COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Records 1967/131

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REPORT ON AN EXCHANGE VISIT WITH THE GEOLOGICAL SURVEY OF CANADA

by

P.W. Crohn

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CONTENTS

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INTRODUCTION

From February 1966 to March 1967 the writer worked with the Geological Survey of Canada under an exchange agreement between the Geological Survey of Canada and the Bureau of Mineral Resources.

As an outcome of this exchange, two reports have been prepared, of which the present one deals mainly with organisational and administrative matters, while a separate report, entitled "The Geology and Mineral Deposits of Canada and Australia", deals with technical and scientific aspects (B.M.R. Record 1967/130).

ORGANISATION OF THE GEOLOGICAL SURVEY OF CANADA

The Geological Survey of Canada is a Branch of the Departement of Mines and Technical Surveys, which at the time of the writer's departure from Ottawa (February 1967) was being transformed into the Department of Energy, Mines and Resources. Under the old organisation, the other major units of the Department were the Dominion Observatories Branch, Geographical Branch, Marine Sciences Branch, Mines Branch and Surveys and Mapping Branch. As part of the re-organisation, a Water Resources Branch was also being established, which will rank equally with the Geological Survey and which will incorporate the former Groundwater Section of the Survey and the former Water Resources Branch (dealing with surface water) of the Department of Northern Affairs, as well as a section dealing specifically with problems of the Great Lakes. In addition, the Department assumed increasing responsibility for various matters relating to sources of energy, - coal, oil and gas, including gas and oil pipelines, hydro-electricity generation and atomic energy, - which were formerly the responsibility of various Boards and Commissions.

The Geological Survey is divided into five Divisions, each with from four to six Sections, and there are also Administrative Services, Geological Manuscripts (editing) and Cartographic (drafting) Sections. Regional Offices are located at Calgary and Vancouver and Resident Geologists are stationed at Whitehorse in the Yukon and Yellowknife in the N.W. Territories.

As at January 1967, the main Divisions and Sections were:

Director:	Dr Y.O. Fortier
Chief Geologist:	Dr C.S. Lord
Regional Geology:	Dr R.J.W. Douglas
Appalachian:	Dr W.R. Neale
Eastern Shield:	Dr S. Duffell
Western Shield:	Dr G.M. Wright
Cordillera:	Supervised from Vancouver Office
Fuels and Stratigraphy:	Dr J.F. Caley

Includes Sections dealing with petroleum geology, palaeontology, coal research and Arctic Island geology.

Economic Geology:	Dr S.C. Robinson
Mineral Deposits:	Dr D.R.E. Whitmore
Geochemistry:	Dr R.W. Boyle
Pleistocene Geology:	Dr J.G. Fyles
Petrological Sciences:	Dr C.H. Smith
Petrology:	Dr J.E. Reesor
Analytical Chemistry:	Dr J.A. Maxwell
Isotope Studies:	Dr R.K. Wanless
Mineralogy:	Dr R.J. Traill
Geophysics:	Dr L.W. Morley

Includes Sections dealing with E.M., Magnetic and Seismic Surveys, and with contract (mainly air-borne magnetic)surveys.

There have recently been suggestions that this organisation into Divisions and Sections might be changed in favour of establishing a number of small working groups, comprising officers of different disciplines, who would be brought together to work on specific projects, but no official announcement of such a change had been made at the time of the writer's departure from Ottawa (February 1967).

The Geological Survey currently has a staff of about 600 full-time employees, including just over 200 professional officers. The field season generally lastsfrom late May or early June to late August or early September, and coincides with the University vacation, so that the Survey also employs between 250 and 300 temporary geologists (lecturers and Ph.D. students) and assistant geologists (undergraduates) each summer. Most parties consist of only one staff geologist and two or three temporary employees; almost every geologist on the permanent staff is therefore in charge of a project and there were 107 field parties listed on the 1966 programme.

Organisation of Field Parties

The organisation of individual field parties is generally similar to that of the Bureau.

Because of the terrain, parties working in remote areas such as the N.W. Territories are not usually equipped with vehicles, but use various combinations of helicopters, fixed wing aircraft and canoes with outboard motors. Jet boats have not been tried to date, but would probably be very useful in some areas. Tents used by such parties are fitted with aluminium frames, but equipment is generally designed for reasonable comfort and durability rather than extreme saving in weight, even where transport is entirely by air. Folding tables, canvas chairs, camp strechers, battery operated wireless transceivers, primus stoves and cooking and eating utensils are generally very similar to items used by the Bureau. Other issues include parkas, sleeping bags, - rather bulky but extremely comfortable, - and head-nets with a wire frame which actually keep off flies, mosquitoes and black-flies without interfering too much with the wearer's vision. Because of the absence of white ants, air photographs and the like can usually be stored in fibre cases rather than tin trunks.

Parties working in settled areas generally use a combination of vehicle and canoe transport, and may live in tents, caravan-type trailers or in commercial accomodation, such as motels or holiday cabins. The most widely used vehicles are eight-cylinder station sedans, e.g. Plymouth or Dodge, which are really only suitable for use on sealed roads, and light trucks, e.g. Dodge or International, of about one ton load capacity with a van-type body. Some of these latter have four-wheel drive, and they are roomy and fairly rugged, with good ground clearance. Land-Rovers or jeeps are not much used; they are criticised as being under-powered and requiring too much maintainance.

Parties in remote localities generally work six days out of seven and do not leave their survey area during the season except in case of emergency, but they generally receive mail and supplies by chartered aircraft at least once a fortnight.

Six parties, mostly in British Columbia and the N.W. Territories, used helicopters in 1966, generally for periods of two to six weeks, but there were no large helicopter surveys, such as had been undertaken in some previous years, when parties of up to 11 geologists, using 2 helicopters, mapped up to 100,000 square miles in one season. I was able to see one Bell light helicopter in action as part of a 4 mile : 1 inch mapping project by A. Donaldson's party in the Dubawnt River area, N.W. Territories. Flying was limited by poor weather conditions during my visit, but I was told that the normal procedure for this helicopter was to set out a 2-man party for an extended foot traverse or for detailed work in an area up to 30 miles from base camp, then to carry out a 100 to 150-mile traverse with the party leader, and finally to pick up the foot traverse party again.

Such a 150-mile traverse might involve about 20 set-downs and require about eight hours, of which 3½ to 4 hours might be actual flying time. One or more caches of petrol were generally put in beforehand by fixed wing aircraft to avoid having to carry an excessive load at the beginning of the traverse. Flight lines were selected before taking off to include as many outcrops as possible, and air photos at 1 mile : 1 inch scale and topographic maps at 4 mile : 1 inch scale were used for navigation.

I was also told that, by hovering a few feet above an outcrop, an experienced geologist could obtain almost as much information as if he had actually landed, but this seems to be a rather optimistic statement, especially in areas of basement rocks where relatively subtle changes of lithology and structure may be of considerable importance.

G.S.C. field parties do not work on a system of travelling or camping allowances, - instead the party leader operates a cheque account from which he pays all actual expenses, including the wages of his party. The funds allocated to each party are based on estimates prepared at the beginning of the field season, but supplementary requisitions may be made if necessary, and the system appears to work smoothly and to involve a minimum of paper work, both for the party leader and for the head office staff. Credit cards are generally used for purchasing petrol and oil.

Officers traverlling long distances on official duty normally travel by air, as in Australia, but except in special circumstances are expected to travel "Economy" class, equivalent to our "Tourist" class. As far as I could see, this does not cause any great hardship.

A very good handbook entitled "General Instructions for Field Parties" is revised annually and issued to all party leaders; this contains information on permissable expenditure, recruitment and payment of wages hands, vehicle operating procedures, etc. as well as samples of various report and financial accounting forms.

Mapping Methods

The actual mapping methods used by G.S.C. parties are very similar to those employed by the Bureau. Vertical air photos at scales ranging from 2 miles : 1 inch to 1 mile : 1 inch are available for practically the whole of the country and are used in all regional mapping projects. Generally, geological information is noted directly on the prints rather than on transparent overlays. Photo-interpretation, other than by the field geologists themselves, is carried out on some projects prior to field work, but is not the rule. Photogrammetry is used mainly in Engineering Geology studies, generally in conjunction with Pleistocene geology. Photo-mosaics are generally available, but their use varies considerably according to the personal preferences of the geologists concerned.

Current regional mapping projects range from reconnaissance surveys at 8 miles : 1 inch to semi-detailed mapping at 1 mile : 1 inch, and the resultant maps are published in two series: - a black and white preliminary series and a coloured final series. Both series commonly have descriptive marginal notes.

Two short cuts used by some parties may be of interest to Australian geologists. One is the use of Polaroid cameras in the field. Photos are developed on the spot, and can be annotated to illustrate stratigraphic sections, record joint patterns, make boulder counts in unconsolidated sediments, etc. This can save quite a lot of sketching and measuring. The other short cut is the use of edge-punched cards to record field observations. These may be punched right at the outcrop, or subsequently in camp, or even back in the office, and the spaces on the card can be allocated to emphasize petrological, mineralogical or structural features according to the main interest of the survey. This system seems to be especially useful when a uniform set of data is required from each of a large number of outcrops, e.g. in widely spaced helicopter touch-downs or in describing localities from which samples have been collected for age determination, chemical analysis or other laboratory work. It would also be very convenient when field data collected by one man have to be subsequently used or interpreted by other people, as frequently happens at the G.S.C. in the case of students and other temporary employees.

One noticeable feature was that G.S.C. geologists were generally very proficient at hand-specimen mineral identification and made a point of keeping in practice by means of informal refresher courses and competitions.

Salaries, etc.

The classification of the professional staff was under revision at the time of the writer's departure from Ottawa (February 1967). At that date, geologists below the level of Division Chief were classified as Geologists 2 to 5 (the Geologist 1 classification was not in use) and officers who did not fit into this classification (physicists, geologists without Ph.D., etc.) were classified as Scientific Officers with an overlapping but generally lower salary scale. The salary scale for Geologists at July 1, 1966, was as follows:

Geologist 2:	$C 7,647 - 9,579
Geologist 3:	10,383 - 12,154
Geologist 4:	12,417 - 14,008
Geologist 5:	14,139 - 15,862

In experience and responsibility, a Geologist 5 is somewhere between a Supervising Geologist (Class 4) and an Assistant Chief Geologist (Class 5) in the Bureau, and many of them are Heads of Sections, although this is not a prerequisite for reaching this classification. A Geologist 4

is about comparable in experience to a Senior Geologist (Class 3) in the Bureau, but in the G.S.C. he would have no administrative responsibility and would be expected to devote himself full-time to original work. Making allowance for the exchange rate and the higher cost of living in Canada, salaries in the G.S.C. are therefore about 30% to 40% above those paid by the Bureau in terms of actual purchasing power, and they are also closely comparable to salaries currently paid by Canadian mining companies. However, there is one other important consideration: In the G.S.C. there is no ceiling on the number of officers in any classification below Geologist 5, so that any geologist of average competence and productivity may expect to reach the Geologist 4 classification within a reasonable time, and this is reflected in the fact that most Sections actually have more officers in the Geologist 4 classification than in the Geologist 2 and 3 classifications combined.

Under the proposed re-classification, two changes are expected to be introduced. One of these is the introduction of direct bargaining for the professional groups of the Civil Service, and the other is the replacement of the existing salary structure by a new Research Scientist classification, which is to apply throughout the Civil Service. Initially, this should not affect the geologists on the present staff, since the change to the new classification is to be made at current salaries, and the prospects for promotion in the senior grades will be improved, as the new classification is to extent above the present Geologist 5 range. However, at the time of the writer's departure (February 1967) it was not yet clear whether all officers previously classified as Geologists could expect to be included in the new Research Scientist classification, and there appeared to be some doubt whether it would be desirable for geologists to be coupled with other groups of scientists for which there might be less employment opportunities in industry, and who would therefore be in a weaker bargaining position.

Another factor in the operation of the Canadian Civil Service which has no equivalent in Australia is the question of bilingualism. Proposals are currently under consideration by the Civil Service Commission that bilingualism, i.e. fluent command of both French and English, should be a factor and ultimately a condition of employment and promotion throughout the Civil Service. So far, application of this principle has been limited to a relatively small proportion of jobs withing the Civil Service, including only very few professional positions, but there appears to be a distinct possibility that this principle will be applied more widely in the future.

In general, Chiefs of Divisions are responsible for the administrative aspects of the work of officers in their Divisions, and Heads of Sections for the technical aspects, but there is considerable variation in the amount of supervision given to officers in different Divisions and even in different Sections of the same Division; projects in the Regional Geology Division, for instance, generally appear to be more closely supervised and to work to a more definite time-table than projects in the Economic Geology Division.

There is also considerable flexibility in the allocation of projects between Sections, and sometimes even between Divisions, so that, for instance, projects involving the study of particular groups of mineral deposits may be handled by the Mineral Deposits Section or the Geochemistry Section of the Economic Geology Division, or on occasion even by the Regional Geology Division.

Publications

Publications by the G.S.C. currently amount to about 15 to 20 major publications (Memoirs, Bulletins and Economic Geology Series Reports) and 40 to 50 "Papers" per year. The G.S.C. "Papers" are comparable to Bureau "Records" in scope and standard of writing, but are counted as publications, which has very great advantages in allowing wider distribution and gaining greater recognition for the authors. The need for a comparable series of publications by the Bureau was clearly demonstrated during the exchange by the fact that there are no publications whatsoever dealing with such major Bureau activities as geochemical surveys, and the Bureau therefore gets no credit for much of its work.

There is also a "Topical Report" Series of the G.S.C., which have restricted distribution and do not count as publications; these are generally used to record the results of special investigations, e.g. in Engineering Geology, and for reports on overseas visits, International Symposia, and the like. The number of these Topical Reports averages about ten or twelve per year.

Some G.S.C. Papers have been produced as rush jobs within a few weeks, but for major publications, especially if coloured maps are involved, a delay of two to three years from completion of manuscript to date of publication is regarded as normal.

Drafting, as in the Bureau, is partly within the G.S.C. and partly by contract. Standard of coloured maps is generally high, although few of them compare in complexity with some recent Bureau maps, e.g. in the Carpentaria region. Drafting of the preliminary black and white maps is generally of a lower standard.

The policy regarding the distribution of G.S.C. publications to staff members differs from that in the Bureau in that geologists are permitted one free copy of all G.S.C. publications related to their own topics of investigation, and are in fact encouraged to build up their own collections of G.S.C. maps and publications. This is a relatively small matter, but it is very much appreciated by G.S.C. geologists.

Laboratory Facilities

Laboratory facilities generally appear to be more than adequate, with some facilities, e.g. for ore microscopy, considerably in excess of current requirements. There is also some duplication, e.g. analytical facilities are provided by the Geochemistry Section in the Economic Geology Division, by the Analytical Chemistry Section in the Petrological Sciences Division, and also by the Mineral Sciences Division of the Mines Branch. Nevertheless, there often appear to be delays of up to nine months in obtaining results of samples submitted for various analytical determinations by field officers; this is attributed mainly to lack of technical personnel for sample preparation and other routine tasks.

Administrative and Clerical Services

Administrative and clerical servises seem to operate smoothly, and I found very few hold-ups in dealing with Staff matters, claims for allowances and expenses, requisitions, etc.

As far as I was able to ascertain, this smooth operation does not reflect any particular organisational structure, except that there may be slightly more delegation of authority from the Department to the Survey at the Director's and Division Chief's level, than applies in the Bureau. However, I was most impressed by the competence of administrative and clerical officers, and by their efforts to facilitate the work of the geological staff and to overcome any restrictions or delays which might interfere with this work.

In addition to the Director and Chief Geologist, all Chiefs of Divisions have personal Secretaries, and in most Divisions there are one or more "staff geologists", generally female, who are available to assist the Division Chief with literature research, compilation of data, editing of reports, etc.

Library

The G.S.C. library, which includes a reference collection of geological maps, is about three times the size of the Bureau's. The Cutter system of classification is used, and - as in the Bureau - a few anomalies result, e.g. in the division of publications into "Mining" and "Geology", so that a report entitled "Department of Mines, West Australia" goes to one side of the room, while a report entitled "Geological Survey of West Australia" goes to the other side.

However, one very valuable feature of the G.S.C. library is a very comprehensive card index system, which includes references to all major articles in journals and serial publications by Canadian authors, and quite a few key articles by others.

Building Accomodation

Since 1960, the Geological Survey is housed in a large, specially designed seven-storey building in Booth Street, about two miles from the centre of Ottawa. Adjoining buildings are occupied by the Mines Branch, Surveys and Mapping Branch and other sections of the Department of Mines and Technical Surveys. However, this accomodation is already inadequate, and parts of the Department, including some officers of the G.S.C., have overflowed into at least two lots of rented accomodation and a temporary building, very like our old home at Childers Street. The Central Equipment Store for the Department is in a former railway depot in Hull, Quebec, on the other side of the Ottawa River, and is impressively roomy, well laid out and well stocked. With the re-organisation of the Department, still more accomodation will be required, and another complex of buildings is proposed on the outskirts of the city, about five miles from the Booth Street offices.

Within the present G.S.C. building, individual rooms, averaging 9'6" by 19'6" are provided for working geologists. Chiefs of Divisions have rooms about twice this size, with separate rooms for their private secretaries. Telephones are provided in all rooms, but the majority are arranged so that three phones in adjoining rooms share one line from the central switchboard.

Regional Offices and Resident Geologists

Apart from its head office in Ottawa, the G.S.C. maintains Regional Offices in Calgary and Vancouver and Resident Geologists are stationed in the Yukon (at Whitehorse) and in the N.W. Territories (at Yellowknife).

The Calgary Regional Office in 1966 had a staff of 40, including 24 professional officers, and deals with all G.S.C. projects in the Eastern Cordillera, the Prairie Provinces and the Arctic Islands relating to oil and gas, stratigraphy, Pleistocene studies and underground water. A new building with greatly expanded laboratory facilities was then under construction, and a further increase in staff was expected after its completion, which was scheduled towards the end of 1967.

The Vancouver office in March 1967 had a staff of about 15, all but three of whom were professional officers, and occupied part of a rather old building almost in the centre of Vancouver city. Ultimately, a new building is also proposed for this group, but this is not likely to be commenced before 1970. Most of the mining companies operating in British Columbia likewise have their head offices in Vancouver city, but the offices of the Provincial Geological Survey are at Victoria, on Vancouver Island, about two hours away by car and ferry.

Only one geologist is stationed at each of the Resident Geologists Offices, giving them "backyards" of about 210,000 square miles (Yukon) and 1,300,000 square miles (N.W. Territories) respectively. The main function of these geologists is to keep the Geological Survey informed of prospecting and mining developments in their respective areas. To this end, they normally visit all mines and active prospects at least once a year, and co-operate closely with the Mining Registrars and Mining Inspectors, who are officers of the Department of Northern Affairs. The Resident Geologists are available to give advice to prospectors and companies, both on individual prospects and on general matters, such as the selection of favourable areas for investigation, but because of the wide range of their commitments, they are not usually able to undertake any major investigations of their own.

NOTES ON SOME CURRENT G.S.C. PROJECTS

Regional Mapping

About 75 percent of Canada is now covered by geological maps at scales of 8 miles : 1 inch or larger. Some of the largest remaining gaps are in central Ontario and southern Quebec, where G.S.C. operations are restricted because of the division of responsibilities between Federal and Provincial organisations. Both these Provinces have strong Geological Surveys of their own, and are currently carrying out some regional surveys, e.g. in the Kapuskasing and Chibougamau areas, but the bulk of their work consists of semi-detailed mapping by "Townships", equivalent to Parishes in Victoria or Hundreds in the N.T. This work is intended for publication at scales of $\frac{1}{2}$ mile : 1 inch or $\frac{1}{4}$ mile : 1 inch, and a party will generally only cover 50 or 100 square miles in a season, so that their contribution to regional coverage is limited. To offset this, both Provinces are currently engaged in compiling information from existing surveys, some of them going back almost 100 years, combined with data from mining companies and a few check traverses to fill in major gaps. Ontario has published two sheets in this series on a scale of 4 miles : 1 inch, and preliminary black and white compilations are available on a scale of 2 miles : 1 inch for several other areas in both Ontario and Quebec. Most of this compilation is done by Resident Geologists, of which each Province has five or six, stationed at various mining centres, such as Sudbury, Timmins, Noranda and Val D'Or.

Altogether, it is likely that at least a preliminary coverage for the whole of Canada at scales of 8 miles : 1 inch or larger will be available by 1975.

Studies of Mineral Deposits

Most of the studies under this heading are carried out by officers of the Mineral Deposits Section in the Economic Geology Division, although one of the foremost workers in this field, Dr A.M. Goodwin, is attached to the Regional Geology Division. However, the G.S.C. does not undertake detailed investigations aimed at locating individual ore bodies, such as the Bureau has been carrying out for instance at Rum Jungle and Tennant Creek, so that "Economic Geology" must not be interpreted too literally.

Studies of Deposits of particular Minerals: The studies carried out under the general heading of "Mineral Deposits" fall into several groups. One approach is for a worker to study deposits of a particular mineral or group of minerals throughout Canada, and the writer had some contact with three projects of this type during 1966. These involved the study of iron ore deposits (Dr G.A. Gross), of nickel deposits (Dr J.A. Chamberlain) and of lead-zinc deposits (Dr D.F. Sangster). With the exception of Dr Gross' work, which at this stage is largely descriptive, these investigations are heavily weighted towards laboratory studies, such as mineragraphy, trace element studies, age determinations, lead and sulphur isotope determinations, etc. Since none of the detailed results of these investigations have been published to date, it is difficult to judge the effectiveness of this approach, but some of the foremost ore bodies in each group still present problems which do not seem amenable to attack by laboratory studies alone, such as the origin and shape of the Sudbury igneous complex and the relation of the Pine Point deposits to the McDonald Fault system, and it is difficult to see how any definitive account of these deposits can be prepared until these problems have been resolved. In some of these investigations, there also appears to be some uncertainty as to whether the main purpose is a predominantly descriptive account of Canadian mineral occurrences, an elucidation of the fundamental geological factors responsible for the formation of ore bodies, or a delineation of criteria which might assist in the search for additional ore bodies.

Case History Studies: Another group or projects, under the supervision of Dr D.R.E. Whitmore, involves a series of detailed investigations of various aspects, such as mineralogy, geophysics, geochemistry and structural geology of individual ore bodies. Two ore bodies have been investigated on these lines to date, - Coronation Mine in Sasketchewan, and Whalesback Deposit in Newfoundland; some of the contributing studies have been undertaken as Ph. D. theses at various universities, but again very little of the material has been published to date.

Matallogenic Study of the Central Portion of the Canadian Shield: A rather ambitious programme, concerned with the metallogenic study of an area of about 600 by 200 miles in the central portion of the Canadian Shield, between Lake Superior and Chibougamau, is being undertaken by Dr S.M. Roscoe. This area contains, among others, the major mining centres of

Sudbury, Cobalt, Elliot Lake, Timmins, Noranda and Val D'Or, and Dr Roscoe has recognised some 20 separate classes of mineral deposits, based largely on age, mineral composition and association with particular rock types. Details of this classification are described in the report on the Geology and Mineral Deposits of Canada and Australia (B.M.R. Record 1967/130).

Miscellaneous Investigations

The G.S.C. is currently engaged in a number of speical long-term investigations, among which three appear to be of particular interest. These are a study of mineral deposits associated with Archaean volcanic-sedimentary successions, being undertaken by Dr A.M. Goodwin, a study of diabase dykes and sills in the Canadian Shield by Dr W.F. Fahrig, and a study of rock and mineral fragments in Pleistocene glacial deposits by Dr H.A. Lee. Details of these projects are described in the report on Geology and Mineral Deposits of Canada and Australia.

Sub-division of the Precambrian and Tectonic Maps

The G.S.C. has recently proposed a sub-division of the Precambrian which, like the current Australian proposals, is largely based on absolute age determinations (mostly by the K-Ar method), and involves a major division into Archaean and Proterozoic, and a further threefold sub-division of the Proterozoic. However, the boundaries of the Canadian sub-divisions have been defined to coincide with the ends of major periods of igneous activity and metamorphism, so that, unlike the Australian scheme, the Canadian proposals do not involve the selection of type sequences for the major Proterozoic sub-divisions.

The new sub-divisions are used on the Tectonic Map of the Canadian Shield, published by the G.S.C. in 1965, but so far no general geological map using these sub-divisions is available, although a compilation is in progress. For this reason, the proposals have gained only limited acceptance within the country to date, and no major organisation other than the G.S.C. has so far adopted the new nomenclature.

The above-mentioned Tectonic Map of the Canadian Shield differs from the Tectonic Map of Australia in that rocks are classified primarily according to the period of deformation, igneous activity and metamorphism in which they assumed their dominant present characteristics, and not according to their original date of deposition, extrusion or intrusion, as the case may be. This map was first published in 1965, but compilation of a revised edition is already in progress.

Geochemistry

Broadly speaking, the number and scope of geochemical surveys undertaken in Canada appears to be comparable to those in Australia. In the past few years, the G.S.C. has carried out pilot studies in the Keno Hills area (Yukon), Bathurst area (New Brunswick), Yellowknife area (N.W.T.), and Cobalt area (Ontario). In each area, stream sediment, water, residual soil, glacial material and bed-rock sampling was tried, and in addition a number of bio-geochemical investigations have been undertaken, involving the determination of trace elements in soils and in the leaves, twigs, bark, etc. of various plant species growing both above and remote from known mineral deposits.

Geophysical Surveys

Geophysical surveys and investigations are divided between the G.S.C. and the Dominion Observatories Branch. By far the largest projects at present being handled by the Survey are a series of joint Federal - Provincial regional aeromagnetic contract surveys. These have now been in progress for about five years, and some 400 to 500 maps, mostly on a scale of 1 mile : 1 inch, are currently being published each year.

Regional gravity surveys have also been carried out in several areas by Federal agencies, and a number of major structural features have been delineated.

The Survey is also carrying out experimental work on air-borne E M methods, especially the INPUT system, which is a refinement of the I P system, and which has been shown to be capable of delineating shallow aquifers, as well as locating anomalies associated with both massive and disseminated sulphide ore bodies.

Conventional seismic surveys have been undertaken in connection with some special geological investigations, such as the structural geology of the Huronian sediments in the Elliot Lake area, and hammer seismic surveys have been used in connection with Pleistocene and Engineering Geology investigations.

Radiometric surveys have been used in areas where uranium mineralisation is known or suspected; no major surveys are at present being undertaken by Federal agencies, but there has recently been a considerable revival of prospecting activity for radioactive minerals by some mining companies.

The G.S.C. has also carried out some colour air photo evaluation, and the preliminary conclusion is that about 50% more outcrop could be recognised in colour photos compared to black and white. However, there was little improvement in the recognition of rock types, and there is no proposal for the general adoption of colour photography at present. Some infra-red photography has also been carried out, and the results appear to be of considerable interest to hydrologists, as it enables water from different sources to be distinguished, e.g. springs discharging into lakes. However, some of the results of this survey are still "classified", as the work was done in conjunction with U.S. Defence Authorities.

Water Supply Investigations

Owing to the fact that the former Groundwater Section of the Economic Geology Division of the G.S.C. was in the process of being transferred to the newly formed Water Resources Branch of the Department in the latter part of 1966, I had only limited opportunities of obtaining information on the activities of this group.

However, it appears that most of the work undertaken to date has been made up of joint projects with Provincial Authorities. These have included the hydrological investigation of typical basins of various sizes; chemical changes in ground water with time and distance of travel; relation of water movement in bedrock aquifers and overlying Pleistocene deposits; problems of salt water intrusion; the use of air-borne E M equipment to detect the occurrence of water in superficial deposits; and the use of infra-red photography to study the outflow of spring water into lakes.

For descriptive purposes, the country has been divided into hydro-geological regions, based on various combinations of physiography, geology, rainfall and climatic conditions, e.g. permafrost. The resulting sub-divisions are not unlike those arrived at in recent Australian studies for the Water Resources Council.

In regional studies of ground-water behaviour, and also in the study of individual basins, much emphasis is placed on the regular or continuous recording of water levels in carefully sited piezometers and observation wells. The possibility of recording such data directly on to punched tape for subsequent automatic processing and publication is at present under investigation. Comparatively less use appears to be made of pump test data. Drillers' reports are required by most of the Provinces.

Miscellaneous

The G.S.C. maintains a Technical File system, similar to the Bureau's, which is used to store unpublished reports by G.S.C. staff and unpublished reports submitted by Provincial Mines Departments and mining companies. This information is indexed according to map sheet areas, comparable to our own Four-mile map areas. One difference worth noting is that accession lists to these Technical Files are circulated to all permanent G.S.C. staff.

The G.S.C. also have one man occupied full-time in keeping track of new exploration and mining developments as reported in mining journals, newspapers and company reports. This information is also indexed according to map sheet areas, and a summary of 20 or 30 items which are regarded as particularly significant is circulated each month to all G.S.C. staff members.

The G.S.C. publish a considerable volume of material intended mainly for amateur collectors and other people with a non-professional interest in geology. These publications include guide books to the various National Parks, lists of localities for mineral collectors, etc. They also sell large numbers of sets comprising Canadian rock and mineral specimens for use in schools and for display purposes at exhibitions, etc.

Maps and Air Photos

As previously mentioned, about 75% of Canada is now covered by geological maps at scales of 8 miles : 1 inch or larger.

Most of the country is also covered by vertical air photos at scales of 1 mile : 1 inch or larger, and photo mosaics at various scales down to 4 miles : 1 inch are generally available.

Topographic maps generally appear to be of very high standard. Most of the country is covered by contoured maps on 250,000 : 1 or 4 miles : 1 inch scales, and there are also large numbers of 50,000 : 1 or 1 mile : 1 inch maps, and a few 25,000 : 1 or larger.

There is at present no general geological map of Canada more recent than 1955 (slightly revised 1962). A new edition, which is to use subdivisions of the Precambrian based on readioactive age determinations, was in preparation early in 1967, and may be available some time in 1968. Among special maps, the Tectonic Map of the Canadian Shield (G.S.C. Map 4-1965) is of particular interest. Various mineral distribution maps are also available, of which the most widely used is that showing the Principal Mineral Areas of Canada (G.S.C. Map 900 A); this is revised annually. The Quebec Department of Natural Resources is currently compiling a metallogenic map of the Province, as well as a number of larger-scale maps of various mining camps, but none of these were available in 1967. The G.S.C. expects to produce a metallogenic map of Canada as a long-term project, but no date has been set for its completion. A metamorphic map of Canada is also under consideration, but is at an even less advanced stage.

SOME GENERAL COMMENTS ON THE ROLE OF THE G.S.C. AND OTHER ORGANISATIONS ENGAGED IN GEOLOGICAL INVESTIGATIONS IN CANADA

Geological Surveys are maintained by all the Provinces, although they vary considerably in size and scope of activities. Ontario, Quebec and British Columbia are currently the largest, and each have some 20 to 30 professional employees, in addition to post-graduate students and University staff engaged on seasonal work. Generally, regional mapping in the more remote portions of the Provinces, and of course in the Federal Territories, is regarded as the responsibility of the G.S.C., and most of the projects undertaken by the Provincial Surveys involve mapping on scales

from 1 mile : 1 inch to 1,000 feet : 1 inch, although Ontario and Quebec are currently also engaged in some regional mapping on a scale of 4 miles : 1 inch. The Provincial Surveys do not generally undertake major geophysical investigations, such as seismic or aeromagnetic surveys, but most of them have one or more geophysicists on their staff in order to assist with the interpretation and assessment of geophysical surveys undertaken by mining and oil exploration companies. Most of the Surveys also employ palaeontologists, engineering geologists and underground water specialists, although in some Provinces the latter are attached to separate Water Conservation Authorities or to the Departments of Agriculture. Most of the larger surveys maintain Resident Geologists' offices in the more active mining centres.

The geological departments of the major mining and exploration companies seem to be comparable in size and status to what we are accustomed to in Australia. The main difference lies in the fact that with a much larger number of companies competing for the available exploration targets, and with no provision in most areas for concessions equivalent to our "Authorities to Prospect", the selection and staking of claims occupies a much larger proportion of their time and effort. One other difference from Australian practice lies in their much greater readiness to undertake diamond drilling; it seems to be rare for any Canadian prospect to be turned down without at least a few hundred feet of drilling, and it is not unusual for a prospect of quite moderate size, say an auriferous lode with a potential of a few hundred tons per vertical foot, to have 10,000 to 20,000 feet of drilling done on it.

One organisation which is at present attracting considerable interest is the Societe Quebecoise D'Exploration Miniere (SOQUEM), which is a corporation set up by the Quebec Provincial Government to engage in mineral exploration, with guaranteed funds of $C1,500,000 per year for the next ten years. The corporation is quite separate from the Provincial Department of Natural Resources, and will be expected to compete on even terms with existing mining companies in developing exploration targets and applying for claims or leases. If any major mineral deposits are discovered, their exploitation is expected to be by means of a partnership with an existing mining company. The reason given by the Quebec Government for setting up SOQUEM is that the existing mining companies in Quebec are not investing a sufficient proportion of their returns in further prospecting in the Province, and that such prospecting as they are carrying out is not sufficiently systematic. SOQUEM will have none of the mapping and publication commitments of a Geological Survey organisation, and will be able to devote its entire effort to mineral development. Moreover, since it will maintain a financial interest in its discovereis, it may be expected to be economically self-sustaining by the end of the ten year guarantee period, and this should have a very beneficial effect on the prestige of the organisation and the morale of its staff.

In general, the relations of the G.S.C. to Provincial Surveys and to mining companies are similar to those prevailing in Australia. As in Australia, the granting of leases, except in the Yukon and N.W. Territories, is a Provincial responsibility, and royalties on mineral production are paid to the Provincial Governments. The G.S.C. is also expected to obtain the concurrence of the Provincial authorities before undertaking any major investigations within a Province, and I have been told that this is not always given automatically.

Most of the mining companies are quite willing to disclose detailed information on a confidential basis, but are very reluctant to authorise material for publication. Personally, I was repeatedly shown very detailed unpublished data, including assay results, at various mines which I visited, and I feel that some of these companies could, without prejudice to their own interests, publish a great deal of information which would be of considerable general interest. In some Provinces, a certain amount of information has to be given to the Department of Mines as "assessment work" on all mineral claims, and this becomes public information if the claims are subsequently relinquished.

There are no groups within the G.S.C. comparable to our Resident Geological Sections, and, apart from stationing one Resident Geologist at Yellowknife in the N.W. Territories and one at Whitehorse in the Yukon, G.S.C. activities in the Federal Territories are no different from those in the Provinces, i.e. regional mapping, some geochemical surveys and some regional geophysical investigations, consisting mostly of gravity and aeromagnetic surveys. This appears to leave a serious gap, and it is my personal feeling that a strong Resident Geological Section, of say eight or ten geologists, undertaking investigations of the type to which we are accustomed in the N.T. and T.P.N.G., would result in a considerable upsurge of mineral exploration and development in these Territories.

RECENT TRENDS WITHIN THE G.S.C.

With the completion of reconnaissance mapping on 4 mile : 1 inch and 8 mile : 1 inch scales in sight, the G.S.C. is now devoting increasing attention to Research Projects, such as the mineral deposit studies, age determination programmes and geochemical surveys referred to in some of the preceding sections of this report.

This has given rise to a number of problems, some of which have also recently become apparent in the Bureau. One of these is the divergence of interests and approach to their projects between geologists engaged in regional mapping and those engaged in more specialised investigations which tends to create problems of morale and of co-ordination. Also, difficulties appear to be encountered in the G.S.C. in finalising some of these projects and putting out reports; some projects have been running for as much as five years without any major reports being produced. As a result of some of these factors, it appears to be almost impossible to avoid some duplication of effort, e.g. in the central portion of the Shield, where regional mapping, studies of mineral deposits, stratigraphic and geochemical investigations are all going on concurrently, but it appears to be left largely to the initiative of individual workers to exchange information and co-ordinate results.

Another consequence of this trend towards research projects is that, generally speaking, a more leisurely atmosphere prevails at the G.S.C., compared to the Bureau. This is accentuated by the fact that few of these projects are carried out in conjunction with or at the direct request of other organisations, and they are therefore not subject to externally fixed deadlines. Also, G.S.C. personnel tend to think of themselves more consciously as research workers, and to be accepted as such, both by other geologists and by the general public.

However, there is one other aspect of this trend which I feel should be stressed, and that is the danger of increasing isolation of the G.S.C., - and of the Bureau, if we follow this trend, - from mining companies, Provincial Surveys and other organisations primarily concerned with the immediate economic applications of geology. The respect in which such organisations hold a central geological survey, such as the G.S.C. or the Bureau, and the amount of co-operation they are prepared to extend, depend almost entirely on the ability of the Survey to contribute directly to mineral exploration or development programmes, either by developing new prospecting techniques, or by directing attention to previously unrecognised favourable ore environments, and preferably by actually finding some ore bodies. I therefore consider that a very high priority for projects with immediate economic applications is essential for the continued existence of a balanced relationship between the G.S.C. or Bureau and the rest of the mining industry in their respective countries.

OVER-ALL RESULTS OF EXCHANGE AND PROPOSALS FOR FUTURE EXCHANGES

As will be seen from the list of recommendations at the end of this report, the exchange has produced a number of ideas regarding survey procedures, administrative matters and new projects to be undertaken by the Bureau, and the opportunity for a personal comparison of Australian and Canadian geology and mineral deposits has provided scope for a number of generalisations (set out in the report on Geology and Mineral Deposits of Canada and Australia), which could not have been arrived at in any other way. In addition, a large number of personal contacts were made with officers of the G.S.C. and other Canadian organisations, and, by facilitating the continued exchange of current ideas and information, these may be expected to be of continuing value to the Bureau as a whole.

From the Bureau's point of view, the main aims of the exchange were therefore realised, and I was told by senior officers of the G.S.C. that they also regarded the exchange as a success.

Having established a precedent, it should be comparatively easy to arrange similar exchange in future, and I would suggest that an exchange every four or five years would be the optimum arrangement. During such an interval sufficient new developments may be expected to occur in the basic geological knowledge, mineral discoveries and survey organisation in the two countries to justify a re-appraisal, and such a programme would ultimately enable each Survey to have four or five geologists with personal experience of such an exchange. If other countries, such as South Africa, India or New Zealand were also to be involved, the interval could be shortened to perhaps two or three years.

As in the exchange which has just been completed, the Bureau officers selected for such exchanges should be of about Class 3 standing, to enable them to speak with some authority on organisational matters, as well as technical and scientific topics, and should not be specialists. There is of course considerable scope for visits of specialists from the Bureau to the G.S.C. and vice versa, but such visits do not generally have to be for as long as twelve months and do not necessarily have to be

on an exchange basis; also, they would not be expected to result in such a wide range of contacts, which was one of the main features of this exchange.

The preliminary planning for this exchange was based on the assumption that both exchange geologists would participate in a specific project by the host organisation, such as a Four-mile mapping project, but this was changed, largely at the suggestion of senior officers in the G.S.C., so that in fact both Dr. Eade and myself spent the greater part of our time familiarising ourselves with the geology and mineral deposists of our host country and exchanging information with officers of the host organisation and other geological surveys and mining companies in the course of a series of short visits. This has certainly proved to be a very satisfactory arrangement for this particular occasion, but, having now established personal contacts and being in each case more familiar with the work of the other organisation, it should be easier in the case of future exchanges to arrange beforehand a programme which combined reasonable scope for general travel and exchange of information with a specific commitment for work on a particular project.

RECOMMENDATIONS

Recommendations hereunder are listed in three groups; one of these concerns policy matters, the second refers largely to administrative and technical matters, while the third comprises recommendations for new investigations to be undertaken by the Bureau, and is based largely on information in the report on Geology and Mineral Deposits of Canada and Australia (Record 1967/130), which is not repeated in detail in this report.

1. Policy Matters:

Consideration should be given to the following proposals:

A. A revision of the Bureau salary structure, so that progress to at least Class 4 is dependent only on an officer's achievement, and does not necessarily involve a transfer from professional to administrative duties.

B. Increased publicity for Bureau achievements, especially in mineral discoveries, but also in other fields, such as publications, addresses to learned societies, overseas trips, etc.

C. Consideration should also be given to establishing a self-contained unit of at least ten professional officers with suitable supporting staff to engage in direct exploration for minerals. This unit could take the form of a Crown Corporation similar to SOQUEM, or could be established as part of the Bureau of Mineral Resources, either in the Geological Branch under a Class 5 officer or as a separate Branch under a Second Division officer. If desired, existing groups concerned with phosphate and uranium search could be merged with this unit.

2. Administrative and Technical Matters:

A. The use of polaroid cameras in the field should be tried in cases where photos may be required on the spot to illustrate stratigraphic sections, make boulder counts, etc.

B. The use of edge-punched cards in the field should be tried in cases where a uniform set of data is required from each of a large number of outcrops, such as the sites of samples collected for age determination, chemical analysis or other laboratory work. However, their use should be at the option of the party leader, and the lay-out would have to be carefully integrated with existing sample registration procedures.

C. An instruction handbook comparable to the G.S.C. "General Instructions to Field Parties" should be prepared and issued to party leaders.

D. Increased attention should be given to ensuring that Bureau geologists are proficient at hand-specimen mineral identification and that they continue to keep in practice. If necessary, refresher courses should be arranged.

E. A Bureau series of publications comparable to the G.S.C. "Papers" should be instituted, either as a new series or by up-grading some of the present Records.

F. All professional officers should be issued free of charge with one copy of all Bureau maps and publications relevant to their own fields of investigation.

G. The library index should be extended to cover major papers in journals and periodicals, including locality references at leastfor all Australian localities.

H. Company reports and other unpublished material on geology and mineral deposits, now held in the library, should be transferred to the Technical Files, and major accessions to the Technical File system and to the collection of reports held by the Mineral Resources Branch, should be notified at least to senior Bureau officers at regular intervals.

I. The preparation of a card index system of Australian mineral deposits should be implemented as soon as possible. This index should emphasise features of possible genetic importance, such as age, temperature of formation, relations to host rock, minor element association, etc. with a view to developing a comprehensive metallogenic classification and outlining major metallogenic provinces.

J. In areas of interest to the Bureau, e.g. Tennant Creek, Rum Jungle, Antarctica, special investigations such as structural geology, mineralogy and geochemistry should be encouraged by means of grants towards Ph. D. theses or be employing University staff or post-graduate students as temporary members of Bureau staff.

K. Preparation of additional popular accounts of geology, guide books and lists of localities for mineral collectors, along the lines of "Rocks and Fossils of Canberra", should be undertaken. Initially, these will presumably have to be restricted to Commonwealth Territories, but it may be possible to arrange a series to be produced jointly with the States.

L. Further exchanges of staff between the Bureau and the G.S.C. should be arranged at intervals of four to five years. If other countries, such as South Africa, India or New Zealand are also to be included in such a scheme, the interval should be shortened to two or three years.

3. Recommendations for further work by the Bureau of Mineral Resources:

A number of investigations patterned on some of those currently undertaken by the Geological Survey of Canada may be expected to produce results of considerable general as well as possibly immediate economic interest in Australia. Among these are the following:

A. A detailed study, in conjunction with appropriate State Government organisations, of one or more Archaean volcanic - sedimentary belts, using structural, petrological, geochemical and geophysical investigations, but with an over-all emphasis on a stratigraphic approach, as exemplified

by recent work in Canada. This will also provide some of the basic data for the investigation recommended under G (1) below.

B. A study of dolerite dykes in the Australian Shield, with emphasis on structural features, petrology, age determinations, and associated mineral deposits, in order to delineate major dyke swarms and relate their emplacement to other tectonic events in the history of the Shield.

C. A comparative study of trace element assemblages (a) in Archaean iron formations (e.g. Mount Goldsworthy, Koolyanobbing) and in Proterozoic iron formations (e.g. Middleback Ranges, Hamersley Range); (b) in iron formations of both Archaean and Proterozoic age and in associated pyritic cherts and pyritic black slates; (c) in pyritic cherts and pyritic black slates associated with iron formations and in comparable rocks associated with massive sulphide deposits (e.g. Mount Isa, Rum Jungle).

D. Consideration should be given to speeding up aeromagnetic coverage by the more extensive use of contract surveys. To provide a complete coverage of areas of interest within a reasonable time, the aim should be to fly ten Four-mile sheet areas per year, of which at least three should be flown at not more than 1/5-mile spacing and the results published at 1 mile : 1 inch scale.

E. Consideration should be given to the possibility of undertaking trials of various air-borne E.M. systems now in use in Canada, especially the INPUT system, which is reported to have applications in the delineation of shallow aquifers as well as in the search for sulphide mineral deposits.

F. The number of age determinations should be increased, especially in areas of Precambrian rocks, using contract work if necessary. Samples should be selected on a regional basis rather than in accordance with specific research projects, and statistical methods should be used in the evaluation of the results, as well as attempting to interpret the results individually.

G. Consideration should be given to ways in which the Bureau could carry out exploration, in conjunction with appropriate State Government organisations where applicable, or promote company activity in the areas listed below. These are areas which, by analogy with Canadian occurrences, may be expected to contain ore bodies of types not higherto worked in Australia, or at least not worked on a large scale.

Area	Type of deposit	Preliminary investigation	Major programme if indications favourable
Greenstone belts of Yilgarn and Pilbara areas, W.A.	Massive Cu-Zn deposits assoc. with volcanic rocks, e.g. Noranda, and Texas Gulf Sulphur Corp. ore body (Timmins)	Reconnaissance examination of rhyolite - andesite sequences. Geochemistry.	Regional mapping with emphasis on stratigraphy of volcanic sequences. Geochemistry, incl. auger drilling. Aeromagnetic surveys. ?Air-borne E.M. Diamond drilling.
Nullagine Conglomerate (Pilbara). Crater and Beestons Formations (Rum Jungle)	Uranium in conglomerate, e.g. Elliot Lake.	Reconnaissance stratigraphic study of conglomerate successions. Radiometric surveys.	Detailed mapping of conglom. sequences with emphais on stratigraphic features. Low-level air-borne radiometric surveys. Stratigraphic and exploratory drilling.
N.margin of Fitzroy Basin, especially in vicinity of "Devonian" lead mine.	Massive Pb-Zn deposits in limestone, e.g. Pine Point.	Studies of regional facies distribution. Extrapolation of structures from adjoining basement areas. Geochemistry.	Regional mapping with emphasis on facies changes and structural features. Regional geochemistry ?Air-borne E.M. Stratigraphic and exploratory drilling.
Chillagoe, Ravenswood and other areas of N. and Central Queensland.	Porphyry Cu deposits and assoc. Mo deposits e.g. Bethlehem, Endako and other deposits of Canadian Cordillera.	Reconnaissance examination of areas of known Cu mineralisation. Geochemistry.	Detailed mapping and geochemistry. Auger drilling and shallow diamond drilling.
Serpentine belts of N.S.W. and Queensland.	Asbestos, e.g. Thetford Mines.	Reconnaissance examination of surface exposures.	Regional mapping. Aeromagnetic surveys. Shallow drilling.
Areas of suspected carbonatite occurrences and of known alkaline igneous rocks.	Columbium-bearing carbonatite-alkaline igneous complexes, e.g. Oka.	Trace element analysis of samples from likely areas, incl. Strangways Ranges, N.T., Fitzroy Basin, (W.A.), Benambra (N.E. Vic.), Port Cygnet (Tas.), and Mt. Dromedary (N.S.W.).	Detailed mapping. Geochemistry. Auger drilling and shallow diamond drilling.

APPENDIX A

Some anticipated future developments in the Canadian Mining Industry.

There are several areas where considerable expansion of present production is likely in the near future, either by the further development of known resources in response to increased world demand, or by the discovery of additional deposits in areas of known mineralisation.

Copper. Increased production may be expected from complex base metal sulphide deposits in the Appalachian region, but the most spectacular developments will almost certainly result from new deposits of the porphyry copper type in the Cordilleran region. Some ten or twelve deposits of this type are at present in various stages of exploration or development; several of these are expected to range from some tens of millions to several hundred million tons in size and from about 0.3 to about 0.8% copper in grade; some of them also carry significant amounts (up to 0.2%) of molybdenum. In many cases, it appears that copper mineralisation has been known in these areas for many years, and that their development at this time is largely due to increasing world demand and the feasibility of large low-grade operations in remote localities.

Nickel. Considerable expansion of production is expected to result from deposits which are now under development by the two major producing companies, - International Nickel Co. of Canada Ltd. and Falconbridge Nickel Mines Ltd. Some of these developments are taking place in the Sudbury area, where total production by both companies is expected to shortly reach 60,000 tons of ore per day, but there are also proposals to develop a number of new deposits associated with Archaean ultra-basic complexes in Manitoba, Northern Ontario and Western Quebec, and with Proterozoic diabase sills in Western Ontario.

Complex base metal sulphide lodes - Appalachian region.

In the Appalachian region, which has long been neglected as a base metal province, recent geochemical and geophysical surveys have resulted in the discovery of a number of major deposits, such as those of the Bathurst area, New Brunswick. Further work in this regionis now in progress by several companies, and it seems likely that further discoveries will result.

Iron. With the increasing importance of pellets, deposits with an iron contents as low as 20% may now be economically attractive, especially if they are conveniently situated to transport and readily amenable to concentration, i.e. preferably coarse-grained and magnetite- rather than hematite-bearing. In addition to the deposits of the central portion of the Shield, described in Record 1967/130, there are very large reserves of this type of material in the Wabush Lake area, at the southern extremity of the Labrador Trough, and it appears that development will

only be limited by demand. There are also very large undeveloped deposits on Baffin Island; provisional estimates of reserves run to several hundred million tons of direct shipping ore (better than 65% iron), and even larger quantities of material suitable for beneficiation .

Tin. Present production is almost entirely as a by-product from lead-zinc production at the Sullivan Mine, British Columbia, but several occurrences have been reported in recent years in both the Appalachian and Cordilleran regions. Of the known prospects, the Mount Pleasand occurrence in New Brunswick, which is a complex tin-copper-zinc-lead occurrence, is the most likely to go into production in the not too distant future.

Columbium. The only Canadian producer at the present time is the Oka property of St. Lawrence Columbium and Metals Corporation, but very large tonnages of material averaging 0.25 to 0.5% Cb_2O_5 are known, both in the Oka alkaline complex and in other comparable complexes in northern Ontario. Production, in the foreseeable future, will therefore be governed by world demand rather than by available resources.

Asbestos. The greater portion of Canadian production comes from the Thetford area, Quebec, especially from the properties of Asbestos Corporation Ltd. and Canadian Johns-Manville Co. Ltd., which between them treat some 40,000 tons of ore per day. Both these companies have plans for further expansion of production from the Thetford area, and deposits are also under investigation, and in some cases being prepared for production, in western Quebec, northern Ontario, the Labrador Trough and northern British Columbia.

Potash. At present, the largest Canadian producer is International Minerals and Chemical Corporation (Canada) Ltd. from its properties at Esterhazy, Sasketchewan, and there are plans for considerable additional production by this company and several others. Total reserves of mineable material at depths of less than 3,500 feet are estimated at 6,400,000,000 tons, so that production in the foreseeable future will only be limited by demand.

Tar Sands. A project to recover 45,000 barrels of oil per day from the Athabasca tar sand deposits in northern Alberta, is at present under construction by Great Canadian Oil Sands Ltd. Average oil contents of the material to be treated in the initial stages of the project is reported to be about 13%, and the total recoverable reserves within these deposits have been estimated at 300 billion (300×10^9) barrels.

Uranium. Canadian uranium production is at present on a very limited scale, with the Denison Mine in the Elliot Lake area as the largest single producer, but a considerable revival of activity is expected over the next few years. Arrangements for the re-opening of several former producers are now in progress, and considerable prospecting is going on in several widely scattered areas. However, the greater part of the known reserves is contained in the uraniferous conglomerates of the Elliot Lake area, which have been estimated to contain between 190,000 and 350,000 tons of recoverable U_3O_8.

APPENDIX B

General Conditions of Prospecting and Mineral Exploration in Canada and and Australia.

As in Australia, the mineral rights on Crown Land and on some privately owned land belong to the Provincial Governments, or in the case of the Yukon and North-West Territories to the Federal Government, but most of the older land titles include the mineral rights. The procedure for staking and registration of claims is also generally similar to Australian practice; the area of claims is generally 40 or 80 acres. In a few areas, such as northern Quebec, temporary exclusive permits comparable to our "Authorities to Prospect" are available, but these are the exception rather than the rule. As a result, there are periodic "staking rushes" in the vicinity of new discoveries; these provide both spectacular and speculative episodes, but they do not neoessarily lead to an orderly or efficient development of a mineral field.

The actual methods of prospecting and mineral exploration vary of course according to the physical conditions of the area to be investigated. In the rugged terrain of the Cordillera and some of the less accessible parts of the Appalachians, there is still scope for surface prospecting by traditional methods, and geochemical surveys, especially of stream waters and stream sediments, are reported to be giving good results. However, many of the occurrences in these areas which are at present being developed for production, e.g. some of the major porphyry-type copper deposits in northern British Columbia, have been known for many years, and their development at this time is largely due to increasing world demand and the feasibility of large low-grade operations in remote localities.

In the Shield, the main difference from the methods currently in use in Australia is the greater availability of aeromagnetic data and the use of air-borne E.M. surveys, which are credited, among other successes, with finding the Texas Gulf Sulphur Corporation massive sulphide ore body at Timmins.

Broadly speaking, the ratio of current exploration activity in Canada to that in Australia seems to be comparable to the ratio of total mineral production in the two countries, i.e. $C4,000 million ($A3,300 million) per year in Canada to about $600million per year in Australia. The absolute rate of new discoveries is therefore obviously much higher in Canada, but apart from air-borne E.M., no methods appear to be in use in Canada which are not also available in Australia, and there is no reason to believe that the rate of new discoveries in relation to the money invested or the number of geologists employed is any higher in Canada than in Australia.

On the other hand, there is no indication that ore bodies are running out; even in the better-known areas, such as the Timmins - Kirkland Lake - Val D'Or - Chibougamau belt, new discoveries are being made at a satisfactory rate, and there are large areas, for instance in the Yukon and North-West Territories, and in northern British Columbia, which have only been very cursorily prospected.

It should also be noted that for many commodities, e.g. iron ore, potash, asbestos, columbium, and uranium, increases in production could be readily sustained by further development of known resources, and do not necessarily depend on new discoveries. Nevertheless, considerable prospecting is still being undertaken for most of these commodities.