineral Information Bulletin* series, one in the *Mineral Survey* series and two in the *Mineral Report* series. The following titles are representative of these publications: *The Canadian Steel Industry — a Pattern of Growth*: *Canadian Minerals in National and International Perspective*: *Canadian Resources of Uranium and Thorium*; and *Open-Pit Mining Practice in Canada.*

Studies continued on several other minerals important to the Canadian mineral industry, and reports were prepared for early publication. The subjects covered included

nickel, copper, uranium, iron ore and zinc. The manuscript for a report on Canadian underground mine haulage was completed, and one on beryllium was nearing completion at the end of the year.

The 22 mineral specialists of the Division provide advice on many subjects to help in the development of Canada's resources, increase production, find new markets, expand existing markets and assist in formulating taxation and legislation policies. They continued through the year to study the possible effects of foreign legislation, controls, tariffs and trade agreements, particularly those of the United States, Europe and Japan, on the Canadian mineral economy. They also kept alive their knowledge of the world mineral scene through extensive reading and field investigations.

Illustrative of the work done in this field during 1964 are the following: the preparation of a detailed 350-page analysis of Canadian mineral and metal production, trade, consumption and tariffs for use by the Canadian Tariffs and Trade Committee in the consideration of tariff changes at Geneva under the General Agreement on Tariffs and Trade (GATT); and preparation of production and export forecasts concerning the country's principal minerals for the Economic Council of Canada.

The Division continued to provide government agencies and private industry with market and price analyses, production forecasts, evaluations of the utility of mining and processing facilities and advice on such matters connected with mining as roads, airstrips, dock and harbor installations, building projects, and area and property developments. The Division also reviewed and commented on certain briefs presented to the Canadian Tariffs and Trade Committee.

The Department of National Revenue was provided with analyses and recommendations concerning tax benefits applicable to the mineral industry under the Income Tax Act. Reports were prepared on 20 applications for three-year tax exemptions. Four applications were processed for the certification of operators of industrial mineral mines on non-bedded deposits.

International Activities — Officers of the Division presented reports at meetings of several international organizations concerned with minerals and the mineral trade. Meetings in which the Division participated include those of the Organization for Economic Co-operation and Development (OECD), the United Nations Economic Commission for Europe (ECE), the International Lead and Zinc Study Group and the United Nations *ad hoc* Committee on Tungsten.

A senior officer of the Division arranged an exchange of Soviet and Canadian iron-ore missions and accompanied each mission. The five-member Soviet group of beneficiation experts was in Canada from May 21 to June 5, and the eight-member group of Canadian experts was in the Soviet Union from August 9 to 24. Another senior officer was an official representative to the 22nd Session of the International Geological Congress, in India.

Wartime Oils Limited — The Division continued to administer the assets of Wartime Oils Limited, a former Crown company. This emergency project, which dates from World War II, has more than repaid the government advance to drill the wells, and most of the wells have accordingly been returned to the owners. Arrangements are being concluded for the return of the remaining wells to the original owners.

Foreign Aid — The Mineral Resources Division, on behalf of the External Aid Office, arranged 26 new technical training programs for foreign trainees. Most of the programs were paid for under the Colombo Plan. Training took place in the Department

of Mines and Technical Surveys as well as with provincial mining departments and private industry. Nineteen trainees completed studies in 1964 under programs previously arranged. At the end of the year, seven were still on study courses, and 15 programs had been set up in expectation of the arrival of candidates. The Department gave employment to 29 foreign students attending Canadian universities under various technical-aid programs.

The Mineral Resources Division, acting on behalf of the Department, continued to advise the External Aid Office on technical aid in foreign countries and to assist in recruiting advisers for foreign-aid assignments.

Information Activities – The Division has a continuing mineral-filmstrip program. During the year, three filmstrips in the junior series for elementary schools reached the test-print stage. The titles are *Learning about Rocks and Minerals, Life in a Mining Town* and *Mining in Canada.* The first-named will be distributed in a kit with manuals, specimens, test materials, supplementary reading and study pictures. The Division hopes for wide use of these filmstrips because they are directly related to the curriculum in elementary schools.

A booklet called Entrance Awards for *Mineral Industry Courses at Canadian Universities,* based on a text provided by the Canadian Metal Mining Association (CMMA) was produced and distributed in co-operation with the CMMA and the General Committee on Education of the Canadian Institute of Mining and Metallurgy.

The 14th edition of the popular map *Principal Mineral Areas of Canada* was issued, and work continued on the preparation of a pictorial brochure to be called *Mining in Canada.*

The Division maintains a Mineral Occurrences Index of Canadian minerals, which is available to government agencies, private companies and individuals.

This index has been in existence for more than 65 years, but compilation has been regular only since 1959.

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

The amending legislation imposed a restriction on the eligibility of lode gold mines after June 30, 1965. Lode gold mines brought into operation after that date will be eligible for assistance only if the mine directly supports 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 Act is administered by the Mineral Resources Division under the direction of the Deputy Minister. 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 the costs in question and upon 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 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 an ounce. Thus a gold mine whose average cost of production is less than $26.50 an ounce is not eligible for the payment of assistance.

There were 44 lode gold mines and 25 placer gold mines receiving assistance in 1964. The average costs of production at six gold mines were 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 1964, the Audit Services Branch examined 222 separate applications, which were 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 — 14,374,268.78 or 6.05 " " "
1963 — 13,797,393.72 or 5.91 " " "
1964 — 10,361,881.23 not available

EXPLOSIVES DIVISION

Since 1920, when the Explosives Act was introduced, the Explosives Division has been responsible for public safety in the manufacture, sale, storage, importation and transportation of explosives by road. During this time the production of commercial blasting explosives has increased from 20 million pounds a year to a 1964 total of more than 250 million. From 1963 to 1964 alone the production increase was slightly more than 50 million pounds, and it is interesting that part of the increase was due to an increase in the production of nitroglycerine (NG) dynamites. This reverses the trend that began in 1957, when new explosives based on ammonium nitrate (AN) started to replace the NG dynamites that Nobel first introduced a hundred years ago. In 1957, before the full impact of the new era of explosives was felt, more than 90% of the explosives consumed were dynamites. Today, their proportion is about 30% only.

Twenty-seven factories were licensed under the Act for the manufacture of explosives. These may be divided into five main categories according to the type of operation, as follows:

1. Military explosives and pyrotechnics (5 factories)
2. Fireworks (4 factories)

3. Commercial ammunition (5 factories)
4. Blasting explosives for sale (10 factories)
5. Blasting explosives for private use (3 factories).

The last category, which includes one of the recent revolutionary concepts, involves the "on-site" manufacture of explosives in a mobile unit that produces them by a continuous process and pumps them directly to the bore hole. Three such units were in operation in 1964.

Licences issued for the storage of explosives amounted to 1,620; permits issued for trucks transporting explosives totalled 270. The latter constitute a danger. In fact, a truck loaded with explosives travelling on congested highways through built-up areas provides all the ingredients of a disaster. After a series of accidents involving fires, it was ruled that on and after April 1, 1964, permits for the transportation of explosives would be issued only for vehicles equipped with totally enclosed fire-resistant vans. This year, to date, there have been no fires.

During the year, 12 fatalities were caused by the use of explosives in mines. Three fatalities occurred in storage when a magazine on a construction project exploded. Two accidents with home-made explosives caused the deaths of two young men. No fatalities occurred in explosives manufacturing in the 27 licensed factories.

There were 34 prosecutions under the Act, 22 for illegal storage and 12 for violations of transportation regulations.

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

Surveys and Mapping Branch

The Surveys and Mapping Branch continued its varied program of surveying, mapping and air charting. The Geodetic Survey had 19 parties in the field engaged in activities ranging from the Arctic operations to primary triangulation for Calgary and Hamilton. The Topographical Survey again employed its aerodist equipment in a chartered aircraft in the James Bay and Hudson Bay areas to take distance measurements where it would be very difficult to map by ordinary methods. The Legal Surveys and Aeronautical Charts Division initiated four new series of aeronautical charts. One of its legal surveys on Indian reserves was completed successfully and economically by photogrammetric means. The Map Compilation and Reproduction Division reported a slight decrease in map and chart production but an increase in sales. Receipts for the first time exceeding a quarter of a million dollars, were 16 per cent higher than in 1963. A new **Map of the World** was published in both English and French and has already had to be reprinted to meet the demand. The National Air Photographic Library again set a record in the number of requisitions handled.

The Interdepartmental Committee on Air Surveys procured aerial photography to meet the needs of nine federal departments and is experimenting in the procurement of colour photography.

The Branch acted as technical adviser to the External Aid Office in connection with several survey projects, two of which are now well under way in Africa. Senior personnel of the Branch represented Canada at a number of international meetings, including those of the Directing Council of the Pan American Institute of Geography and Hydrography, the International Cartographic Association and the International Society of Photogrammetry. In October, at the invitation of the Manitoba government, the annual meeting with provincial survey officials was held for the first time outside Ottawa. Personnel from the Branch participated in the satellite geodesy program of the U.S. Coast and Geological Survey and in November assisted with the establishment of observing stations at Lynn Lake and Cambridge Bay.

During the year 14 major tours were made through the Branch by groups that comprised, in all, 260 high school students, 140 university undergraduates, and 76 teachers, town planners, military personnel and professional groups from various federal and provincial associations.

GEODETIC SURVEY

The Geodetic Survey extended its horizontal- and vertical-control networks, which provide a national framework for mapping, charting and major engineering projects, and also carried out some investigational work. In all, 19 field parties were engaged.

A large triangulation loop in the Northwest Territories, extending from Great Slave Lake to Victoria Island and back to Great Slave Lake, was completed by means of an arc extending from Coppermine to Cambridge Bay. In British Columbia and Alberta, timber towers were constructed for a triangulation arc that will connect the Alaska Highway net near Fort Nelson to the Mackenzie Highway net near Meander River. In northern Quebec, to the north and west of Fort Chimo, triangulation was carried out to complete one loop and commence an arc that will extend to Hudson Strait and loop to Lake Minto. In New Brunswick work was carried out near Bathurst, and a large area network between Fredericton and Moncton was completed. First-order control for municipal surveys was established at Calgary and Hamilton, and in the area between Hamilton and metropolitan Toronto. Reconnaissance was carried out for similar surveys at Lethbridge and Medicine Hat. A small survey was executed at Mill Village, N.S., to provide vertical control for a satellite-communication ground station. Reconnaissance was also carried out for two projects to investigate the possibility of horizontal ground movements. One of these projects straddles the St. Lawrence River from near Quebec City to Tadoussac. The other project is in the far north, where a network has been proposed to connect Greenland with Ellesmere Island. It is thought that the relative positions of these two land masses are changing and that careful surveys made now and repeated in about 10 years may reveal the movement.

In British Columbia, Alberta, Saskatchewan, Manitoba, Ontario and Quebec the first-order vertical-control network was extended and strengthened. In addition, the annual relevelling of the Quebec Bridge piers was carried out. The results of some of these levelling operations will serve as data for the study of possible vertical ground movements. This is particularly true of work near the Peace River Dam (Hudson Hope), the Saskatchewan River Dam and the Manicouagan Dam (Lac Mushalagan), and of the work near Lake St. John. In the last-named locality, there is strong evidence that the land has risen more than half a foot in the past 40 years.

A geodimeter party, using the Model 4D instrument, measured a number of lines in Nova Scotia and eastern Quebec to strengthen existing triangulation arcs. This party also provided length control for the Mill Village operation and measured the lines of the small Beaupré net just east of Quebec City. The net was established in 1926 to check for possible horizontal ground movements in this area of seismic activity. The measurements taken in 1964 indicated no appreciable horizontal movement.

Five small parties established precise astronomic stations in the Northwest Territories and northern Quebec and on the Prairies. Three Laplace azimuth stations were set up to control triangulation networks, one in the Northwest Territories and two in northern Quebec. Precise astronomic observations of longitude and latitude were made to determine the deviation of the vertical at 52 triangulation stations.

The Survey continued to increase its use of specialized electronic equipment in the field and laboratory. During the field season two engineers and one technician, specially trained in the use and maintenance of electronic equipment, worked with triangulation parties. The assessment of the Aerodist Test Project, conducted jointly by the Topo-

graphical Survey and the Geodetic Survey in the autumn of 1963, indicates that this equipment is capable of measuring distances, in the range of 60 to 160 miles, with first-order accuracy.

TOPOGRAPHICAL SURVEY

In 1964 the Topographical Survey made a record with 300,000 square miles of coverage in map compilation. The maps cleared for reproduction covered 283,000 square miles and consisted of the following: 58 at the scale of 1:250,000; 278 at 1:50,000; and 21 at 1:25,000. The record was due, in large part, to the absence of "crash" programs and large special projects.

Continued emphasis was placed on 1:250,000 mapping in a program integrated with the Army Survey Establishment to effect complete coverage of Canada by 1967. Nearly 700 of the 925 maps required are now available, and prospects are bright that the objective can be achieved.

Compilation of 1:50,000 mapping continued to be restricted to the most urgent requirements for new mapping and the revision of outdated maps. Pressure is mounting, however, for more attention to production of this map series for water management, power development, land-use studies and development of resources opened by the "roads to resources" programs.

Production at 1:25,000, mainly for urban and suburban areas, fell short of the objective of 30 sheets.

For the third field season the aerodist system was used successfully in some surveys to propagate mapping control in areas difficult of access by other means. Other surveys completed the control required for 1:250,000 mapping on the Canadian mainland.

Thirty-eight field officers and three of the office staff participated in a field program extending from Newfoundland to the Yukon. The trend continued to the more exacting survey procedures required for municipal use as well as for revision mapping, and to field editing after compilation rather than to field interpretation before plotting. The program included two major air-supported operations and a two-party winter assignment.

The aerodist system was used first to establish trilateration and photo control for 1:50,000 mapping of 50,000 square miles of land in Ontario and Quebec south of James Bay, that was in demand for agricultural, water-power and water-diversion investigations. Later the aerodist party continued the program of establishing control for mapping islands and shoals in James Bay, and Hudson Bay in co-operation with the Hydrographic Service. The project covered over 25,000 square miles with aerodist-fixed photography. Supplementary control was also obtained for 1:50,000 mapping along the adjacent Quebec coastline.

The second major party secured supplementary control for 1:50,000 and 1:250,000 mapping of 62,000 square miles in northeastern Quebec and in Labrador. With the exception of work to be done in connection with a few islands in Hudson Strait, this completes the control required for the 1:250,000 mapping of Canada.

Field work for revision of 1:50,000 maps was carried on for the whole of Prince Edward Island and for 32 sheets representing the Eastern Townships and 20 sheets representing the country surrounding Ottawa. Surveys for new mapping on this scale for the Geological Survey covered 13 sheets of the mineralized zone around Mayo, Y.T.

Control for 1:25,000 mapping was established for six sheets for Charlottetown, P.E.I.; two for Moncton, N.B.; five for Morrisburg, Ont.; 30 for southwestern Ontario,

one each for Medicine Hat, Lethbridge and Red Deer, Alta., and five for Kamloops, B.C. Vertical control for a number of these sheets is to be obtained in 1965.

At municipal request the Topographical Survey assisted in the establishment of co-ordinate systems of control in Hamilton and Sudbury, Ont.; Medicine Hat, Lethbridge and Red Deer, Alta.; and Kamloops North, B.C. and in completion of work at Whitehorse, Y.T. These surveys fixed the positions of about 400 permanent monuments, which will promote the integration of all municipal surveys.

Extension of control for future revision of mapping was carried on in Saskatchewan by correlating Dominion Land Survey and Geodetic systems in the vicinity of Yorkton and Rosetown and by levelling under a federal-provincial agreement in the Melfort and Carrot River districts.

Two winter parties ran 700 miles of spirit levels for studies of a proposed diversion of Churchill River water to the Nelson River for power development.

Special projects included assistance to the Newfoundland government in making an integrated survey at Bay de Verde; the fixing of Funk Island in the Atlantic Ocean and a loran site in Newfoundland by aerodist; surveys for large-scale plotting of settlement areas in the Yukon Territory; and assistance to the Defence Research Board and Polar Shelf Project in Arctic surveys.

The Topographical Survey now has files of about 100,000 cards showing co-ordinates, descriptions and photo identification of monumented control in Canada. This comparatively new system works well in supplying compilation needs and meeting federal, provincial and private requests for control data. The 125 hours allotted on the department's IBM 1620 computer greatly assisted computation.

In the field of air surveys, compilation of 1:250,000 and 1:50,000 maps from those of larger scale has become a normal operation. For 1:25,000 and revised 1:50,000 mapping the trend was to compilation from uninterpreted photographs with dependence on field completion for corrections just before clearance for publication. As a part of its normal work, the Topographical Survey continued the inspection of photography done for the federal government and recommended payments on contract.

Special plotting projects, numbering 24, were undertaken for the Legal Surveys Division, the Polar Continental Shelf Project, the Canadian Hydrographic Service and the Geological Survey, all of this Department, the departments of Transport, Northern Affairs and National Resources, and Public Works, and the Saskatchewan government.

Several members of the staff, engaged in research and development, continued to design programs for electronic computers, to analyze characteristics of plotters and pantographs and to redesign for improved operation. In co-operation with the Hydrographic Service and the Bedford Institute of Oceanography, this unit designed a method of measuring water currents by timed photography of floating aluminum powder targets. A computer program for reduction of aerodist data to ground positions is now in use, and a method of using the aerodist system for continuous trilateration was under study.

Technical assistance in foreign mapping engaged three senior officers and required part-time help. The work concerned the preparation of specifications for contract mapping and for its acceptance. The contract mapping was done by Canadian companies under the Colombo Plan, the Special Commonwealth Aid to Africa program and the Commonwealth Caribbean Assistance program. Nigerian acceptance of 132 map sheets completed one contract while a second contract for additional areas got under way. Reports on the feasibility of mapping in Nigeria, Tanzania, Trinidad,

Tobago and Jamaica were completed. Two field-staff members are currently supervising aerodist surveys in Nigeria and Tanzania.

LEGAL SURVEYS AND AERONAUTICAL CHARTS

A program of legal surveys in Indian reserves, national parks and territorial lands was undertaken as usual. One case, involving resurvey and subdivision of 450 lots in the Caradoc Indian Reserve, was successfully and economically completed by using photogrammetric methods to determine boundary dimensions. The report and atlas for the north boundary of Saskatchewan was tabled in both Parliament and the Saskatchewan Legislature. The demand for additional services in aeronautical charting continued.

Five interprovincial and territorial boundary commissions were active in 1964. Work continued on the preparation of reports and atlases for the north boundary of Manitoba, the north boundary of British Columbia and the northern part of the boundary between Manitoba and Saskatchewan. The functions of the Manitoba-Saskatchewan Boundary Commission were extended to provide for further surveys to complete the proper demarcation of the whole boundary and for maintenance of the boundary markings. The Alberta-Northwest Territories Boundary Commission completed the inspection and restoration of that part of the boundary lying to the west of the Mackenzie Highway.

Sixteen field parties carried out legal surveys in public lands of Canada for departments of the federal government. In addition, instructions were issued to private surveyors for 102 legal surveys for private and provincial agencies. Surveys for federal departments were undertaken in 62 Indian reserves, three national parks and the Yukon and Northwest Territories. In the Yukon Territory the right-of-way of Canol pipeline from Carcross to MacRae was monumented. Two small subdivisions and 57 miscellaneous lots and parcels were also surveyed. In the Northwest Territories a 160-lot addition to the new townsite of Hay River and a 46-lot subdivision at Snowdrift were surveyed as well as individual lots at Cambridge Bay, Port Radium, Snare River, Fort Providence, Fort Resolution and Fort Smith.

Four new series of aeronautical charts or publications were initiated, and existing series were extended and redesigned to accommodate the continually increasing amount of aeronautical information that is being made available for air navigation.

An experimental aeronautical chart on the scale of 1:250,000 for the Mannheim area of Germany was produced at the request of NATO and was well received by Canadian and NATO military mapping personnel.

Survey documents entered in the Canada Lands Surveys Records numbered 446 plans and 184 field books. About 23,500 document extracts, publications and astronomical field tables were dispatched, and information on 319 airline distances was provided for official purposes. Four meetings were held by the Board of Examiners for Dominion Land Surveyors. Of the 43 candidates who wrote the examinations, eight qualified for a certificate of preliminary examination and three for a commission.

MAP COMPILATION AND REPRODUCTION

Map and chart production for the year was slightly lower than in 1963.

The conversion of the eight-mile map series to 1:500,000 continues, with 168 maps, or 76 per cent of the total, now completed.

Publication of the 1:50,000 series exceeds 25 per cent, or 5,597 of a potential 21,855; that of the 1:250,000 series stands in excess of 61 per cent published, or 572 of a potential 928. Maps received from the Topographical Survey for reproduction numbered 311. These were made up as follows: 19 at 1:25,000; 232 at 1:50,000; and 60 at 1:250,000.

The number of maps and charts printed decreased to 4,147 from 4,450 printed in 1963. Of these, 1,931 were printed on the large offset presses and 2,216 by multilith.

Map distribution dropped to 1,006,589 copies, from the 1963 total of 1,081,598.

The total stock of maps increased from 10,715,083 copies recorded for 1963 to 11,725,123.

The decision to print the UTM grid on all maps of the three standard series (1:25,000, 1:50,000 and 1:250,000) led to economies in handling and a reduction in the quantities printed. Experimental photo-composed maps were produced, in final form, from larger-scale maps. Thus produced were 1:500,000 maps from 1:250,000 and 1:125,000 maps from 1:50,000.

Information booths were set up at the National Sportsman's Show in Toronto and the Central Canada Exhibition in Ottawa. In addition, information material was supplied for redistribution to map displays at Quebec City and Victoria, B.C., and to the National Boat Show in Toronto.

Map requests for the year numbered 45,103 and involved 1,006,589 maps. Over-the-counter sales increased from $11,532 to $13,766. Revenue from sales rose to $253,849 for the year from the $217,609 received in 1963. The number of research and development projects completed during the year totalled 63; in 1963 they totalled 36.

INTERNATIONAL BOUNDARY COMMISSION

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

The Commissioners for Canada and the United States made joint inspections along the line and inspected the work of field parties on the boundary between Quebec and Maine, Vermont and New York and along the Yukon-Alaska boundary.

A Canadian field party carried out maintenance along the Quebec-Maine boundary, inspected and repaired monuments, recleared growth along the boundary vista to a sky-line width of 20 feet through 25 miles of forested country and treated 65 miles of vista with herbicides.

Another Canadian party worked along the Yukon-Alaska boundary, inspected and established new monuments and recleared 21 miles of boundary vista in the vicinity of the Alaska Highway, Sixty-Mile Road and Yukon River crossings.

Still another Canadian party resurveyed the section near the mouth of the Pigeon River, on the Ontario-Minnesota boundary, where a number of reference monuments had been lost through erosion and construction operations. New reference monuments were established, and the boundary line was marked on the new highway bridge across the Pigeon River.

Tests were again carried out along the British Columbia boundary to control vista growths through the application of herbicides by helicopter.

The positions of buoys marking the boundary through western Lake Erie were rechecked, and the geographic position of Oswego Harbor lighthouse, New York, which serves as a reference for boundary turning points in Lake Ontario, was established. In all, the Canadian parties recleared 46 miles of vista, treated with herbicides 85 miles of vista, repaired 10 monuments and established 11 new monuments.

NATIONAL AIR PHOTO LIBRARY

In 1964, requisitions for photographic work numbering 5,324, the highest annual total in the Library's history, were prepared for processing. They covered 453,060 reprints from federal government air-survey negatives (contact prints, enlargements, multiplex diapositives, mosaics, lantern slides, etc.)

The Library received 27,652 new photos, which brought the total of the Library collection to about 2,994,000.

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

On April 1, with no interruption in production, the storage of federal-government air-survey film and print production was transferred from the RCAF to the Department of Mines and Technical Surveys. For more than 40 years, the unfailing co-operation of the RCAF Photographic Establishment fully complemented the efforts of the Library in maintaining the best possible service to the public, and this collaboration will continue.

The fourth edition of the *Air Photo Coverage Map of Canada (1963)* was made available for distribution in April, and the mosaic-coverage map was corrected to October 1964. 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 third printing in October.

A start was made on a program to copy, on 70-mm film, some 800,000 prints from nitrate-base negatives that are deteriorating. The purpose is to preserve this pictorial history of Canada recorded between 1920 and 1940.

Marine Sciences Branch

The Marine Sciences Branch is responsible for the hydrographic survey of all Canadian navigable waters and adjacent oceans, the measurement and prediction of tidal phenomena, and the production, publication and maintenance of nautical charts and associated publications for the assistance and safety of navigation. It carries out research into the physical properties of these waters; it also does research on bottoms and subbottoms for the efficient exploitation of the resources they contain.

The activities of the Branch are planned to meet the needs of commerce, industry, fisheries, maritime defence, and weather and ice forecasting. An increasing proportion of its effort is being directed toward the provision of charts for recreational boating. It carries a share of Canadian participation in international studies of the world's oceans. Through the Canadian Committee on Oceanography, its program is co-ordinated with the programs of other Canadian agencies.

For the performance of its tasks the Branch is organized into three functional divisions: the Canadian Hydrographic Service; the Division of Oceanographic Research; and the Ship Division, whose activities are co-ordinated in Ottawa.

In 1964 the fleet of the Marine Sciences Branch totalled 11 ships and 50 launches and had a complement of 707 officers and crewmen. It was supported by two Bell helicopters, a chartered vessel (MV **Theta**), and a Hiller helicopter chartered to transport heavy equipment on ship/shore operations.

Late in 1964, after a series of disappointing delays caused by the repair and reconstruction of several items of major equipment, CSS **Hudson** was turned over to the operational control of the Bedford Institute.

During the year, the Ship Division continued to work on the design of a new major survey/research ship. The designs and specifications for two new tidal and current vessels and a replacement for the small and aging CSS **Ehkoli** neared completion in preparation for construction after mid-1965.

THE EASTERN REGION

The eastern region includes the Atlantic Coast, the Gulf of St. Lawrence and the Eastern Arctic. Research and survey in this region are based at the Bedford Institute of Oceanography, Dartmouth, N.S.

The momentum of the operations reflects the Institute's growing achievements in research and engineering technology. Theoretical studies have been carried out on models showing the growth and melting of an ice sheet, wave- hindcasting and -forecasting techniques, and new concepts of deep-water formation and circulation.

The interest in offshore oil rights has stimulated the staff to increased effort in submarine geology, sedimentology, organic geochemistry and geophysics.

The most complex and varied study of the year involved the completion of an offshore hydrographic survey of the Bay of Fundy. In addition to this task, and coincident with this survey, CSS *Baffin* carried out trials of the telemetering of tidal data from shore to ship. It collected gravity and magnetic data using a recently developed automatic data-recording system. Experiments in the use of a magnetometer flown in a helicopter positioned by the survey ship were also undertaken. This demonstration of the successful integration of traditional hydrographic survey with the measurement of other geophysical properties promises a marked improvement in the ability of the Marine Sciences fleet to cope with increasing survey and research demands.

CSS *Maxwell* continued the charting of the Nova Scotia coast, concentrating on Sheet Harbour, East Pubnico and Canso Harbour.

Geophysicists aboard CSS *Hudson* discovered an unusual gravity anomaly off Cape Breton Island on a survey/research cruise. The 20-mile-wide structure is now known as the Orpheus anomaly. It extends 110 miles east from the entrance to Chedabucto Bay at least to the edge of the Laurentian Channel. This structure, of major geological interest, has important economic implications if it is caused by an accumulation of sediments. If, on the other hand, it is due to a granitic intrusion, its discovery may contribute to the theory of continental drift. Studies of this anomaly are continuing.

Investigations east of Sable Island involved coring and dredging and an evaluation of the bottom topography.

MV *Theta* carried out experiments in laying and recovering deep-sea current moorings off the east coast. Nine experiments involving different techniques of mooring were performed with varying degrees of success. MV *Theta* also co-operated with vessels of the Royal Canadian Naval Auxiliary and of the Fisheries Research Board in seismic and crustal studies of the Gulf of St. Lawrence.

CSS *Acadia* completed the survey of East Point, P.E.I. and, as the oldest ship in the fleet, shared honors with CSS *Hudson,* the newest ship, in displays presented in conjunction with the annual meeting of the Royal Society of Canada at Charlottetown.

CSS *Kapuskasing* commenced the re-survey of Chaleur Bay for the production of a modern nautical chart. It co-operated with CSL *Anderson* in a detailed study at Belledune Point to provide information for the construction of a harbor for the use of a base-metal smelter plant being erected there.

Standard techniques of current survey, involving meters and drogues, were augmented by aerial photogrammetric studies in which the movement of aluminum "slicks" was recorded by repetitive photographic flights.

The movement of bottom sediments in the area near Belledune Point was studied by marine geologists.

On the coast of Newfoundland, CSS *Acadia* made surveys of St. Bride's, Baie Verte and Botwood and continued the survey of Carmenville. It assisted in the accurate determination of Funk Island by the use of aerodist.

A study of deep-water characteristics involving the examination of the physical processes contributing to the formation of slope water and Atlantic intermediate water continued in the convergence zone of the Gulf Stream and the Labrador Current. New techniques employing fission-product concentrations of strontium 90 and caesium 137 were used.

Similar studies are being conducted in the Gulf of St. Lawrence, where techniques in mooring and instrumentation are being evaluated on the smaller oceanic phenomena.

Research scientists from the Bedford Institute and from Woods Hole Oceanographic Institute carried out a comparison of methods of measurement of turbulence and wind velocity over the sea surface in the Caribbean. The performance of a special stable platform was examined. The success of these experiments will enable Canadian scientists to employ these and improved techniques in the more difficult condition existing off the Canadian coasts.

After participating in these studies, CSS *Baffin* moved north to carry out a hydrographic survey of a 2,000-square-mile area in the British Virgin Islands. This project was combined with a program of training in modern survey techniques.

The survey-research requirements of the hydrographers and oceanographers have called for the introduction of a wide range of new instruments and adaptations to existing equipment. An automated geophysical data logger has been brought into service for continuous high-speed ship surveys. Other systems developed and evaluated during the year include the use of buoy magnetometers and wave and temperature recorders. With the use of such instrumentation, acoustic homing devices, bottom release mechanisms and pressure capsules have had to be designed for recovery.

Graphic analogue and digital converters have been constructed for automatic and semi-automatic readout of data records. These developments are proving themselves in the quantity and quality of data collected and analyzed on survey/research operations.

Oceanographers in CCGS *Labrador* studied the geology and geophysics of northern Baffin Bay to provide information leading to a better understanding of geological relations between Greenland and Canada. The deep-water characteristics of the area were also studied.

THE CENTRAL REGION

CSS *Cartier* continued surveys of the inshore small-boat route along the northern and eastern shores of Georgian Bay. With the completion of this work and the publication of the relevant charts, yachtsmen will have valuable sailing information for a route extending from Killarney to Parry Sound.

CSS *Cartier* also completed the survey of the entire central part of the Bay, an area of some 1,500 square nautical miles, the last large area of the Great Lakes to be charted by standard survey. This ship commenced re-charting the West Entrance Channel leading into Georgian Bay south of Manitoulin Island, which was last surveyed in 1884-85 by Commander Boulton.

At Pelee Point, the ship also carried out a bottom-survey, bottom-sampling and current-study program, which was part of a shore-erosion study.

CSL *Cygnet* completed charting the Ottawa River between Ottawa and Carillon, begun in 1963.

CSL *Rae* made a reconnaissance survey of the Mackenzie River from Fort Providence to Norman Wells, providing continuous soundings for 565 miles over what is approximately the southern half of the river course. It also carried out a survey between Point Desmarais and Beaver Lake, a continuation of the detailed 1963 program of charting the approaches to the Mackenzie River entrance on Great Slave Lake.

CSL *Petrel* worked on the St. Lawrence River and completed the survey from Grondines to Neuville, Que.

During the year, 76 tide and water-level installations were inspected. Levelling, maintenance, erection of tide staffs and other necessary work were performed at each station.

Telemetering equipment was installed at three more gauge stations in the Montreal area to provide important information during the period of low water levels in Montreal Harbor. Readings from the gauge at Verchères, Que., are now being transmitted 30 miles by radio to the office of the St. Lawrence Seaway Ship Channel Branch.

THE PACIFIC REGION

CSS *Stewart* surveyed Vancouver Harbor, the west coast of Kunghit Island (at the southern tip of the Queen Charlotte Islands), and Dixon Entrance. The last-mentioned survey marked the final stage of a seven-year program to obtain accurate soundings, with Decca electronic equipment, of the rich offshore fishing grounds in Queen Charlotte Sound, Hecate Strait and Dixon Entrance.

CSS *Marabell* surveyed Pedder Bay, Winter Harbour and Forward Inlet. This ship also continued to survey the northern part of the Gulf Island and Portland and Observatory inlets.

CSL *Owl* started surveys from the Trial Islands to Cadboro Bay, near Victoria.

Current surveys of Stuart Narrows, Porlier Pass and Active Pass were made by CSS *Parry*. CNAV *Whitethroat*, on loan from the Department of National Defence, carried out an eight-week current survey in Juan de Fuca Strait.

THE ARCTIC REGION

Three hydrographers of the Canadian Hydrographic Service on duty with the Polar Continental Shelf Project carried out a hydrographic survey in the Fram area, using a helicopter-towed echo sounder.

Five hydrographers were assigned to the Canadian Coast Guard vessels CCGS *John A. Macdonald*, CCGS *D'Iberville* and CCGS *Labrador*. A survey of Milne Inlet and Cumberland Sound and the positions of islands off the coast of Labrador, south of Nain, were accomplished.

Heavy ice in the western Arctic severely curtailed the work of CSS *Richardson*, restricting the work to west of Cape Bathurst. Considerable progress was made, however, on the survey of Kugmallit Bay with radar transponder beacons.

The Frozen Sea Research Group has successfully conducted winter field operations at Cambridge Bay, where its members studied the formation and growth of ice and heat transfer, using automated sensor equipment. The group is based at Victoria, B.C., and collaborated with a similar ice-research group of the Pacific Naval Laboratory.

HEADQUARTERS SERVICES

Of the 40 new charts put out in 1964 by the Canadian Hydrographic Service, the two that created the most interest were the yachtsmen's chart of Georgian Bay and the fishermen's chart of a part of the Nova Scotia coast, each the first in a new series.

Eighty-two revised editions of charts were issued, and the number of navigational charts maintained rose to 864. The distribution of charts, including the special charts for government agencies, totalled 247,000.

Canada, as a member of the International Hydrographic Bureau (IHB), accepted responsibility in 1958 for compiling bathymetric data (depth measurements) of the Polar area north of 72° and from the Greenwich Meridian westward to 180° and for Hudson Bay and its approaches, as recommended by the bureau for all member states. In 1964, staff was made available to start meeting this commitment, and the compilation of the Canadian plotting sheets is now well on its way.

The second edition of the *St. Lawrence Pilot* was published as well as supplements for seven of the 14 pilots.

In 1964 the first edition of the *Hudson Bay and Arctic Waters Tide Table,* which covers the normal navigational season, was published and the *1963 Water Levels,* an annual publication, was revised and considerably enlarged.

The year showed a marked increase in the use of the computer. Most of the routine computations as well as analyses and predictions were done by this means. The procedures for checking basic data were developed on the new automatic plotter.

The Marine Sciences Branch, under the direction of the Chief Oceanographer, operates a national data centre for the processing of all Canadian oceanographic data and their international exchange. In 1964 the Centre processed data from 5,563 oceanographic stations, 401 of which were in countries participating in reciprocal exchange agreements.

The dynamics of tides in the Labrador Sea, Davis and Baffin Straits may have been investigated in theoretical mathematical studies for which the region has been modelled as a narrow rectangular sea of constant depth. A survey of tidal-analysis methods employed throughout the world was initiated in 1964 and will continue in 1965.

The Branch prepared four new records of environmental data and an atlas of oceanographic conditions in Hudson Bay. These will be followed by additional atlases of other Arctic regions. Special studies are being conducted on heat-budget analyses of Arctic waters to determine winter structure as well as the seasonal subsurface environment of temperatures and salinity and its relation to the formation of bottom water in Foxe Basin and Hudson Bay.

Geological Survey of Canada

The activities of the Geological Survey are designed to add to the knowledge of the geology of Canada and to contribute to the understanding of earth sciences. They extend from observations of large-scale phenomena in the field to analyses of almost infinitesimal samples in the laboratory. In its over-all scientific functions and, indeed, in most of its projects, laboratory and field research are combined. Each year nearly 150 scientists travel to all parts of Canada to make systematic observations and to collect the samples required for their investigations. Between field seasons, these scientists collaborate with some 50 others who man the analytical and experimental laboratories and with them study materials and problems arising from field observations, evolve theories and develop new methods and scientific instruments.

Paramount among the pragmatic aims of the Geological Survey are: to make an inventory of the potential mineral resources of Canada; to aid in the discovery of mineral deposits; and to assist in other aspects of the national economy that are affected by geological factors. A major result of Survey activities is information on the geological environments, types of rocks and other factors that are favourable to the formation of mineral deposits. Location of these phenomena is a prime requisite for mineral exploration and resource evaluation and is the main utilitarian motive for the systematic investigation of the geology of Canada.

In investigating the geological architecture of Canada, one group of Geological Survey scientists describes and interprets the phenomena now observable at the surface and, more and more, explores and interprets the unexposed geological phenomena below the surface. This group is concerned with the regional geology of the Canadian Shield; the mobile sedimentary basins of the mainland and Arctic Archipelago, the peripheral continental shelves and the unconsolidated Quaternary deposits. The first systematic reconnaissance, which is now nearing completion, identifies the country's main geological features and is a prerequisite to more fundamental studies of the components of Canadian geology.

During the year 55 field parties were active in reconnaissance studies — 25 in regional geology, 10 in regional geophysics, 5 in marine studies of the polar shelf and Hudson Bay, and 15 in regional studies of unconsolidated deposits. Operation Wager completed the study of a 55,000-square-mile area along the

Arctic coast made in a single season with three helicopters and one support aircraft. Other large areas were studied in continuations of Operation Liard and the Coast Range project. Combined federal-provincial aeromagnetic surveys flew 346,000 line-miles in five provinces and the Northwest Territories. Other parties made inventories of groundwater, surficial materials and oceanic sediments.

A second group of Geological Survey activities is directed toward the investigation of specific topics that are substantially dependent upon a knowledge of regional geology. Studies of the principal processes that affect the evolution of the crust of the earth — the igneous processes arising deep in the crust and mantle and the sedimentary processes that comprise the weathering, erosion and sedimentation of the upper surface and oceans — are involved in whole or in part in special studies related to economic geology, geophysics, geomorphology, petrology, geochemistry and other fields. Topical studies accounted for 66 field parties engaged in projects that covered such diverse fields as the petrology of granites, volcanic and other rocks, the stability of clay banks, hammer-seismic surveys for water and gold-bearing placers, and engineering studies of damsites, the Welland Canal and the Red River Floodway.

Laboratory studies ranged from new methods for the interpretation of aeromagnetic data to the development of mass spectrometers, counters for radiocarbon dating, magnetometers and remote-sensing apparatus. Seventeen field programs were mounted in support of laboratory investigations and the testing of new instruments. Chemical analyses of more than 28,000 samples of rocks, minerals, ores, waters and plant materials resulted in more than 175,000 individual determinations. The problem of handling, storage and retrieval, and the future processing of such large volumes of data is leading to the introduction of electronic data-processing methods.

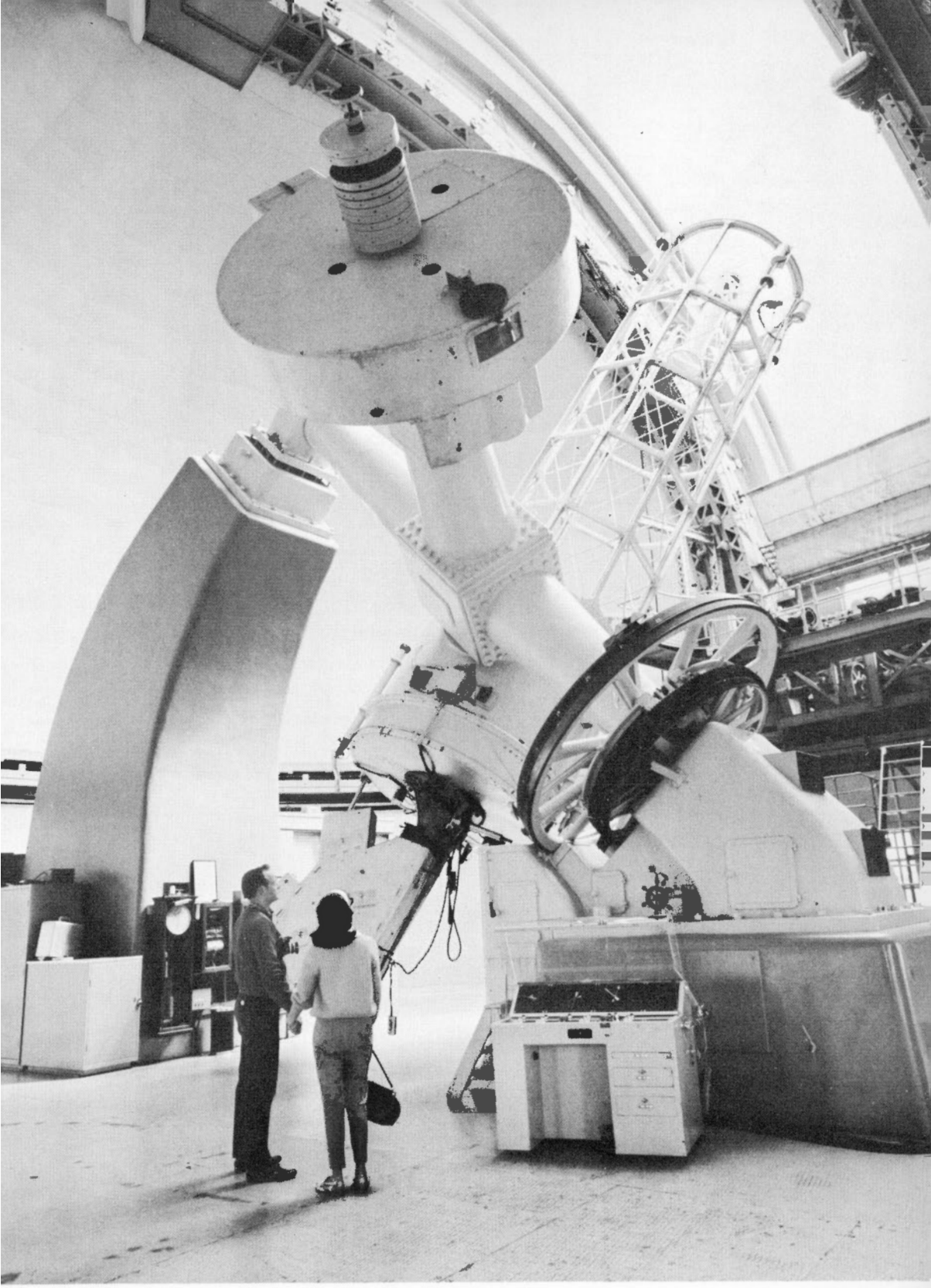
During the past year survey staff was called upon to advise on or carry out projects under the United Nations, the Colombo Plan, the International Union of Geological Sciences, the International Geologic Congress, the International Upper Mantle Project and the Commonwealth Geological Liaison Office and in connection with the International Hydrologic Decade.

To stimulate geological research at Canadian universities, the Survey awarded 52 grants to university personnel amounting to $100,000.

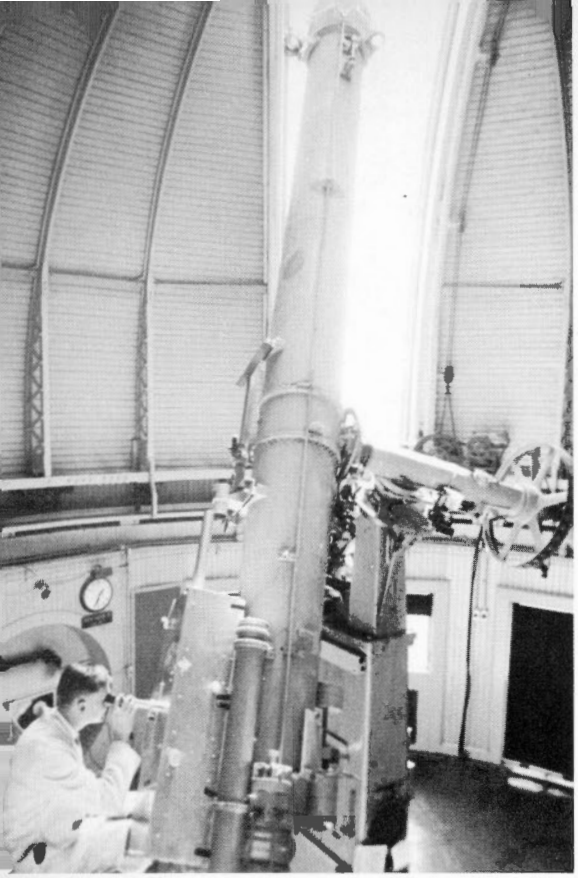
About 350,000 copies of maps and reports were distributed to 20,691 purchasers, and more than 10,000 (20 tons) rock and mineral collections were sold.

In addition to the headquarters in Ottawa, the Survey maintains offices in Whitehorse, Yellowknife, Vancouver and Calgary, and has staff at the Bedford Institute of Oceanography.

In June Dr. J. M. Harrison, who had been Director of the Geological Survey since 1956, assumed new duties as Assistant Deputy Minister (Research) of the Department of Mines and Technical Surveys, and Dr. Y. O. Fortier was appointed Director.

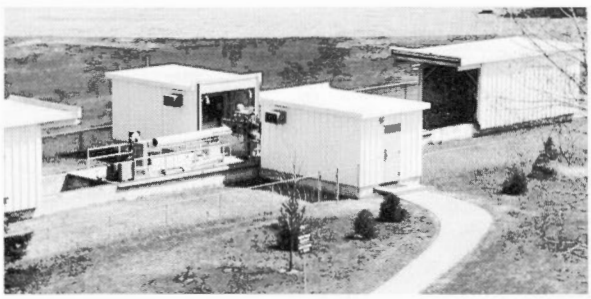


Two visitors are dwarfed by the 73-inch telescope at the Dominion Astrophysical Observatory, Victoria, B.C.



Observations of the solar chromosphere are made daily at the Dominion Observatory with the aid of a narrow band-pass birefringent filter. Photographic records are obtained at intervals of 30 seconds or less with an automatic time-lapse camera mounted on the tube of the refractor.

The horizontal mirror transit telescope of the Dominion Observatory incorporates a new concept in meridian astronomy. Two telescopes of 10 inches aperture and 168 inches focal length are fixed in the meridian, one to the north, the other to the souh of an optical flat. The optical flat, with declination circle attached, is mounted on east-west pivots with all the precision of the classical transit circle. Stellar images are reflected from the flat to one or other of the two horizontal telescopes during the brief interval of meridian crossing. The north and south wings of the building move together on rails to form a compact weather-tight building.

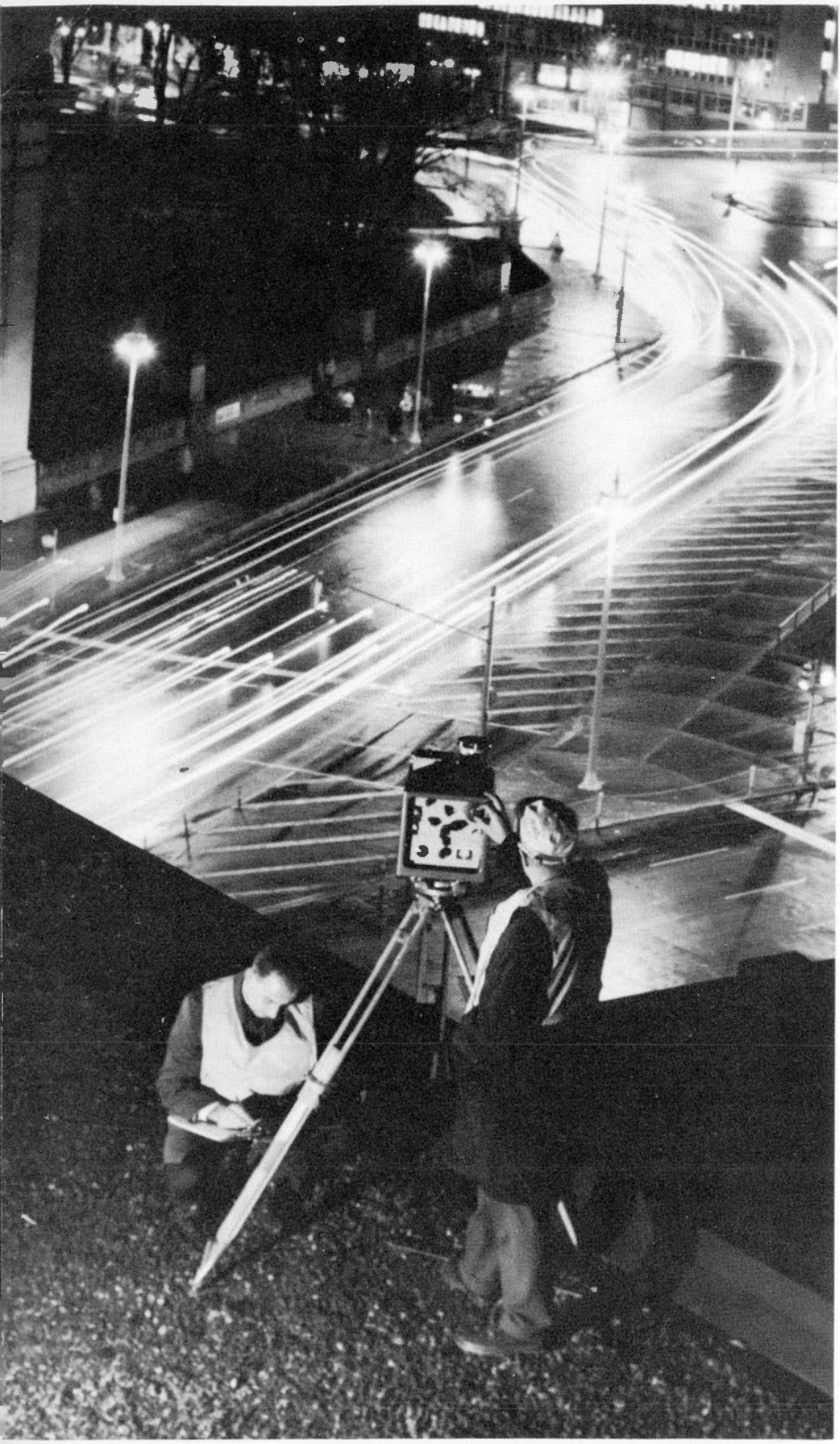


The Canadian Hydrographic Service charts the small-boat route in Georgian Bay. Here a hydrographer aboard one of the CSS CARTIER launches uses a leadline to outline a shoal.

CSS KAPUSKASING hydrographers chart Chaleur Bay for the proposed new copper smelter complex at Belledune Point. Two hydrographers fix the position of a station.

Physical geographers in Baffin Island extracting ice from ice-cored moraine for radiocarbon dating.

Site of the base camp, Geographical Branch Baffin Island Project. The building is 60 x 18 ft. and is being constructed on a gravel terrace at the head of Inugsuin Fiord. With other buildings it will serve as the main base for a 28-man party supported by rotary and fixed-wing aircraft.

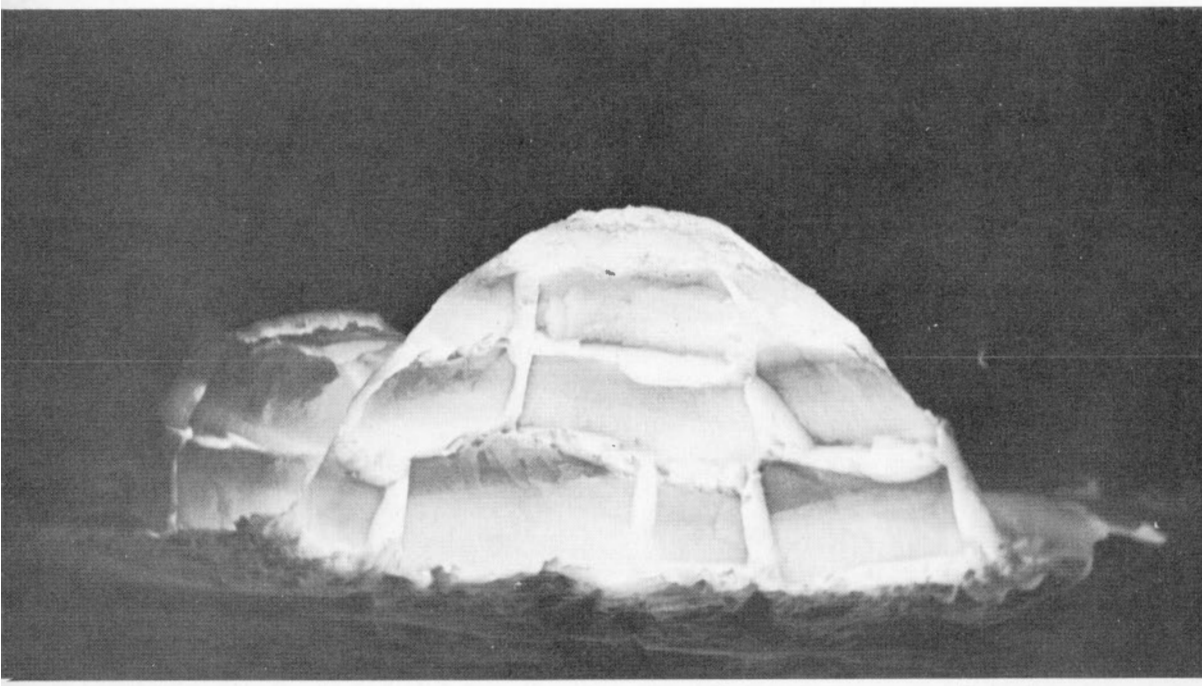


Modern electronic measuring instruments are used by Topographical Survey engineers. Here a geodimeter atop a building scans heavy traffic at night for a municipal control survey.

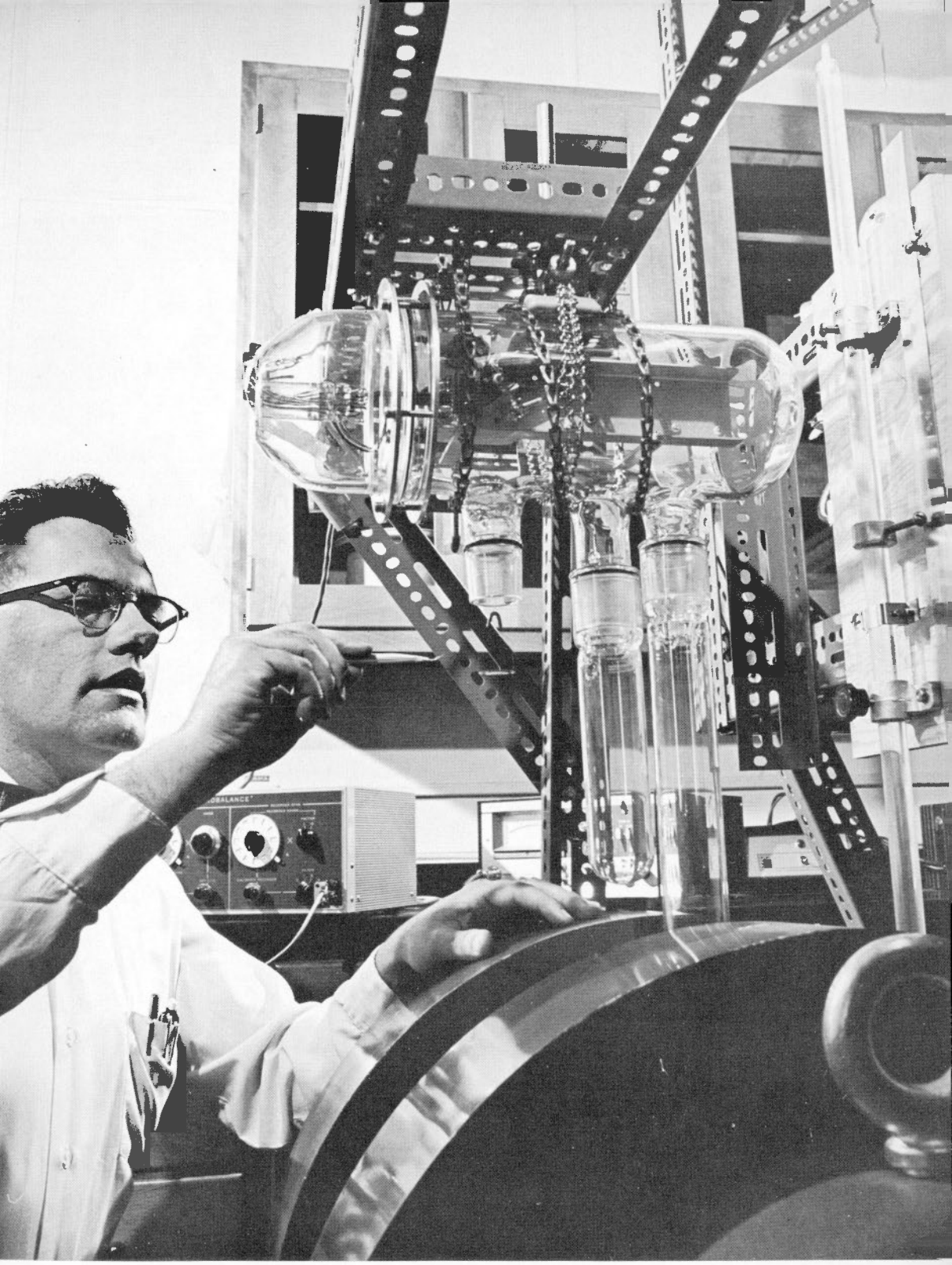
Map Compilation and Reproduction Division of Surveys and Mapping Branch produces many thousands of maps and charts each year. Here a pressman checks the quality of print against that of the plate.

Geological Survey officers examine igneous layering in peridotite of the Bay of Islands Complex, western Newfoundland.

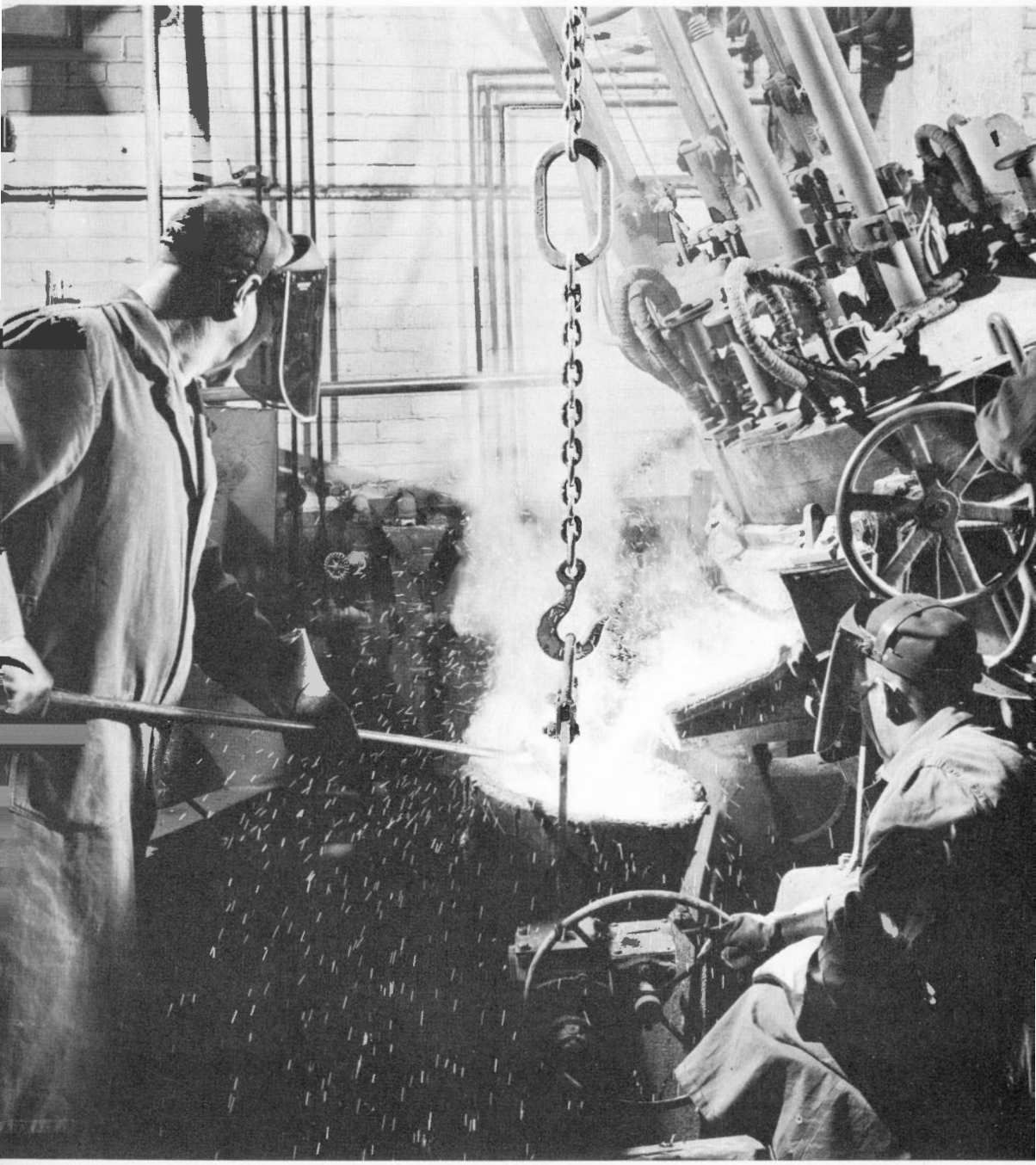
Iceberg and Brantley B2A helicopter at Admiralty Inlet, Baffin Island.



Nighttime in the Canadian Arctic. Departmental scientists working in the arctic often occupy snow-block shelters.



Scientists of the Mineral Sciences Division determine magnetic susceptibility of minerals by using a sensitive microbalance in conjunction with an electro magnet.



In the foundry of Physical Metallurgy Division studies are conducted of the deoxidation of molten steel by addition of a granular calcium alloy.

REGIONAL GEOLOGY

The Regional Geology Division is responsible for geological investigations of three of the four orogenically disturbed regions of Canada — the Cordilleran Region of the west, the Appalachian Region on the east, and the extensive Precambrian-aged Canadian Shield in the central part of the country. These investigations are concerned primarily with the effects and processes of metamorphism, plutonism, vulcanism, deformation, sedimentation and ore deposition.

Geological field parties were divided among the three regions as follows: in the Cordilleran Region, 12; on the Canadian Shield, 12 (of which 7 worked in the western Shield and 5 in the eastern Shield); and in the Appalachian Region, 5.

In the Cordilleran Region, one party completed an investigation of the copper-bearing rocks in the eastern half of the Greenwood map-area of British Columbia, while another completed a stratigraphic and structural study of the Mesozoic rocks in the Taseko Lakes area and began a similar study of the late Palaeozoic, Triassic and Tertiary rocks in the eastern half of the Bonaparte map-area of British Columbia. Five other Survey geologists continued their field studies in British Columbia, two investigating the internal structures and constitution of a complex of Coast Range granitic batholiths in the Bella Coola and Prince Rupert areas, a third establishing structural and stratigraphic relations for the metamorphic rocks in the Canoe River area, a fourth studying the stratigraphy of the Lower Palaeozoic succession and associated structures and gypsum and silica deposits in the west half of Kananaskis Lakes map-area, part of a continuing investigation of the Rocky Mountain Trench in southeastern British Columbia, and the fifth continuing a study of Permian and Triassic sedimentary and volcanic rocks in the Alberni area of Vancouver Island. Two Survey geologists spent a few weeks in the field completing geological reconnaissance of the part of the Yukon Territory investigated in 1959-60 on Operation Pelly and of the Big Bend area of southern British Columbia. In the Yukon, a Survey geologist began and completed a field investigation of the structure, stratigraphy and mineral deposits of the Mount Haldane and Dublin Gulch areas, within the Galena Hill-Keno Hill silver-mining district, and a graduate student from McGill University, seasonally employed by the Geological Survey, began a Ph.D. thesis study of Precambrian and Palaeozoic rocks in the Tombstone area, northeast of Dawson. In southern British Columbia a geology professor and a graduate student from the University of British Columbia, both seasonally employed by the Survey, carried out structural studies, the professor along the eastern margin of the Shuswap metamorphic complex near Revelstoke and the graduate on Mesozoic low-grade metamorphic rocks near Manning Park. Both studies formed part of the Survey's Southern Cordillera Structure Project.

Northwest of Hudson Bay, five Survey geologists and supporting personnel carried out Operation Wager, a helicopter-supported reconnaissance, to establish the fundamental geological framework of the barren grounds of the western part of the Canadian Shield. Since 1952, in a series of seven such operations, of which this is the last in the western half of the Shield, Survey geologists have studied some 400,000 square miles of barren ground west and north of the Ontario-Manitoba boundary and have established the main significant geological features and metalliferous belts. Now, all but three relatively small areas have been systematically and scientifically examined by modern methods in this half of the Canadian Shield.

Apart from Operation Wager, a geological party completed investigations of critical

areas in the vicinity of the Kognak River, of the southern part of the District of Keewatin. These areas contain rocks of the Herwitz Group. Two other parties commenced studies in the gold-bearing Yellowknife Group rocks of the Contwoyto Lake region, in the northern part of the District of Mackenzie. A party began special stratigraphic studies of a group of sediments in the Rocknest Lake area to solve a problem arising from the geological interpretation of data collected in a 1959 helicopter reconnaissance (Operation Coppermine); another party completed reconnissance studies of the gneissic rocks in the Nejanilini Lake and Caribou River map-areas of northeastern Manitoba; and a geological party spent four months in the Sipiwesk map-area of central Manitoba investigating the boundary between the Superior and the Churchill structural provinces and relating structural, metamorphic, geophysical and economic aspects within the important nickeliferous belt that lies in this region.

In the eastern half of the Canadian Shield, which comprises the Precambrian strata of Ontario, Quebec and Newfoundland-Labrador, and on Baffin Island, Survey geologists participated in five full-season projects and a part-season one. These ranged from detailed investigations to large-scale, multidiscipline, air-supported operations. One field party completed the preliminary geological examination of the Andrew Gordon Bay area and of Salisbury, Mill and Nottingham islands, which are just southwest of Baffin Island. Another continued geological studies of the structure, petrology and tectonic significances of anorthositic intrusions, paying special attention to the Morin Anorthosite north of Montreal. A Survey geologist commenced detailed investigations in the Lake Panache area, southwest of Sudbury, seeking solutions to the problems of metamorphism of Huronian rocks affected by the Grenville orogeny. Another geologist headed a party that made reconnaissance geological studies in the Sioux Lookout area of western Ontario, a region in which the mining industry has renewed its exploration for base metals. The largest operation in the eastern part of the Canadian Shield, which was experimental and had the support of helicopter and fixed-wing aircraft, was known as the Grenville Project. It was under the direction of a Queen's University professor seasonally employed by the Survey, who with three Survey staff members and supporting seasonal employees undertook to devise and test new reconnaissance methods of investigating the complex Grenville terrain, using the Mont Laurier and Kempt Lake areas near Ottawa as testing grounds. The methods employed proved that in such areas adequate geological information of a reconnaissance nature could be quickly obtained.

In the Appalachian Region Survey, personnel completed reconnaissance investigations of the gneisses and Devonian strata of the Port aux Basques area of southwestern Newfoundland, of the Ordovician to Devonian sedimentary and igneous rocks in the Gander Lake (west half) map-area, and of the Devonian and older granitic rocks in the Wesleyville area of northeastern Newfoundland. In northern Nova Scotia, Survey geologists continued detailed studies in the lower Palaeozoic rocks and granites of the Cobequid Mountains and Browns Mountain.

FUELS AND STRATIGRAPHY

This Division is concerned primarily with the geological investigation of the unaltered stratified and largely marine fossiliferous rocks, for it is in these rocks that most of the fuel resources — oil, gas, and coal — are found. Scientific personnel carry on field work to determine the succession, lithology, structure, age and correlation of the outcropping sedimentary bedrock formations and to conduct research in structural

geology, stratigraphy, sedimentology and palaeontology and on the constitution and origin of coal seams. Studies of the distribution, character, thickness and economic potential of subsurface formations based on examination of well cores and cuttings are conducted largely in the laboratory and office. For this purpose, the Division maintains a permanent repository for well cores and cuttings and makes these materials available to visiting geologists for study.

Stratigraphic studies in parts of the foothills and mountains of southern Alberta and British Columbia yielded valuable information on the lithology, thickness, sedimentology and correlation of rock units and on their potentialities as source and reservoir rock in their underground extent. Reconnaissance geological mapping and structural analysis of a large area in the northern part of the Rocky Mountains, the Liard Plateau and the Interior Plains region of northeastern British Columbia, which were commenced in 1963, were continued and have already yielded geological data spanning virtually the entire sedimentary column in this potential oil-and-gas region. This project, Operation Liard, will be completed during the 1965 field season. The asphaltic sandstones of northwestern Melville Island were also subjected to detailed stratigraphic and sedimentological study. The "tar-bearing" rocks were mapped and sampled and analyses of the bitumen and studies of its possible extent and origin are currently under way. Detailed geological and structure mapping of Bathurst Island was virtually completed, and a forthcoming map indicating the distribution, lithology, thickness, structure and correlation of the several formations will furnish an important guide to further drilling and exploration for oil and gas on the island. The outcropping Pennsylvanian and Permian rocks of parts of Grinnell Peninsula and Cameron, Helena and Melville islands were also the object of reconnaissance mapping and stratigraphic study. These rocks comprise the oldest Sverdrup Basin sediments, and knowledge of their character, distribution, correlation and facies is essential to assessment of their economic potential.

The interlake region of southwestern Ontario has yielded oil and natural gas since about 1859. During 1964, subsurface study of Silurian rocks, one of the main gas producers, was completed, and a detailed report illustrated by subsurface-structure and isopach maps is in press. This report will serve as a guide to further exploration and drilling in the region, one of the most thickly settled and industrialized areas of Canada.

Fossils are an important criterion in determining the succession of marine sedimentary formations, and they form one of the more important bases of correlation. In order to furnish palaeontological data, therefore, the palaeontologists of the Division prepared 115 reports on 1,388 lots of fossils submitted by geologists conducting field investigations. In addition, special studies were either started or continued on corals, trilobites and microfossils from Anticosti Island, on Devonian spores from eastern Canada and on Ordovician, Silurian, Devonian-Triassic and Jurassic fossils from central, western and Arctic Canada.

Study and mapping of subsurface formations were carried on largely in the foothills and plains area of western Canada. Isopach, structure and facies maps were made of Cretaceous, Triassic, Mississippian and Devonian formations, each of which is known to produce oil and gas at several localities.

Laboratory study of the petrology of Canadian coals is being continued to obtain information on the problems of coking qualities and of other aspects of coal utilization. Palynological (spore) investigations are also made as an aid in determining the stratigraphy of coal fields and the associated coal measures. During 1964, coals from Nova Scotia, New Brunswick and British Columbia were examined.

ECONOMIC GEOLOGY

The Economic Geology Division is concerned primarily with those aspects of geology that have a direct economic application. They include the study of the geology of mineral deposits, geochemical processes and geochemical prospecting, Pleistocene geology, groundwater and engineering geology.

The geology of mineral deposits is studied from two points of view. One emphasizes knowledge of the geological facts of the occurrence of mineral commodities, which is fundamental to a realistic appraisal of the actual and potential mineral resources of the nation. The other examines the deposits genetically, relating them to one another and to the geological framework in which they are found, seeking knowledge that may be applied to improve the techniques of mineral exploration. In 1964, studies of the geology of beryllium, copper, iron, nickel, tin and vanadium deposits were carried out in areas in all parts of Canada. They included an initial examination of the newly discovered high-grade iron deposits of Baffin Island in preparation for more intensive work in the coming year. Metallogenic studies continued on the Canadian Shield and in the Appalachian and Cordilleran regions. The economically important class of massive sulphide deposits in volcanic rocks received additional attention, with laboratory and office investigations of deposits in northern Ontario, Quebec, New Brunswick and Newfoundland.

Operation Keno, a large helicopter-supported field project in the Yukon, was carried out to provide new geochemical data for the stimulation of prospecting and at the same time to evaluate and develop further both heavy-mineral and geochemical-exploration techniques.

Geochemical research seeks to define the conditions under which elements are concentrated or dispersed in nature. The knowledge of geochemical cycles so gained not only serves to illuminate the processes of ore formation but aids in the search for orebodies through the location and interpretation of dispersion halos, which may surround them. Research during 1964 included a combined geological and geochemical investigation of a sulphide deposit in northern New Brunswick and a trace-element study of granites in the same region. The composition of carbonates of the Slave Point Formation in northeastern British Columbia was studied in relation to the lead-zinc orebodies of Pine Point, N.W.T. Mineralogical and geochemical studies of the Walton barite-lead-zinc-silver deposits in Nova Scotia were also carried out.

In the laboratory, methods were developed for measuring the surface area of fine-grained particles, for geochemical prospecting for gold, for routine analysis of biological materials in biogeochemical research and prospecting, and for rock analysis with the quantograph. Investigations were made of adsorption of trace elements by minerals and the solubility of quartz, soda and potash feldspars under various conditions of temperature and pressure.

Pleistocene geology concerns itself with the unconsolidated deposits, largely of glacial origin, on which Canada's agricultural soils have developed or on which Canadian cities are built, and with the processes that have shaped them. Not only are these deposits the source of most of the sand and gravel used in construction, they also serve as a reservoir for much of the nation's groundwater. Basic research studies are undertaken in northern areas, where conditions are ideal for gathering information. They are commonly done in conjunction with reconnaissance projects of regional geologists. During 1964, investigations of this kind were carried out on Bathurst Island and Melville Peninsula, at Wager Bay and in the western Queen Elizabeth Islands, all in the Northwest Territories.

More southerly areas in which similar studies were undertaken included those of Vernon, B.C., Bassano, Alta., Riding Mountain, Man., Gananoque, Ont., Richmond-Sherbrooke, Que., and Prince Edward Island. In mineralized areas where glacial deposits may conceal orebodies, knowledge of the form and history of the deposits is of more than usual interest. Among such areas studied in 1964 were those of Kirkland Lake, Ont., Mayo, Y.T., and the Chaudière Valley of Quebec.

The availability and quality of groundwater are matters of increasing concern to industry and the economic well-being of Canada, as the country's demand for that resource continues to rise. This concern is, in fact, world-wide and has resulted in the co-operative effort known as the International Hydrologic Decade, in which the Geological Survey is playing an important and responsible part. Current groundwater studies are focussed on the underground flow systems in several different types of drainage basins. In Manitoba and Saskatchewan during the past season, six field parties were engaged in these studies. In addition, engineering geologists studied and provided technical advice on Manitoba's Red River Floodway, the Welland Canal and several potential damsites in northwestern Canada.

In co-operation with other Divisions, the Economic Geology Division advised the External Aid Office on mineral exploration and related matters in Kenya, Tanganyika. Uganda and India.

PETROLOGICAL SCIENCES

The Petrological Sciences Division conducts basic research in the fields of isotopes, chemical elements, minerals and rocks to solve geological problems, develop determinative methods and provide basic data for other units of the Geological Survey. This research consists in laboratory investigations of materials collected by Survey personnel in many parts of the country.

The Division measures the geological age of minerals, rocks and carbonaceous materials. It also determines the abundance ratios of selected stable isotopes to provide information on the natural processes that cause ore genesis and mineral formation. Facilities for this work now comprise four mass spectrometers, a second solid-source mass spectrometer having been completed during the past year. Since the inception of the potassium-argon age-determination program in 1959, more than 1,000 K-Ar age measurements have been completed. These are used to unravel tectonic history and also to identify periods of intrusion and metamorphism in the Appalachian, Precambrian Shield and Cordilleran regions. In areas subjected to more than one period of metamorphism, this technique identifies only the most recent geological event. To penetrate this metamorphic "age barrier," increasing attention is now being given to the application of rubidium-strontium whole-rock isochron studies. Under certain conditions, these can indicate the initial or primary age of the rocks. Measurements based on them have been completed for the granitic rocks of the White Creek batholith in British Columbia and for the Preissac-Lacorne batholith in northeastern Quebec.

The age of carbonaceous samples is determined by measurement of the remanent radioactivity ascribed to carbon 14. Two proportional counters with capacities of 2 litres and 5 litres and very low background counting rates are installed in a specially designed cosmic-ray shield. Design and construction of a new 5-litre counter has extended the maximum dating limits from 40,000 to 54,000 years into the past. The age results obtained are used to establish and correlate events that occurred during Quaternary

time. In 1964, analyses were completed on 148 samples. The information thus obtained helps, for example, to establish the rate of glacial movement and the rate of emergence of land masses. In addition measurements have been carried out on tree rings and modern leaves to monitor variations in the natural C14 production rate as well as contamination of the atmosphere by bomb-produced material. During the year, a detailed study of the sulphur-isotope distribution in the Northwest Territories' Muskox Intrusion was completed.

Chemical and instrumental analyses of rocks, minerals and related terrestrial and extra-terrestrial materials and continual study of new methods and techniques are undertaken to meet the increasing demand for varied and more sensitive analytical data. Rapid rock analyses rose almost four times above their 1962 level, largely owing to the introduction of X-ray fluorescence spectrometer methods. The demand for classical mineral analyses for major petrological and mineralogical studies increased considerably, and efforts are being made to cope with the growing backlog of these analyses. The individual determinations totalled 79,000, which is almost 30 per cent greater than the number made in 1963. Studies of new methods and techniques included a flame-photometric method of determining calcium, sodium and potassium on small amounts of feldspar, a combined chemical-spectrographic method for the concentration and determination of trace elements in sulphide, sulphate, carbonate and oxide minerals, the determination of small amounts of fluorine; the specific determination of palladium in meteorites in the presence of the other platinum-group metals, and the revision of a general air-jet controlled DC arc spectrographic method for quantitative silicate trace-element analysis.

Mineralogical studies cover the physical and chemical properties of minerals, by means of X-ray and electron-beam techniques. The Survey's mineralogists care for the Systematic Reference Series of the National Mineral Collection, process geological materials for laboratory experiments and analysis, compile data on Canadian minerals and their occurrence, provide the general public with information on Canadian mineral occurrences and prepare mineral and rock collections for sale to the public. During the field season, studies and collections were made in Ontario, Quebec and the Maritime Provinces. In the laboratories, major research was conducted on the alteration of micas, on the nature and distribution of feldspars in the Muskox Intrusion of the Northwest Territories and on intensity-concentration relations in X-ray spectro-chemical analysis. Several new and rare Canadian minerals were also studied. Laboratory services included the identification of 2,100 minerals by X-ray diffraction techniques, analyses of 1,100 samples by X-ray emission spectrography, the crushing and grinding of about 4,000 samples and the preparation of more than 2,000 concentrates of minerals. The design of the electron-probe microanalysis instrument was modified, and a considerable variety of minute mineral grains were analyzed. A new method, introduced during the year, of packaging the mineral and rock sets for sale to the public proved very successful. The number of sets distributed amounted to 10,007, or almost 3,000 more than in 1963. The Systematic Reference Series of the National Mineral Collection, which is an outgrowth of the systematic mineral collection assembled in 1925 by former officers of the Geological Survey, now contains about 7,000 specimens on active file, some of which were collected as far back as 1843. These are available for study, upon request, to qualified scientists in all fields of research. During the year, 408 specimens or groups of similar specimens were added to the series and 255 samples were provided for research projects at the Geological Survey and for other government agencies.

Petrological investigations concerned the systematic description of rocks in the field and laboratory, with the interpretation of their ultimate origin and evolution. The application of electronic data processing to the collection of geological data on rocks and minerals was investigated, and a pilot analytical file was started. Detailed field studies of granitic rocks in southern British Columbia continued as part of the systematic study of granites in Canada. As several of the initial field investigations on this project are reaching completion, emphasis is changing to laboratory studies and the compilation, evaluation and synthesis of field and laboratory data. Petrographic studies of materials collected in previous years from the Muskox Intrusion continued; these included compositional studies of the plagioclase feldspars and statistical analyses of the distribution of trace elements in the various rock types in the intrusion. Field studies were made on the Bay of Islands Igneous Complex in western Newfoundland to assess its suitability as a possible drilling site under the International Upper Mantle Project.

GEOPHYSICS

The Geophysics Division makes geophysical surveys as an aid to the understanding of the geology of Canada and carries out research on the development of new geophysical methods and instruments to assist geological investigations and prospecting. Personnel of the Division assisted each of the other divisions in the Geological Survey in several ways. Members of the Geophysics Division also provided consulting services in exploration geophysics for several federal and provincial organizations and carried out both pure and applied research in the fields of palaeomagnetism, the development of geophysical prospecting instruments and methods, mathematical methods of interpreting geophysical data, photogeology and methods of remote airborne sensing.

Field activities of the Survey's geophysical staff during 1964 consisted of the following: (1) an integrated program of gravity and surface-resistivity surveys near Steelman, Sask., which demonstrated the value of surface-resistivity surveys in detecting and delineating buried sand and gravel deposits, which are potential groundwater aquifers; (2) field tests on low-frequency resistivity equipment in three areas of Manitoba, which may be useful in differentiating between types of unconsolidated sediments by means of their electrical properties; (3) hammer-seismic surveys in the Cobalt silver-camp area, in the Niagara River, in the Mer Bleue area near Ottawa, and in the Hudson Bay Lowlands, principally for determining the thickness of overburden to ascertain bedrock topography and possible buried channels, but also as an aid to structural and lithological investigations; (4) geophysical studies of the Briarcliffe orebody in the Kapiko Iron Range, north of Nakina, Ont., part of the Survey's iron-formation investigations; (5) an experimental gamma-ray spectrometer survey in Carlow township, Ont., over granitic rocks to test procedures in establishing and interpreting their uranium, thorium and potassium content; (6) field tests of the efficiency and accuracy of laboratory geological interpretations of terrain underlain by Grenville-type rocks in the Coulonge River area of Quebec, by the use of small- and large-scale photographs, including panchromatic, color and infrared film, as well as aeromagnetic maps; (7) a preliminary marine seismic survey of part of the Gulf of St. Lawrence, the start of a systematic study of the geological structure of the Gulf and the area east of Newfoundland as part of the Survey's tectonic study of the Appalachian Mountain System; (8) conducting an airborne magnetometer survey over parts of Foxe Basin, Baffin Island, Labrador and the Labrador Sea, in co-operation with the National Aeronautical Establishment and the Royal Canadian Air Force; and (9) the sampling of

Mesozoic and Cenozoic volcanic and intrusive rocks in the Whitehorse and Laberge areas in Yukon Territory for palaeomagnetic studies and geological correlations.

Members of the Division continued to take part in the management of the federal-provincial aeromagnetic survey program, and the first set of three-year aeromagnetic-survey contracts was completed successfully in 1964. Aeromagnetic surveys were conducted in the northern Queen Elizabeth Islands, the southwestern part of Yukon Territory, southeastern British Columbia, northern Alberta, Saskatchewan, and Manitoba, northeastern Ontario, and central Quebec. Geophysics personnel checked 591 one-mile aeromagnetic map compilations resulting from this federal-provincial program, checked 127 map-sheets and compiled an additional 70 map-sheets from aeromagnetic surveys flown by the Survey.

In the laboratories, staff geophysicists undertook the design and/or construction of several types of electronic equipment, including light-weight magnetometers, remote sensing apparatus involving infrared and low-frequency resistivity equipment, all of which are expected to provide information useful to the field geologist. In the palaeomagnetic laboratory, work continued on the determination of the remanent magnetism of oriented samples from the southern part of Yukon Territory, from Victoria Island and the Muskox Intrusion, both in the Northwest Territories, from the Mont Laurier area of Quebec, and from a large number of diabase dykes in many parts of the Canadian Shield. During the year equipment for magnetic "washing" of the specimens was constructed and tested.

Investigations were conducted on the development of new techniques for a reliable and efficient interpretation of aeromagnetic anomalies, and a new method was developed for calculating the dimension and depths to top and bottom of magnetized bodies.

MARINE GEOLOGY

During the year, personnel of the marine-geology unit, seconded to the Bedford Institute of Oceanography, at Dartmouth, N.S., undertook investigations over the Arctic Ocean, adjacent channels of the Arctic Islands, Nares Strait, Baffin Bay, the St. Lawrence River and Gulf, Northumberland Strait and numerous bays and inlets of the Atlantic Provinces. The studies involved in these activities concerned sediments on the sea floor and the associated fauna, submarine topography, geological formations and structures, and the stratigraphy of the unconsolidated sedimentary layers. In the laboratories at the Bedford Institute, samples were studied from mechanical, petrographic, spectrochemical, wet chemical and palaeontological aspects. The whole program is designed to lead to knowledge of the origin of the continental shelves, geological processes, the evolution and speciation of certain faunas, past oceanic climates and geography, and modern oceanic environmental factors that govern sedimentary deposition and ecological niches.

Mines Branch

In 1964, continuing its research and experimentation on metals and minerals, the Mines Branch aided Canadian industry and defence both directly and indirectly in many interesting ways.

Working directly with specific industries or government agencies, the Branch investigated weaknesses in a wide range of metal components from ship propellers to faucets; it perfected the use of compound water cyclones for fine-particle separation, which resulted in the formation of a new company to manufacture the equipment; it gave technical assistance to operators and developers attempting to revive an old Ontario silver-mining area; it took over evaluation of a new cyanide process installed in a gold mine in western Quebec; it started a joint investigation with uranium producers of flotation techniques and studied the new process of leaching by means of bacteria; it developed ore-treatment processes for 10 new mines, three of which started production during the year.

More general in application were the completion of a pilot plant for the hydrogenation of petroleum at pressures up to 10,000 pounds per square inch; the opening of a field laboratory for mining practice at Elliot Lake, Ont.; a "material research" program to study the physical properties of synthetic and natural minerals; the development of a process for the production of electronic ceramics by chemical co-precipitation; a treatment of steel to inhibit corrosion from atmospheric sulphuric acid; and two new methods of pressure-forming ceramic materials.

These are but a few highlights of what the Mines Branch achieved in 1964, details of which will be found in the following reports of the several divisions.

PHYSICAL METALLURGY

Technical assistance to industry, the armed forces and other government departments continued to be the principal activity in physical metallurgy. In support of this practical work, fundamental and applied research was conducted in the development, fabrication and application of a wide spectrum of metals and alloys; and numerous shorter investigations were made to resolve problems of immediate urgency.

In the international sphere, staff members participated in scientific activities and exchanges with laboratories and organizations throughout the world and served on executive and technical committees of professional societies and advisory groups.

The certification of industrial radiographers on behalf of the Canadian Government Specifications Board is carried out by the Branch. During the year, after examinations held at a number of centres, 30 senior and 50 junior radiographers received certification.

As in recent years, many investigations were conducted on apparently defective or damaged metallic items, metallurgical examination and laboratory testing being employed to determine the cause of unsatisfactory performance. Among the wide range of items and materials examined and reported on were boiler tubes, steel castings for icebreaker service, alloy-steel chain, aluminum-alloy hydraulic pipe, cement-form tie rods, ship propellers, cast bronze faucets, stereotype metal, naval-helicopter components and historic relics such as a tin-plated canister found in the Arctic and a steel knife from a mound in Manitoba.

The armed forces, other government departments and industry continued to use the services of the Branch as a source of metallurgical advice and recommendations, as well as to obtain other technical assistance on questions of physical metallurgy and on the selection of materials. The services offered these organizations included determination of traces of gases in metals, non-destructive testing for crack detection and internal defects, weld evaluation and mechanical testing.

Fundamental and applied research provided knowledge necessary to meet the demands of the development and application of metals. Alloy research is one of the key phases, and work directed toward the development of materials to meet increasingly severe service was carried out in both the ferrous and the non-ferrous fields. The study of the influence of uranium additions to various types of steel continued, as did the development of niobium-bearing steels, which show much promise. Copper-nickel alloy steels, which show excellent corrosion resistance in sea water coupled with high strength and ductility, were under study, and work is progressing on the development of a steel specially suitable for steam-turbine rotors for naval vessels. Work was done on aluminum and magnesium alloys, with a significant development in the field of high-strength magnesium alloys containing silver. Studies of the dispersion-strengthening of niobium and zirconium have produced useful data, which will be extended as the work progresses. A high-density uranium-alloy development program directed toward the production of useful engineering properties of interest to the military continued.

Metal-casting research encompassed studies of the solidification of steel and vacuum degassing and casting in addition to studies of metal flow in moulds, centrifugal casting and the operational controls required to produce premium-quality light metal castings. Work on the foundry characteristics of copper alloys was directed toward the development of a fundamental basis for interpretation of their behavior for the development of optimum characteristics. Research in powder metallurgy concerned the evaluation of hypereutectic aluminum-silicon alloys with an Si content as high as 45 per cent, which

cannot be produced by conventional means, and some work was done on the consolidation of iron powders produced by direct reduction from ore.

Welding research continued to be centred chiefly on the problems of welding under Arctic conditions but also embraced the investigation of welding the maraging steels and a new vertical welding process for steel plate. Studies continued of the mechanism of metal transfer in the inert-gas-metal arc process.

Surface treatment and the effects of corrosion were studied, the former to improve galvanized coatings on steel and the latter to learn about the influence of certain alloying additions on steel corrosion in aqueous media and about the corrosion fatigue of mine-shaft conveyances in mine waters of different origins.

The mechanism of fatigue damage in metals was studied in continuance of previous work, and the effects of atmospheric environment were investigated. Studies of the physics of melting and solidification were focussed on the density, viscosity and surface tension characteristics of liquid zinc and lead and certain of their alloys.

The work of the Branch in metal physics consisted in fundamental studies of dislocation movement, fatigue and plastic deformation, in all of which electron microscopy is indispensable. Ion bombardment as a means of metal-crystal orientation determination continued to be studied, with useful results. The use of delicate measurement of the magnetic properties of metals to evaluate fatigue damage has met with some encouragement.

FUELS AND MINING PRACTICE

Adequate supplies of cheap petroleum products are an essential factor in Canada's industrial economy, and the Branch has continued its research to find better means of converting low-grade Canadian crude oils into marketable commodities. Studies are now in progress in three major areas: hydrogenation, catalytic cracking and distillation.

Hydrogenation research centres on the construction and operation of a combined liquid-and-vapor-phase pilot plant that runs at pressures up to 10,000 pounds per square inch. Its construction has been finished, and preliminary testing is in progress. In addition to the complete processing of heavy crude oils to finished products, the plant will be used as a cost indicator and as a training ground for mechanical and chemical engineers. For this reason it simulates as closely as possible the conditions expected in large commercial operations.

Considerable progress was made during the year toward the development of a suitable substitute for the liquid-phase "iron grude" catalyst used in Germany in the Combi process. The indications are that cheap active catalysts can be produced that will bring about economies by reducing not only catalyst costs but the severity of operating conditions.

The Branch continued catalytic-cracking research, which involves the construction of a fluid-bed pilot-plant unit capable of hydrogenating and cracking feed stocks too heavy for conventional plants.

The Branch has long recognized the important role of catalysts in the refining of heavy crude oils. Initially the studies were concentrated upon the creation of catalysts with a large arterial-pore system to permit the reactants and products to flow to and from the active surface. This was achieved by adding high polymers during the preparative stages of catalyst manufacture and subsequently removing the high polymer from the catalyst by combustion. During the year progress was made in finding cheaper methods of pore-size control.

Advances were also made in the production of acid sites on alumina and in the measurement of the number and type of these sites. In the future, an attempt will be made to establish the desirable optimum levels of surface acidity.

The Branch's Western Regional Laboratory, at the Research Council of Alberta in Edmonton, was engaged on a program of research and development to perfect the use of compound water cyclones for mineral separation of fine particles. The program has resulted in the formation of a Canadian company to manufacture the equipment for this system under licence from the Department.

During 1964 slightly more coal was produced in Canada than in the immediate past. The chief users continued to be the electric-utility and metallurgical industries. As there are encouraging trends toward greater uses of cokes and chars in various metallurgical applications, the Branch continued the evaluation of coking coals and blends and experiments in producing chars and improving coke by blending and the heat treatment of coal. It also undertook to construct a vertical research carbonizer.

Important progress was made on the use of petrographic control for predicting coking quality from coal samples, and the method has been extended from coal to the finished coke to provide fundamental information concerning the changes of the basic constituents of coal as it is converted to coke.

The past year's intensive stoker-research program has culminated in the new-design grate bars now being fabricated by commercial foundries to improve the combustion of coals from the Atlantic region. A new pulverizer mill was being installed to be used with the combustion-research rig in the study of pulverized coal or residual oil in turbulent diffusion flames under slagging conditions. Pending completion of the mill's installation, the rig was used for research on mechanical and air-atomizing nozzles worked with residual oil; experiments were also undertaken to reduce corrosion by operating with low-excess combustion air. These projects were part of a comprehensive research program and were intended as a further contribution to the Navy-sponsored objective of overcoming slag deposition and corrosion on superheater tubes of marine furnaces.

The mining research laboratories in 1964 continued and extended studies of rock properties and their classification, research and development in instruments for measuring stress and strain, and field studies of the stability of both underground and open-pit workings. The last-mentioned studies involve projects in coal mines in eastern and western Canada, salt and potash mines in Ontario and Saskatchewan, iron-ore mines in Ontario and Quebec and a fluorspar mine in Newfoundland. In addition, basic research was being carried out in co-operation with industry on optimum blasting patterns for excavation in hard rock.

Grants-in-aid in mining research were made during the year to seven Canadian universities. The Branch's mining research has been stimulated by the decision to facilitate field studies by opening a laboratory at Elliot Lake, Ont.

The analytical laboratories analyzed 1,413 samples of solid, liquid and gaseous fuels, including 157 mine-air samples. The explosives research laboratory examined 87 explosives and formulations, and the electric-certification laboratory completed 57 investigations of equipment while carrying out a number of research projects. The federal certification officer, as chairman of the Canadian Committee on Flameproof Enclosures, was head of a Canadian delegation at the international conference in France, where a number of proposals were accepted.

MINERAL SCIENCES

During the past year research in mineral sciences was focussed on the fundamental properties of the ore minerals, particularly on those of the more common sulphides. The combined efforts of many of the physicists, mineralogists, chemists and spectrochemists were brought to bear on various aspects of a "material research" approach to the study of minerals. While the primary object of the program is to obtain basic data on the structure, bonding, constitution and other properties of synthetic and natural minerals, the ultimate possibilities of practical applications of such data are not being overlooked. Since the program was undertaken late in the year, many of the projects are in the planning stage or are being evaluated as to experimental feasibility. The mineral sphalerite ZnS, in which iron (Fe) is present in amounts ranging from traces to significant quantities, was selected for study because of its economic importance. Natural crystals of the best type obtainable were procured all over the world from museums and other sources; crystallographic data, optical absorption spectra, magnetic-susceptibility measurements and chemical data have been obtained in preliminary laboratory studies. A program of synthesis of zinc-sulphide crystals, for use in studies of the foregoing kind, was also undertaken. Apparatus for Mössbauer Effect measurements was set up and used for the study of the bonding of iron in pyrite (FeS_2); it appears feasible that this new and powerful technique may be of much value in the study of bonding in ore minerals containing iron even where it is present in substantially lesser quantities than in pyrite.

With the completion of the mineralogical study of the Mount Pleasant tin deposits of New Brunswick, a new project of a similar but more extensive kind was started on the silver deposits of the Cobalt-Gowganda district of Ontario. Owing to the present very high price of silver, there has been a resurgence of interest in this old, classical mining region, and the Mines Branch, at the request of the mine operators and developers, is giving technical assistance. The mineralogical work is one of several technological projects designed to aid the rapid and successful redevelopment of this mining camp.

Projects that were referred to last year and continued active throughout the review period included: the development of highly purified piezoelectric ceramic bodies, which was carried further with success; detailed work on the phase relations existing in oxide systems between tantalum and niobium on the one hand and iron and manganese on the other; flotation research on the use of oleic acid on tin ores; and preliminary investigations of radioactive xanthates on sulphide minerals. Participation continued with national and international agencies on co-operative-standards projects in the analytical chemistry and spectrochemistry of ores, metals and alloys. Late in the year encouraging results were obtained from specimens of fine-mesh wire gauze. Further improvements in the electronic circuitry and its assembly are being made.

A number of projects advanced during the year as follows:

Experimental work was completed on a new scheme for the determination of the platinum-group metals, and papers were prepared on the final stages of the analytical procedures.

Laboratory work that had been in progress intermittently for several years on the $CaO\text{-}Nb_2O_5\text{-}SiO_2$ was completed.

The project of mathematically programming, by computer, the data from the X-ray spectrograph on stainless steels and high-temperature alloys was successfully completed.

An electronic device for the automatic counting of dust particles on konimeter microscope slides, under development on behalf of the Mines Accident Prevention Association of Ontario for the past three years, was completed; the prototype unit has been used successfully in field trials at North Bay, Ont.

A new type of ore-sorting device was designed and developed, it operates when the metals in the ore are irradiated with an electron beam and thus made to generate characteristic X-rays. A patent has been applied for.

EXTRACTION METALLURGY

The Branch program in extraction metallurgy included applied research on a number of hydrometallurgical and pyrometallurgical processes and basic research on chemical reactions of metallurgical importance. Research on corrosion and electroplating was also carried out.

In the work involving hydrometallurgy, the cyanide process for extracting gold received considerable attention. An important aspect of this work is the development of instrumental methods to control the process, and a device for automatically determining and continuously controlling the cyanide content of mill solutions was developed. The Branch has also accepted responsibility for evaluating the effect on cyanide-process efficiency of the installation of automatic controls in the grinding circuit of a gold mine in western Quebec.

In a study of factors that affect cyanide-process efficiency, it was shown that residual xanthate carried over from the operation of flotation concentration circuits may, under certain circumstances, have a decidedly adverse effect on the extraction of gold in the subsequent cyanidation process. Consequently, the use of xanthate in gold-mill flotation circuits will have to be controlled more closely than is customary if cyanidation efficiency is to be at its maximum.

The Branch is maintaining close liaison with the uranium industry, and a permanent joint flotation pilot-plant program was started to investigate the flotation techniques previously developed at the Mines Branch for the beneficiation of uranium ores to produce leaching-plant feed. In the bacterial leaching process, in which bacteria decompose iron sulphides in the uranium ore to form acid solutions that will dissolve uranium, some samples yielded uranium extractions as high as 79 per cent over extended periods. Other studies have been made of the treatment of mine waters from uranium mines so as to recover as high-grade products not only the uranium dissolved in such waters but also the thorium and rare earths.

The growing manufacture of chlorinated hydrocarbons has resulted in increasing quantities of by-product hydrochloric acid, which can be advantageously employed in the production of phosphoric acid from phosphate rock. A Canadian company arranged with the Mines Branch to carry out a joint pilot-plant project to test the hydrochloric-acid leach process.

In the previous year a process was developed on a laboratory scale to produce, by chemical co-precipitation, a uniform mixture of lead, zirconium and titanium oxides for use as raw material in the manufacture of electronic ceramics. In 1964 a pilot plant was assembled to test the process, and methods of preparing the feed solutions, conducting the co-precipitation operation and drying the precipitate were successfully worked out. Adequate quantities of material were produced for the subsequent manufacture of electronic ceramic test discs, and tests made on the products indicated that better coupling

factors and higher densities could be obtained with the new mixed oxides than with commercially available material. With the process in operation, it is now possible to obtain a series of products of varying lead, zirconium and titanium oxide content, with the result that the best composition for specific purposes can be determined.

Because of the severe competition of foreign tungsten producers, an investigation was started of the production of premium-grade tungstic oxide from tungsten concentrates of Canadian origin. A laboratory study has shown that the Canadian concentrates are amenable to leaching by standard procedures and that the leach solutions so obtained can be treated by ion-exchange techniques to produce a high-purity tungsten oxide.

After the recent development at the Mines Branch of a process to produce medium-grade vanadium pentoxide from oil-refinery fly ash, an investigation was made to discover methods of refining the product to a high purity. Laboratory work has now shown that this is possible.

In the field of pyrometallurgy a study is being conducted of various aspects of the electric-arc furnace, with the object of making it a more economic smelting device. As the electric-arc furnace is already efficient in utilizing electrical power, the main area of improvement lies in the conservation of the energy of the smelting-process products, particularly of the hot carbon-monoxide-bearing off-gases that result when carbon is used as the reductant. An electric smelting unit was designed in which pelletized feed was introduced into a 250-KVA electric-arc furnace through a shaft situated above the electric furnace proper and through which the off-gas was exhausted to pre-heat and pre-reduce the incoming feed. In the preliminary work, the heat recovery obtained was excellent and no unused carbon monoxide was detected in the gas that had passed through the incoming feed.

In view of the increasing importance of the pelletizing of iron-ore concentrates, studies of pelletizing continued. The acquisition of improved evaluation equipment has made it feasible to compare laboratory results with plant operations. The possibility of developing a Canadian bentonite to replace the commonly used Wyoming bentonite as a binder in the pelletizing process was explored, but no Canadian bentonite was as good as the Wyoming commodity.

The hydrogen embrittlement suffered by high-strength steels during electroplating in alkali-metal cyanide baths is a major industrial problem and has been studied for several years in the Mines Branch laboratories. In the earlier work on zinc and cadmium electroplating, it was shown that suitable control of cyanide bath composition and current densities would go far to prevent such embrittlement, and in the past year the work was extended to develop more satisfactory plating baths for copper electroplating.

Experimental work continued on electroplating chromium on steel to improve the corrosion resistance of commercial chromium electroplatings, but the problem still defies solution.

It is well known that under conditions of humidity in certain industrial areas mild steel is corroded by sulphurous acid formed from the sulphur-dioxide-contaminated atmosphere. Since the corrosion is costly for industry, an extended research program has been carried out to develop methods of combatting it. It was found that, of the many techniques examined, treatment of the surface of the steel with a solution containing ammonium oxalate and hexomethylenetetramine satisfactorily inhibits corrosion caused by sulphurous acid.

Programs of basic research related to metallurgical processes included a kinetic study of gas-phase chlorination reactions, for which the example was the reaction between chlorine and ferrous chloride, which results in ferric chloride. In another study the kinetics of leaching reactions are under investigation, the example being the dissolution of chalcocite in an aqueous acidified solution containing ferric ions. The notable effect of sodium sulphate in promoting the formation of metal sulphates during roasting is being examined with particular reference to its application in the sulphation of cobalt. Studies were completed of the thermochemistry of metal sulphates, in particular the nickel-sulphur-oxygen, the copper-sulphur-oxygen and the iron-sulphur-oxygen systems, as well as kinetic studies of the formation and thermal decomposition of nickel and copper sulphates. The investigation of the operating variables of a hydrocyclone was continued, and new equations relating the pressure-drop, through-put, density and viscosity were developed.

MINERAL PROCESSING

During 1964 both personnel and facilities for mineral processing were engaged to capacity.

The metallic-minerals laboratories carried out 38 investigations to assist the mining industry and a research program to improve mineral-processing methods.

Industrial-assistance projects dealt with a variety of problems. Ore-treatment processes were developed for 10 new mines, and three of these started production during 1964. Successful treatment processes were developed for 10 other mining projects, which were still in the exploration stage. A number of projects required the improvement of industrial-product quality and value, the better use of raw materials, the development of new industrial-processing methods and the recovery of new by-products. Many of these projects included direct assistance to the increasingly numerous Canadian industrial-research laboratories.

Field work to assist the metal-mining industry was curtailed by a shortage of personnel. At the request of the Temiskaming Mine Operators Association, two scientific officers investigated methods for improving silver concentration at the many small silver mines in the Cobalt area. The problems were so complex that field work, supported by laboratory investigation at Ottawa, is continuing in 1965. Field work was also carried out to assist the Preissac molybdenum concentrator to start production; the treatment process was developed at Ottawa in 1963.

Investigations included flotation studies to determine the function of reagents used to separate undesirable silica and phosphorus from iron ore, and studies of specific physical-chemical properties that affect flotability of oxide minerals. Under Canada's program of technical assistance, the Branch co-operated in research for Bolivia on tin flotation and copper-bismuth separation in complex ores.

The pilot plant was fully occupied throughout the year on 14 projects, including the processing of 60 tons of copper-nickel ore, 53 tons of niobium ore, 50 tons of uranium ore, and 25 tons of iron-titanium ore. The feasibility of the process for the production of high-purity iron concentrates was proven in the pilot plant, and several large lots were prepared for industrial research on utilization in pigment and direct iron production.

The large number of mineral samples that continued to come in from private industry imposed a heavy demand on both personnel and equipment. Staff shortages delayed progress on several long-term investigations and research projects.

The Branch continued its research on piezoelectric ceramics, on silicates and other refractory materials with high heat capacity for thermal storage, and on the development of materials suitable for thermal-conductivity standards at elevated temperatures.

During the year two new methods of pressure-forming ceramic materials were placed in operation. "Hot pressing" by means of high-frequency heating and "Isostatic pressing" are being applied to ceramic powders to study the effects of these methods in the processing of ceramic products.

Seven major investigations were completed on structural clay products. Most of these concerned processing problems of immediate interest to industry. As part of a long-range program, the study of correlation between the composition of Canadian clays and shales and ceramic properties continued.

During the year 74 samples of clay and shales from across Canada were evaluated. Refractory studies were completed on three raw materials.

The Mines Branch co-ordinated a CSA cement-testing program in which the entire cement industry participated.

Ornamental marble and granite from newly discovered deposits were investigated for their suitability as building stone and exposed aggregate.

Because of regional shortages of natural sand suitable for concrete, the processing of manufactured sand from crushed rock was investigated.

In the field of non-metallic minerals, samples of minerals from different localities in Canada were investigated as potential raw materials for industry. Research was in progress on the physical properties in beneficiation of domestic bentonites, on improved methods for obtaining high-quality silica, and on asbestos fiber.

The Branch's industrial-minerals mill processed 50 samples and completed an intensive study of the physical concentration of magnesite from a deposit in northern Ontario. This investigation provided the basis for the construction of a pilot plant to determine the economic feasibility of the process. As part of Canada's program of technical assistance, an investigation was in progress to recover fluorspar from Indian fluorite ore.

The Branch continued its applied research on the flotability of pure non-metallic minerals and on the automatic colour sorting of minerals. New equipment for fine grinding by the vibration process and for air classification of non-metallic minerals in particle sizes ranging down to 5 microns was installed to assist in investigations for mineral fillers and ceramic raw materials.

The industrial-waters laboratories analyzed 4,430 samples, including samples connected with water-quality studies, mine-waste water pollution, water conservation, scaling, corrosion and the chemical-treatment control of cooling and boiler water.

The long-term survey of water quality continued in western Canada for the International Joint Commission. Increased assistance was given the Eastern Slopes (Alberta) Water Research Program by intensifying studies in the Marmot Creek and headwater streams of the Saskatchewan River System.

Branch assistance to the Department of Fisheries and provincial departments in New Brunswick was continued through collaboration on the problem of stream pollution from mine waste.

The boiler-water treatment-control program continued at 45 heating plants of the Department of National Defence and the Department of Public Works. Additional

assistance was given to the Department of National Defence with problems on treatment, scaling and corrosion in water-supply systems and cooling waters.

The study conducted in co-operation with the National Association of Corrosion Engineers to correlate water quality and the corrosion of water-distribution systems was completed, and data are being processed for publication. Co-operation continued with national and international organizations on the evaluation of water-analysis methods and their improvement.

The Branch obtained approval for the establishment of an industrial-waters laboratory in the Atlantic Provinces.

In the mineralogical laboratory the study of clay materials was intensified. With an X-ray diffraction technique based upon a Guinier-deWolff quadruple focussing camera, a system has been developed for the quantitative determination of minute amounts of mineral impurities in clay materials. The system was applied in a study of Ontario clays and shales and Manitoba kaolin to assist in the solution of processing problems.

Observatories Branch

The Observatories Branch consists of six units, each of which has a considerable degree of autonomy: the Dominion Astrophysical Observatory, Victoria, B.C., which operates as an independent scientific institution under the direction of the Dominion Astronomer; the Division of Positional Astronomy, Ottawa; the Division of Stellar Physics, with headquarters at Ottawa, which operates the semi-independent Dominion Radio Astrophysical Observatory at Penticton, B.C.; the Division of Seismology, whose research activities are centred in Ottawa but which carries out seismological field work in various parts of Canada and operates 19 seismological observing stations, one of which, at Victoria, is an independent centre of seismological research; the Division of Geomagnetism, which has research headquarters at Ottawa but conducts an extensive field program and maintains a network of seven magnetic observatories, three of which carry out independent research programs; the Division of Gravity, which is centred at Ottawa but carries out field operations in all parts of Canada.

POSITIONAL ASTRONOMY

The Dominion Observatory time signal, which radiates each day over the Canadian Broadcasting Corporation network and is familiar to many Canadians, has a history extending over many generations. It is a history of patient observation, of the discovery of the telescope, of the development of modern clocks, of the discovery of photographic methods of observation, and of the adoption of new techniques for the reduction of data. Never have people been so conscious of time, and never before has it been available with a precision of a ten thousandth of a second. The time service comes under the Positional Astronomy Division.

Astronomical time is determined by noting the rotation of the earth with reference to certain well-known stars, whose positions and motions have been observed many times over a long span of years. These observations make it possible to know the relative positions of the stars on the celestial sphere and the position of the sphere with respect to the meridian of Greenwich at a given instant.

Because the field of view of transit instruments is relatively small, it is generally possible to observe only one star at a time; and since observations are taken only at meridian passage (when the star crosses the overhead north-south line), a star can be observed only once in 24 hours. Furthermore, observation is made through a continually disturbed blanket of air, which causes temporary and unpredictable displacements of the star image. Hence there must be several observations so that the errors in position will cancel out statistically. The importance of the work provides the impetus, for, as in the photographic survey of our Canadian North, so in the photographic survey of the stars, certain stellar positions must be known with precision if they are to serve as references. Positional astronomy is a co-operative endeavour of a relatively small group of astronomers stationed at national observatories such as that at Ottawa. During the past year the Ottawa group completed the reduction of 3,754 stars observed during 1956-62. The work of observation and reduction goes on continually, for perfection of star positions and motions is a goal that can be approached but never quite reached.

Late in 1964 the new mirror transit telescope was finally used for the routine observation of stars. This marked the termination of seven years of design and development punctuated by unexpected setbacks due sometimes to bad design and sometimes to poor manufacturing techniques. Such an experience might well be expected in the evolution of a new research instrument, the like of which had never been attempted anywhere before. This instrument replaces the old meridian circle and gives promise of ushering in a new era in the techniques of meridian astronomy.

The operation of the photographic zenith tube on 200 nights in 1964 secured a total of 4,126 transit observations. The plate co-ordinates of each of the 4,126 stars were measured and the data placed on punch cards for processing at the data-processing centre. The final result of these calculations is the determination of astronomical time and latitude. Weekly summaries of them are sent to the *Bureau International de l'Heure,* the *International Polar Motion Service,* and the *Service International Rapid (des latitudes)* and are used to study changes in earth rotation and wander of the earth's pole.

Time of day conforms to mean solar time (UT2), which is intimately associated with earth rotation and serves the needs of surveying, geodesy, and celestial navigation. National time services are controlled by atomic standards which are independent of earth rotation and make it possible to synchronize radio time signals to the nearest millisecond (one thousandth of a second). CHU Canada, the short-wave outlet for the

time from the Dominion Observatory, provides, in fact, a standard of frequency as well as of correct time because the three frequencies 3330 kc, 7335 kc and 14670 kc are held constant to within a few parts in 10^{10}. CHU Canada's radio time is the only one with a bilingual announcement of time each minute of the day (the voices of Harry Mannis and Miville Couture).

Variation in earth rotation causes UT2 to deviate from the internationally co-ordinated time signals, plus making it necessary to adjust the transmitted signal. The adjustments, limited to exactly one tenth of a second, are applied simultaneously to all time services in accordance with advance instructions from the *Bureau International de l'Heure*. During 1964, because the rate of the earth's rotation was consistently slow, it was necessary to retard the time signals on four occasions.

Moon observations to determine ephemeris time were planned for the lunar eclipses of June and December, but only the latter were successful. Observations were obtained by the method of occultations as well as the Markowitz moon camera. Even so, conditions were not ideal for the purpose: the brightness shown by one edge of the moon throughout totality indicated a grazing eclipse.

Time zones are a provincial matter in Canada. An attempt is made to keep track of the boundaries between the zones, viz., Newfoundland, Atlantic, Eastern, Central, Mountain, Pacific, and Yukon, so that there may be some order in the divisions cartographers have to plot. In some instances, however, local municipalities adopt the time of the adjacent zone, usually the one to the east. Some confusion is becoming apparent where urban centres' observance of one time and rural areas' observance of another is making the time-zone boundary indistinct. In this age of rapid communication, the establishment of some sort of uniformity might soon be a matter for Dominion-provincial discussions.

STELLAR PHYSICS

The Dominion Astrophysical Observatory, at Penticton, continued the study of the emission of radio waves generated within our galaxy and in external sources. The aim is to gain an insight into the processes of energy production through measurements of the radio emission at widely spaced frequencies. Observations were continued at a frequency of 1420 Mc/s with the equatorially mounted 84-foot reflector, and observations were begun at a frequency of 22 Mc/s, with a large part of the T-shaped aerial array that is to be completed early in 1965. An aerial array to operate at 10 Mc/s was completed, and testing began late in December. Routine operation of this instrument, which is a joint venture of the Dominion Observatory and Cambridge University, will start early in the new year.

At the Penticton site the National Research Council installed a solar radio telescope to monitor the sun at a frequency of 2700 Mc/s. This instrument, which is operated by observatory personnel, extends the daily period of observations formerly made solely with instruments in eastern Canada and the continuous monitoring of solar radiation that it provides at its site has an influence on observations made with the other radio telescopes.

Reduction of observations made during the total solar eclipse of July 20, 1963, was completed. The data, obtained by photoelectric techniques from an RCAF aircraft flying along the eclipse path over Great Slave Lake, have yielded reliable determinations of the distribution of both white-light and coronal green-line emissions in the solar corona.

Routine observations of solar flares were continued throughout the year with the patrol telescope at Ottawa. At regular intervals on all clear days, this telescope obtains photographs of the entire solar surface in the light emitted by hydrogen atoms. The program, a co-operative one involving many observatories throughout the world, provides data necessary for studies of the relation between solar activity and geophysical phenomena and data used in the prediction of such terrestrial effects as magnetic storms and short-wave-radio fade-outs.

Also continued was the study of the bahaviour of meteors in the upper atmosphere and of their importance in the solar system. The photographic instruments at the observatories in Alberta secured new data on the rate at which the luminosity observed in the sky decays after the passage of a meteor. This type of observation should lead to a better understanding of the interactions between meteoric and atmospheric particles.

SEISMOLOGY

The program to expand and modernize the network of seismological observatories in Canada continued during 1964, instruments being installed at Yellowknife, N.W.T., St. John's, Nfld., and Fort St. James, B.C. In addition, vaults were completed at Flin Flon, Man., Great Whale River, Que., and Baker Lake, N.W.T., and arrangements are in hand for the commissioning of these stations. The seismic stations operated by the Department now total 19, the planned network being about two-thirds complete.

There were no major Canadian earthquakes in 1964, but a number of small shocks occurred near Deep River, the largest of which reached Magnitude 5 and was felt between Ottawa and a point beyond North Bay. Further progress was made in the study of seismicity within Canada, and in research aimed at making realistic estimates of the seismic risk in Canada for engineering, safety and insurance purposes.

International co-operation among seismological institutions has been strengthened. For example, six Canadian stations contributed daily seismogram readings, decoded automatically in Ottawa by computer, to the U.S. Coast and Geodetic Survey preliminary epicentral determination office. Similarly, all stations contributed readings in punched card form to two European international seismological research centres. In programs that are being written, the same cards are to be used to produce the yearly bulletin from the computer.

The crossed array of seismographs set up at Yellowknife, N.W.T., in co-operation with the Department of National Defence and United Kingdom scientists was maintained in operation, the tapes being sent to England for processing. During the year, considerable effort was put into establishing the requirements for a necessary analysis centre in Ottawa for continuous-tape processing, and plans are now well advanced for the acquisition of the peripheral equipment and computer facilities within the Department. Meanwhile the performance of the large array is being simulated on a computer to assess various mathematical techniques and the accuracy with which the velocity and angle of arrival of teleseisms might be deduced. It seems likely that this powerful research tool will significantly extend knowledge of the earth's structure and seismicity within Canada. It may also serve to police any test-ban agreement.

Fundamental studies of all the information contained in the seismic records have continued, and further progress has been made in surface-wave studies, the study of the mechanism of earthquakes, and research on the character of certain seismic signals and earthquake detection. It is now becoming clear that high-speed computers and suitable

translation equipment can vastly extend the scientific interpretation of records beyond the limited information contained in phase arrival times, from which, nevertheless, much of the present knowledge of the structure of the earth has been obtained.

Seismic field work in the Arctic archipelago has been continued (by the Polar Continental Shelf Group). One refraction line extended across the continental shelf north of Prince Patrick Island, and a second line paralleled the coast about 50 km inland. A special effort is being made to explore the upper mantle in this area in view of other geophysical evidence for unusual conditions. Three recording stations located between Chapleau and Hearst and the Ontario-Quebec boundary were occupied in 1964 during the continuation of the important study of the crust in the vicinity of Lake Superior, begun in the previous year. Branch seismologists also began a seismic refraction program by studying the crust and upper mantle in the interior plateau area of British Columbia.

The heat-flow section was handicapped by loss of staff but succeeded in drilling holes at Roberval and St. Jerome, Que., and at Winnipeg, and in carrying out the appropriate bottom-hole tests. Further progress was made in locating and examining holes drilled for other purposes in Canada, and thermal measurements were made in the first of these near Russell, Ont.

GRAVITY

The Gravity Division is the agency responsible primarily for regional gravity mapping, gravity-control surveys, the maintenance of gravity standards, and the application of gravity data to structural studies of the earth's crust and upper mantle and to problems of geodesy. Measurements of gravity over the continental shelves and inland waters of Canada are also carried out, usually in co-operation with the Polar Continental Shelf Project and with the Bedford Institute of Oceanography. During 1964 the Gravity Division placed considerable emphasis on problems related to data-handling and the production of gravity maps. Important computer programs required to process large volumes of field data were completed, and an analog point-and-line plotter was put in operation for the preparation of anomaly maps on any scale.

During 1964 gravity mapping continued in southern Canada and in the Arctic, with helicopters and fixed-wing aircraft for transportation. A major survey covered most of Quebec and Newfoundland east of longitude 72° and south of latitude 55°. Approximately 5,000 field observations necessary to compile 11 map sheets in the 1:500,000 Gravity Map Series were completed. In conjunction with the Polar Continental Shelf Project, approximately 500 stations were established on the sea ice between Brock, Melville and Bathurst islands, and northwest over the continental shelf out to a distance of 150 miles. As a preliminary to a more extensive survey made in 1965, a gravity traverse was carried out along the northern coast of Somerset Island. In September, an underwater gravimeter survey was made on the Great Lakes from CGS *Porte Dauphine,* which is operated by the Great Lakes Institute of the University of Toronto. Some 300 stations were observed in the North Channel of Lake Superior and in the western part of Lake Erie.

In preparation for updating the *Gravity Map of Canada,* which is to include all observations to the end of 1965, several reconnaissance surveys were carried out to give some indication of the gravity field in areas in which few or no gravity measurements have been made. One hundred and eighty stations were observed in the District of

Keewatin, 120 on Coats, Nottingham and Southampton islands in Hudson Bay and Strait, and 180 along all passable roads in the Yukon Territory.

In support of the observatories' regional mapping program and of detailed surveys carried out by the mining and exploration industries, about 200 gravity control stations were established in widely separated areas. The program of measuring gravity systematically at precise-level bench marks throughout Canada continued. In close co-operation with a bench-mark inspection party of the Geodetic Survey, measurements were made at 690 bench marks along roads in eastern Ontario and western Quebec.

Although regional gravity measurements in Canada were initiated in 1947, it was not until 1958 that systematic mapping at eight-mile intervals began. At the present rate the gravity mapping of Canada, with the exception of that of the Cordilleran regions, should be completed by 1972. Observations have been made in sufficient detail for the preparation of 74 Bouguer anomaly maps on a scale of 1:500,000; 11 of these have been published, 22 are in press, and 41 in various stages of completion.

Paralleling the field work, progress was made during the year in the interpretation of gravity and in theoretical studies. A study of the regional gravity field and its structural significance was initiated for the Precambrian areas of northern Saskatchewan, Ontario and Quebec. Analyses of measurements carried out at sea in co-operation with the Marine Sciences Branch were completed. The measurements were made to determine the reliability of gravity measurements made from ships under a variety of sea conditions.

Crater research again included air-photo search, geophysical and structural surveys, diamond-drilling programs and laboratory studies. Laboratory facilities were expanded with the installation of an X-ray powder camera diffraction unit and photomicrograph and mineral-separation equipment. Theoretical studies of cratering mechanisms in the light of observations from drilling results and other programs were begun. Mapping of the Holleford crater was completed, and laboratory examination of drill cores and surface samples from the Brent, Holleford, Deep Bay, Clearwater, Carswell, Couture and Manicouagan craters continued.

Instrument development for the construction of a vibration gravimeter for earth-tide studies and observation in drill holes also continued.

GEOMAGNETISM

A new magnetic observatory began operation in November at Great Whale River, Que., at the southeast corner of Hudson Bay. This location was chosen because it is joined to a similar observatory at Byrd, in the Antarctic, by magnetic field lines, which curve out into space and reach a height of 30,000 miles over the equator. It is believed that some kinds of magnetic disturbance travel along the field lines, producing similar effects at the two ends. A study of the correlation of the records of magnetic disturbances obtained at the two observatories should supply valuable information on the state of the atmosphere at great distances above the earth.

Continuous recordings of the earth's magnetic field were made at seven permanent magnetic observatories operated by the Division — at Alert, Mould Bay, Resolute Bay and Baker Lake, all in the Northwest Territories, and at Victoria, B.C., Agincourt (near Toronto) and Meanook (100 miles north of Edmonton). During the summer, the Department constructed a second non-magnetic building at Churchill, Man., and supplied the station with absolute instruments in preparation for the conversion of the present variation station to a first-class magnetic observatory.

Detailed specifications were prepared for the new magnetic establishment near Blackburn, Ont., a few miles east of Ottawa, on a 200-acre site protected from artificial magnetic disturbances. Plans call for an instrument-development laboratory, laboratories for paleomagnetic research, and many small isolated buildings of non-magnetic construction to provide a magnetic observatory and facilities for testing new techniques of measurement and training observers. Construction should begin during 1965 and occupancy probably in 1967.

Twenty-nine magnetic stations, out of some 100 repeat stations uniformly distributed over Canada, were occupied during the year for study of the secular variation of the geomagnetic field.

Fourteen of the stations were in the Foxe Basin area, which includes Baffin and Southampton islands and Melville Peninsula. The survey was made in April and May with a DC-3 aircraft on skis. Instruments included portable fluxgate magnetometers, a proton precession magnetometer and a recording fluxgate magnetometer, used to correct for magnetic disturbances.

The other 15 secular-variation stations occupied were in western Ontario, Manitoba, Saskatchewan and Alberta.

A complete set of charts of Canada at a scale of 100 miles to the inch was prepared, showing all components of the geomagnetic field and their secular change as of January 1, 1965.

Further investigations were made of the anomalous electromagnetic induction in the crust beneath Mould Bay, Prince Patrick Island. Three temporary magnetic observatories were operated on a line between Mould Bay and Resolute Bay. In the same study, heat-flow measurements were made in M'Clure Strait, with the sea ice as the base of operations.

DOMINION ASTROPHYSICAL OBSERVATORY

The main programs of the Observatory were continued during 1964 with modifications as dictated by progress and new requirements. Original observations of stars and other matter are obtained with spectroscopes attached to the two main instruments of the Observatory — a 72-inch reflecting telescope and a 48-inch reflector. Photographic records obtained with these instruments are studied and measured in great detail. The advent of direct space exploration has broadened the Observatory's programs to include planetary observations.

Observations were made on 150 nights with the 72-inch telescope and on 146 nights with the 48-inch telescope. They yielded a total of 1,402 photographs of stellar and planetary spectra.

During the year there was brought to completion a long program of detailed measurements of stellar spectra that was carried out by international agreement and was perhaps the most extensive ever undertaken at any observatory. This program will give the basic material for studies of the chemical composition of stellar matter. The numerous other related researches that were continued have a bearing on the matter of interstellar space, the formation of molecules in the atmospheres of cool stars, and the content of the atmospheres of Jupiter and Venus.

Other programs have been continued to obtain information on the motions of stars in clusters and double-star systems and to keep a regular record of the behaviour of stars whose surfaces appear to be unstable. These studies give information about the masses,

sizes and energy production of the stars and lead to knowledge of their formation and evolution and of their sources of nuclear energy.

Much of the Observatory's auxiliary equipment is devised and built in its own shops to meet the special requirements of astrophysical observation. New and more efficient spectrographs have been designed and constructed, special analyzing devices have been completed and a stellar photometer of original design has been planned and is under construction.

Special Observatory studies leading toward modernization of Canada's astronomical facilities have received approval with the Government's announcement of plans to build a new institution, The Queen Elizabeth II Observatory, which will contain a modern telescope with a 150-inch aperture. Through extensive field studies made during the year, a suitable site for the project has been found in southern British Columbia. Studies of the optical and mechanical features of the new telescope have reached an advanced stage.

Some 25,000 persons visited the Observatory and 31 public observation periods drew a total attendance of 3,800. Twenty-five educational and study groups visited the Observatory on special tours. Staff members gave 14 lectures in all to service and educational organizations in British Columbia and adjacent territory.

Geographical Branch

Studies of the natural landscape of Canada and man's impact upon it are the main preoccupations of the Geographical Branch. While the development of many of the pre-existing programs continued, 1964 saw the beginnings of reorientation of Branch research attendant upon the change in directorship and the appointment of new chiefs to three of the four research divisions. An extensive reappraisal of the entire structure and research philosophy of the Branch was initiated. Liaison was developed with many government agencies and university departments of geography. This culminated in late November with a special conference to discuss the future role of the Branch. At the conference, which was attended by senior government scientists and administrators and senior university geographers, the foundations were laid for the promulgation of new terms of reference and policy formulated for the establishment of a National Advisory Committee on Geographical Research.

Government approval for the production of a centennial atlas of Canadian geography and for the development of a large research program in glaciology and geomorphology was obtained in principle; the latter will represent part of Canada's contribution to the International Hydrological Decade. These two programs and acceleration of research in economic geography will result in the virtual doubling of the staff.

Owing to a vigorous recruitment policy, 40% of the present staff was appointed during the 12-month period.

With this rapid development of geography within the Department, the year-end adoption of a Branch crest was perhaps appropriate. The design centres upon Samuel de Champlain's astrolabe and suggests a parallel between federal geography as it is today and as it was in 1603, when Champlain was appointed geographer to King Henry IV of France and thus became the first government geographer in Canada.

The Branch is organized in four divisions, individual accounts of which now follow.

PHYSICAL GEOGRAPHY

The Baffin Island project remained the main field program of the Division of Physical Geography, and 18 geographers were in the field for varying periods during the summer. The glaciology party continued the study of accumulation, ablation and weather on the Barnes Ice Cap for the third year, while glacial-hydrological work continued along the Lewis River. The latter program included observations of discharge, silt-transport and the chemical properties of the stream water, all aimed at a further understanding of the geomorphological activity of glacial-meltwater streams.

The geomorphological field work was concentrated in the fiord region on the east coast of Baffin Island, where four parties studied the glacial geomorphology, the recent changes of the local glaciers and the postglacial changes in sea level. A number of shell and vegetation samples were collected to date the postglacial events. A reconnaissance survey was made of some of the local glaciers as a step in planning a more detailed survey to be undertaken later as part of the Geographical Branch's contribution to the International Hydrological Decade.

A base camp was established at the head of Inugsuin Fiord to serve as a centre for future field research in the area. An A-frame hut and two semi-permanent buildings were erected, and a prefabricated building was delivered to the site by icebreaker for erection in 1965.

Systematic aerial mapping of sea-ice distribution continued in the Gulf of St. Lawrence during the winter and in the Queen Elizabeth Islands during the summer. In the latter area it was undertaken as a contribution to the Polar Continental Shelf Project. Flying time amounted to 143 hours for the Gulf of St. Lawrence and 165 hours for the Queen Elizabeth Islands.

The geomorphological program in southwestern Saskatchewan continued as detailed mapping of surface forms. The first experimental physiographic map at the scale of 1:250,000 was published. The result is now being assessed as a step in the development of the most suitable system for geomorphological mapping. Three detailed geomorphological maps of Ellef Ringnes Island, N.W.T., were also published.

Geographical Branch personnel studied break-up and freeze-up patterns of the Mackenzie River and Delta in conjunction with studies of the heat balance of the river and of an adjacent lake. Studies of the physiography of the lowest part of the delta continued.

Office projects included the compilation of historical data, photographs and old sketches of glaciers as part of a study of their past variations.

The data-processing section extended its activities to meet an increasing demand from several parts of the Branch. Machine processing of break-up and freeze-up data and till-fabric analyses were undertaken, and preparations are under way to do similar analyses on data from dendrochronology and cirque-distribution studies.

ECONOMIC GEOGRAPHY

Land-use surveys and urban studies constituted the main activities during 1964. Much of the work was carried out in co-operation with the administrations of ARDA and EMO.

Field work was carried out in British Columbia, Newfoundland, Ontario, Quebec and Saskatchewan.

Land-use surveys covering the whole of southern Canada are being made as part of the ARDA-sponsored Canada Land Inventory, and the Branch is acting as co-ordinator. While producing the maps for the six eastern provinces, it is co-ordinating the work of other agencies in the west. By the end of 1964, more than 400 half-sheets at the scale of 1:50,000 were in various stages of completion.

In collaboration with the federal Emergency Measures Organization, the Division continued its program of mapping the urban land use and the physical characteristics of the 16 largest Canadian cities on a scale of 1:25,000. Field work in Montreal and Toronto was completed during the year. Nine sheets covering the Greater Vancouver area were published.

In addition, work was begun on a number of projects carried out by individual researchers. These included a study of the migration of the farm population in the Prairie Provinces, studies of land ownership and land classification in Renfrew County, Ont., a study of railway-line abandonment in western Canada, an economic survey of part of the west coast of Newfoundland, and, in co-operation with ARDA, the development of a classification of land according to its suitability for recreation.

TOPONYMY DIVISION

The Toponymy Division is responsible for investigating and doing research on the origin, usage and propriety of geographical names in Canada. The Division maintains name records and advises the Canadian Permanent Committee on Geographical Names on problems of nomenclature. It also produces the *Gazetteer of Canada.*

During 1964, the Division investigated 20,483 names, of which more than 2,100 were officially approved as new. The nomenclature was verified for 187 map-sheets, as well as for 158 aeromagnetic maps submitted by the Geological Survey. More than 600 inquiries concerning geographical names from members of the Committee, the mapping agencies, other government departments and the general public were answered. Progress was made on the *Gazetteer of Newfoundland.* The revision of the *Gazetteer of British Columbia* was begun, and the *Gazetteer of Prince Edward Island* was reprinted. Plans were made to collaborate with the government of Quebec in the preparation of a gazetteer for that province. Three supplements to the *Gazetteer of Canada* were issued during 1964. A special supplement was published, in which all the named glaciological features in Canada were listed. A bibliography of Canadian toponymy appeared in May. Field research included a study of the place names of Renfrew County, Ont., and the lower Gatineau Valley.

The Canadian Permanent Committee on Geographical Names was reorganized in September by an Order in Council that made changes in the federal representation, provided for a vice-chairman (Director, Geographical Branch) and established the position and defined the responsibilities of an executive secretary (Chief, Toponymy Division). The new chairman is J-P Drolet, Assistant Deputy Minister (Mines) of this Department. While in session at Winnipeg in October for the first such meeting outside Ottawa, the Committee approved the naming of Mount Louis St-Laurent, in the Premier Range of British Columbia.

CARTOGRAPHY

The Cartography Division initiates research for and production of geographical atlases and provides other divisions of the Branch with cartographic, drafting and map-

library services, as well as limited photographic and photogrammetric services. As conditions demand or permit it undertakes research in cartography.

In 1964, the planning of a small atlas of Canada was completed and its production was formally adopted by the federal government as a departmental centennial project. Detailed planning and the accumulation of data were completed for many of the individual plates. By the end of the year base maps were well under construction and a number of topical maps were in the early stages of production.

Nine of the 32 multi-coloured maps showing the urban physical characteristics of Vancouver were produced. These are at a scale of 1:25,000 and are being produced at the request of the Emergency Measures Organization.

The Division also produced eight land-use maps at various scales and six geomorphological maps.