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NATIONAL ADVISORY COMMITTEE ON RESEARCH IN THE GEOLOGICAL SCIENCES

SEVENTEENTH ANNUAL REPORT
1966-67

ANNUAL REVIEW AND
REPORTS OF SUBCOMMITTEES

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601 Booth Street,
Ottawa, October 31, 1967.

The Honourable Jean-Luc Pépin,
Minister of Energy, Mines and Resources,
Ottawa, Ontario.

Sir:

I have the honour to submit to you the Seventeenth Annual Report of the National Advisory Committee on Research in the Geological Sciences covering the period September 1, 1966 to August 31, 1967.

Respectfully submitted,

Y.O. Fortier,
Chairman.

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MEMBERS OF COMMITTEE

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Professor A.R. Byers	University of Saskatchewan, Saskatoon, Saskatchewan.
Mr. A.E. Buller	Union Carbide Exploration Ltd., Toronto, Ontario.
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Professor C.W. Stearn	McGill University, Montreal, Quebec.
Dr. C.J. Sullivan	Kennco Explorations (Canada) Ltd., Toronto, Ontario.
Professor H.R. Wynne-Edwards	Queen's University, Kingston, Ontario.

Meetings:
April 24-25, 1967, Ottawa, Ontario.

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Dr. Y.O. Fortier, Chairman	Geological Survey of Canada, Ottawa, Ontario.
Professor A.R. Byers	University of Saskatchewan, Saskatoon, Saskatchewan.
Professor R.E. Folinsbee	University of Alberta, Edmonton, Alberta.
Dr. C.S. Lord	Geological Survey of Canada, Ottawa, Ontario.
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Dr. C.S. Lord	Geological Survey of Canada, Ottawa, Ontario.
Professor E.W. Nuffield	University of Toronto, Toronto, Ontario.

Meeting:
June 8, 1967, Ottawa, Ontario.

THE YEAR IN REVIEW

The National Advisory Committee on Research in the Geological Sciences has a threefold purpose: to stimulate and coordinate geological research in Canada; to suggest research projects that should receive attention; and to aid in having these projects undertaken. Its function is to stimulate research by the universities, federal and provincial departments of mines, and by other organizations equipped for the work.

The first part of this report gives a summary of the work of the Committee over the period September 1, 1966, to August 31, 1967. This is followed by the reports of the subcommittees. These reports cover the different fields of the geological sciences, record developments in 1966-67 and suggest further problems for study. An appendix lists the research grants to Canadian universities for 1967-68 which were awarded by the Geological Survey of Canada on the basis of the National Advisory Committee's recommendations.

The annual survey of current research in the geological and related sciences in Canada is published as a separate volume[1]. It records information on research by the universities, federal and provincial departments and research councils and foundations.

Other current publications of the National Advisory Committee include the Symposium on Geochemical Prospecting (Geol. Surv. Can., Paper 66-54, 1967) and the final report of the Ad Hoc Committee on Storage and Retrieval of Geological Data in Canada. This report which is entitled "A National System for Storage and Retrieval of Geological Data in Canada" is distributed for the Committee by the Geological Survey of Canada.

RESEARCH GRANTS TO UNIVERSITIES

Grants by the Geological Survey of Canada were initiated in 1951 at the instigation of this Committee to stimulate and support geological research in Canadian universities. Applications are received from members of university staffs and must be submitted to the Director, Geological Survey of Canada, before May 1 of each year. They are reviewed by the Projects Subcommittee of the National Advisory Committee in June and the applicants are notified at that time whether they will receive grants.

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[1] Survey of Current Research in the Geological Sciences in Canada, 1966-67, National Advisory Committee on Research in the Geological Sciences, Ottawa, 1967; Geol. Surv. Can., Paper 67-58, 1967.

The National Research Council of Canada also awards grants-in-aid for research in the geological sciences (earth sciences) on a more substantial scale[1]. Applicants for N.R.C. grants apply by December 1 and are notified of awards in April of each year. The National Advisory Committee has full knowledge of grants in the earth sciences awarded by the National Research Council. In addition, to assure full coordination in the award of grants by the two organizations, one or more members of the National Research Council Grant Application Screening Committee serve on the subcommittee of the National Advisory Committee which reviews the applications to the Geological Survey.

For 1967-68, 100 applications were received (98 in 1966-67) and the total of the grants applied for was $370,377 ($309,272 in 1966-67). Ninety grants totalling $185,000 were awarded to 21 universities. The names of the recipients, the titles of their research projects and the amounts awarded are listed in the Appendix (p. 102).

STORAGE AND RETRIEVAL OF GEOLOGICAL DATA

In 1964 the National Advisory Committee asked the Geological Survey of Canada to assess the possibility of formulating a system or several compatible systems for the storage and retrieval of geological data which might come into general use in Canada. S.C. Robinson was appointed to carry out this assessment. His report, presented to the N.A.C. in April 1965[2] concluded that data-processing techniques offer geologists an opportunity to exchange data rather than hypotheses and the opportunity to test hypotheses on the basis of common data. As a result of recommendations in this report, the National Advisory Committee set up an ad hoc committee to take the necessary steps to develop a national system for the storage and retrieval of geological data in Canada under the charimanship of Robinson. The ad hoc committee presented an interim report to the N.A.C. in April, 1966[3]. Its final report, entitled "A National System for Storage and Retrieval of Geological data in Canada,"[4] was presented in April, 1967.

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[1] Annual Report on Support of University Research, 1965-66, National Research Council, No. 9159, pp. 124-134.

[2] Robinson, S.C., Interim Report on Possible Applications of Data Processing Techniques to Storage and Retrieval of Geological Data; Geol. Surv. Can., January, 1965.

[3] Interim Report of the Committee on Storage and Retrieval of Geological Data in Canada, National Advisory Committee on Research in the Geological Sciences; Geol. Surv. Can., Paper 66-43, 1966.

[4] A National System for Storage and Retrieval of Geological Data in Canada, Report of Ad Hoc Committee of the National Advisory Committee on Research in the Geological Sciences in Canada, April, 1967, available from Geol. Surv. Can.

In presenting this report to the National Advisory Committee, Robinson summarized its content as follows:

"The first section contains the firm recommendations of the main committee and some of the subcommittees; the second section comprises progress reports of those other subcommittees which were devoted to establishing practical requirements for files of (a) geological field data, (b) data on mineral deposits, (c) data on fossil fuels and (d) geophysical data.

"The first section presents broad principles for establishment of a national system for recording and storing data in the earth sciences. This system is a model that may be used by any organization that intends to establish machine-processible files of geological data. Undoubtedly each organization will modify this model to suit its own requirements. In general, the committee believes that the model incorporates a minimum of essential data and that most modifications will involve additions to, rather than substitutions for, the principal data categories that comprise the model.

"The second section exemplifies the problems involved in applying principles to actual files, Although this section contains progress reports only, it is my personal opinion that it is these reports that will stimulate the greatest interest and certainly will generate the greatest criticism among potential users of the system. These progress reports contain a first appraisal of the categories of data that should be recorded in each of the four fields and the units and terms that should be used to record them. We hope that these tentative standards and formats will be tested and criticized constructively so that they may evolve as an acceptable basic core of all files in each of these fields. Such a standard core would materially increase effective exchange of data.

"The national system will evolve continuously to respond to new uses, to new techniques, to new categories of data and mainly to changes indicated by testing in use. To provide for this evolution in the national system, the ad hoc committee has made specific recommendations for establishment of a standing committee supported by a full time secretariat.

"Recording of descriptive facts in a form that will permit them to be blended with numerical data and assessed statistically is one facet of the study on which progress of the committee has been slow. Geological terminology is largely traditional, and often combines genetic connotations with observed facts. It is therefore not well suited to recording facts alone. The principal hope for a solution to this problem lies in university teaching. This will come about only if the universities themselves are involved in research in this field. The committee has made two recommendations to stimulate this research; first that government agencies collaborate with universities in developing their specific formats for

storage, processing and retrieval of geological data; and second that the National Advisory Committee recommend an additional sum of $50,000 in grants to universities for research in this field.

"In conclusion, I would like to express my gratitude to the members of the ad hoc committee and its subcommittees for their effective and unremitting effort over the past two years. None of us, I think, realized the magnitude of the task you had set us until we were caught in the net of our own enthusiasm. At least it can be said that we are converted by our own reports. Finally, I would like to congratulate the report's two editors, Professor Brisbin and Mr. Ediger, for its brevity, its lucidity and above all for getting it out on time."

The main conclusions of the ad hoc committee may be summarized as follows:

(1) The National System may be used in the files of geological data of any organization in Canada wishing to participate. The files will be computer-based, user-oriented, user-controlled and will be linked through the use of recommended reference numbers, location reference, and methods of coding.

(2) The index to the contents and location of geological data files within the system will be the computer-assisted National Index.

(3) Standards for defining and recording geological data can and must be developed through the widespread participation of Canadian earth scientists in the continuation of present pilot studies and the initiation of others.

(4) The National System can attain the objectives envisaged by the National Advisory Committee only under the guidance of a continuing organization consisting of a permanent secretariat body with advisory and operational arms. This organization must stimulate participation by government agencies, universities and industry in the implementation and continued development of the National System.

The recommendations of the committee include:

(1) That the National Advisory Committee adopt the National System of geological data files as proposed in this report.

(2) That the National Advisory Committee immediately establish an advisory organization and a permanent secretariat body – to facilitate the use of the National System and ensure its continued development.

(3) That the National Advisory Committee provide funds for the employment of the secretariat body and such consultants as may be required.

(4) That the National Advisory Committee take steps to encourage the geological agencies of federal and provincial governments:

(a) To accept the principles and standards of the National System as proposed in this report.

(b) To cooperate with the secretariat in the implementation and continued development of the National System.

(c) To participate with the universities in pilot studies to develop and test standards for the defining and recording of observational data.

(d) To participate with universities in research projects involving the application of computer technology to geology.

(5) That the National Advisory Committee encourage university research and education in the application of computer technology to the geological sciences, and in the development of standards for defining and recording data. In this report the committee recommends that the National Advisory Committee grants-in-aid of research be increased by the amount of $50,000, to be awarded for research in these fields.

(6) That the National Advisory Committee appoint in April, 1967, a Standing Committee on the Storage and Retrieval of Geological Data in Canada. The standing committee would continue as the advisory arm of the permanent secretariat.

The National Advisory Committee adopted the report of the ad hoc committee and, as recommended in the report, appointed a Standing Committee on Storage and Retrieval of Geological Data in Canada. Dennis A. Sharp, Department of Energy and Resources Management, Toronto, has been appointed chairman of the standing committee. The standing committee will consider immediately the establishment and method of financing of the secretariat and the implementation of the other recommendations in the ad hoc committee report.

In presenting the report, members of the ad hoc committee stressed that all files would be under the owner's control and no data would be stored in the National Index. All the Index requires from contributors is a record of what data are in their files – not the data itself. A junior geologist or geological librarian (a librarian with some knowledge of geology and geological terms) could fill out the index forms adequately once the concept authority list is established. These forms would be forwarded to the secretariat for incorporation in the National Index.

EARTH SCIENCE SYMPOSIUM ON HUDSON BAY

An Earth Science Symposium on Hudson Bay was originally proposed and is being organized by the Subcommittee on Exploration Geophysics of the N. R. C. Associate Committee on Geodesy and Geophysics. Because the symposium will be concerned with the geological as well as the geophysical aspects of Hudson Bay the National Advisory Committee and the Associate Committee on Geodesy and Geophysics are acting as co-sponsors.

The symposium will be held in Ottawa in February 1968 for the two days immediately preceding the meetings of the Associate Committee on Geodesy and Geophysics. About 20 papers will be presented covering Quaternary geology, on-shore and off-shore bedrock geology, bathymetry and sedimentology, and seismic, gravity and magnetic studies of the Bay.

TECTONICS RESEARCH CONFERENCE

On the recommendation of the Subcommittee on Structural Geology, the National Advisory Committee is supporting financially a Tectonics Research Conference to be held at Ottawa University, Ottawa, Ontario, on March 14-15, 1968.

The conference will explore the area where laboratory studies of brittle failure in geological materials may provide new insight and criteria for understanding similar failure conditions in the field and, conversely, where field investigations may assist in the understanding of brittle deformation in the laboratory. The first session will be devoted to kink bands followed by sessions on other forms of brittle failure in geological materials.

Forty-two geoscientists from the United States, Great Britain and Canada are expected to participate in the conference.

INTERNATIONAL GEOLOGICAL CONGRESS - 1972

The Canadian Government has given approval in principle to inviting the International Geological Congress to meet in Canada in 1972. The formal invitation will be extended at the Congress in Prague, Czechoslovakia, in August 1968.

The executive of the National Advisory Committee with additional members it may select acts as the Canadian National Committee for Geology. Now that the invitation to the congress to meet in Canada in 1972 has been sanctioned, representatives from the Alberta Society of Petroleum Geologists, the Geological Association of Canada, the Mineralogical Association of Canada and the Geology Division of the Canadian Institute of Mining and Metallurgy will be invited to join the National Committee to plan future action.

INTERNATIONAL UNION OF GEOLOGICAL SCIENCES

The International Union of Geological Sciences issues about four circular letters a year containing current information about the I.U.G.S., future international meetings, reports on recent meetings, abstracts of papers presented to symposia, progress reports on international research projects and reports of I.U.G.S. commissions, committees and affiliated organizations. I.U.G.S. circular letters may be ordered from the Secretary-General, I.U.G.S., Mechelse Steenweg 206, Antwerp, Belgium.

New commissions of the I.U.G.S. on petrology and structural geology have been organized recently. Professor H.D.B. Wilson, University of Manitoba, has been appointed to the Commission on Petrology and Professor H.R. Wynne-Edwards, Queen's University, to the Commission on Structural Geology.

The International Commission on Geochronology, on which Professor R.E. Folinsbee, University of Alberta, is the Canadian representative, held a successful conference in Edmonton, Alberta, June 10-17, 1967. The subject of the conference, which was chaired by Professor R.A. Burwash, was "The Geochronology of Precambrian Stratified Sequences around the World". Field trips to the Belt Series of southern Alberta and the Yellowknife Group, Yellowknife, Northwest Territories, preceded and followed the conference. Funds for the conference were provided by the University of Alberta and the Geological Survey of Canada.

The Commission for the Geological Map of the World, which was set up by the International Geological Congress, has several subcommissions of which one is for the Metallogenic Map of the World. The Canadian Metallogenic Map Committee which was organized in 1964 is composed of members from the provincial departments of mines and the Geological Survey of Canada; G.B. Leech is the present chairman. The Metallogenic Map of North America, the Canadian part of which will be derived from the Metallogenic Map of Canada, will be on the scale of 1:5,000,000; agreement on the map legend was reached in April 1966. The Canadian map will outline the districts characterized by various metals or metal groups, and insofar as the scale will allow individual deposits will be represented by symbols. The base map will combine features of geologic and tectonic maps. The major fold belts will be shown and within these fold belts the pre-batholithic vs. post-batholithic strata, the main igneous areas, and where possible the type of rock sequence (chert-argillite-greywacke-volcanic vs. sandstone-shale-limestone). The symbols for mineral deposits will indicate the metals or minerals; the size of deposit; the geologic environment (depositional environment of sedimentary and volcanic rocks and nature of intrusive rock if any); the geological class of deposit (vein, shear zone) pegmatite, placer, etc.); the age; and the mineralogical nature (sulphide, silicate, carbonate, oxide etc.).

A new geological map of Canada for publication 1:5,000,000 scale is being prepared by R. J. W. Douglas, Geological Survey of Canada; data from it will be incorporated in the Geological World Atlas. The four principal geological parameters of age, facies, structure and metamorphism of the rocks are used on the map to typify and unify the geology of major sections of the country and thus to portray the significant characteristics in a meaningful way. Rocks are categorized by age according to two standards – depositional ages and orogenic ages. For the Phanerozoic, age is indicated by fossils and represented by a standard based on formal successions. Orogenic and tectonic effects, and the age of the rocks so produced, can be referred to this standard in a relative way. For the Precambrian the age of depositional sequences can be determined only relatively by dating the preceding and succeeding orogenic events. The map includes information on the geology of the offshore regions to the edge of the continental shelves. It is hoped to publish the map on 1:5,000,000 scale before the end of 1968. The map will be accompanied by a completely revised edition of "Geology and Economic Minerals of Canada" (Geol. Surv. Can., Economic Geology Series, No. 1).

The International Upper Mantle Committee, of which C. H. Smith, Geological Survey of Canada, is chairman, met in Tokyo, Japan, in September 1966. At this meeting it was decided to extend the upper mantle program, which was initiated in 1961, to 1970 to allow some of the countries that had been slow in starting to complete their programs. This will also give time for development of a number of world-wide programs. The committee continues to sponsor symposia, such as the successful Ottawa symposium of 1965. Three large volumes of papers given at that symposium were published by the Geological Survey of Canada in 1966, entitled "Drilling for Scientific Purposes" (Geol. Surv. Can., Paper 66-13); "The World Rift Systems" (Geol. Surv. Can., Paper 66-14); and "Continental Margins and Island Arcs" (Geol. Surv. Can., Paper 66-15). Symposia are planned for the meetings of the International Union of Geodesy and Geophysics in Switzerland in September 1967 and the International Geological Congress in Prague, Czechoslovakia, in August 1968.

CHANGES IN PERSONNEL OF COMMITTEE

L. G. Berry, W. C. Brisbin, W. O. Kupsch, C. R. Stelck, and D. M. Shaw retired from the Committee in 1966. All members join in expressing appreciation of the contribution of time and effort made by these men during their terms of office. We look forward to their continued support.

New members appointed in 1966 are: A. E. Buller, Union Carbide Exploration Ltd., Toronto, Ontario; A. R. Byers, Department of Geological Sciences, Saskatoon, Saskatchewan; R. E. Folinsbee, Department of Geology, University of Alberta, Edmonton, Alberta; E. W. Nuffield, Department of

Geology, University of Toronto, Toronto, Ontario; Dennis A. Sharp, Department of Energy and Resources Management, Toronto, Ontario; H. R. Wynne-Edwards, Department of Geological Sciences, Queen's University, Kingston, Ontario. Robert Sabourin, Department of Geology, Université Laval, has been re-appointed for a second term.

SUBCOMMITTEE REPORTS

REPORT OF THE SUBCOMMITTEE ON

GEOPHYSICAL METHODS APPLIED TO GEOLOGICAL PROBLEMS

Presented by J.E. Blanchard

Members of Subcommittee

J.E. Blanchard (Chairman)	Nova Scotia Research Foundation, Halifax, Nova Scotia.
W.C. Brisbin	University of Manitoba, Winnipeg, Manitoba.
L.S. Collett	Geological Survey of Canada, Ottawa, Ontario.
L.W. Morley	Geological Survey of Canada, Ottawa, Ontario.

INTRODUCTION

1966 was a year of continued growth in geophysical research in Canada. The theory proposed by L.W. Morley and A. Larochelle several years ago to explain patterns of magnetic anomalies at sea has recently aroused great interest among geologists and geophysicists. The late recognition of their work is due to J.T. Wilson's use of their hypothesis as evidence for his most recent theories on continental movement. R.J. Uffen, a former chairman of this subcommittee, has become chairman of the Defence Research Board of Canada.

REVIEW OF CURRENT RESEARCH

In the 1965 report of this subcommittee, reference was made to the comprehensive reviews of geophysical research in the volumes of the Canadian Geophysical Bulletin which is published annually by the National Research Council. The reader is this year referred to Vol. 19, 1966, of the Bulletin, which reports on geophysical research in the nine disciplines of the International Union of Geodesy and Geophysics and in exploration geophysics.

Much of the geophysical research in Canada is of direct or indirect concern to geology, and this Bulletin includes information on research of interest not only to this subcommittee but to several other subcommittees of the National Advisory Committee.

The report in the Bulletin on research in geodesy and gravity describes a research program new to Canada – a program to measure earth tides using tilt meters. In addition to information about the physical properties of the interior of the earth this program may provide information about local features such as differential movements in the earth's crust.

CANADIAN CONFERENCES ON GEOPHYSICS

Marking the occasion of the 100th anniversary of Canada's Confederation, an international conference on mining and groundwater geophysics sponsored by the National Research Council and the Geological Survey of Canada was held in Niagara Falls, Ontario, October 22-27, 1967. This conference brought together authorities in mining and groundwater geophysics to review technological advances over the past decade with emphasis on practical results.

The program included approximately 60 papers on geophysical exploration for minerals and groundwater and the state of the art. The symposia included "Human Resources for Geophysics", "The Organization and Role of National Geophysical Facilites", and two evening discussion sessions.

Prior to the conference, a two-week lecture and field demonstration course on geophysical techniques was given to approximately 25 delegates from the developing nations who were sponsored by the External Aid Office.

The Earth Physics Section of the Canadian Association of Physicists sponsored two days of scientific papers at the annual meeting of the Association in Toronto on June 2-3, 1967. Some thirty papers on solid-earth geophysics were presented. This is the most ambitious geophysics program that has been presented at an annual CAP meeting. It is hoped that similiar sessions will become at least a bi-annual event to meet the needs of Canadian scientists interested in these disciplines. The program was arranged by Gordon West and Derek York.

The Canadian Advisory Committee on Rock Mechanics of the Department of Energy, Mines and Resources sponsored the 4th Canadian Rock Mechanics Symposium at the annual meeting of the Canadian Institute of Mining and Metallurgy in Ottawa, March 1967. This group is interested in the physical properties of rocks and pressures in strata as they affect mining and drilling, but most of the work it is doing and certainly all of the papers presented at the symposium are of interest to geophysicists and geologists.

Two of the papers were concerned with measurements of absolute stress in the crust of the earth. Such measurements on a much broader scale could well provide answers to some of the problems in geology, such as continental drift.

A GAP IN GEOPHYSICAL AND GEOLOGICAL RESEARCH IN CANADA

Rather than repeat the information on research so well documented in the Canadian Geophysical Bulletin, Vol. 19, 1966, it may be worth considering a gap in Canadian geophysical research of which most geophysicists are aware. A.E. Beck, University of Western Ontario, describes it as follows:

> "There are numerous theories concerning continental drift, continental growth, sea-floor spreading, orogenesis, epeirogenesis etc., all of which implicitly assume that the crustal and mantle material will behave in the way that the theories require it to behave. Thus a knowledge of the physical properties of rocks at the temperatures and pressures to be met in the upper mantle and lower crust is of vital importance to earth scientists. The two most important areas where much more information is required are: (a) the elastic (and viscosity) constants and (b) the thermal properties of these materials.
>
> "The elastic constants and viscosity are obviously important when one tries to compare rates of tectonic movement, as suggested by geologic observation, with theoretical rates based upon rock properties and force systems in the mantle and upper crust.
>
> "Knowledge of thermal properties of rocks at elevated temperatures and pressures is necessary, not only because of their relationship to elastic properties, but also for a better understanding of the thermal history of the earth. One of the most perplexing problems is to find the relative contributions to heat transfer from the radioactive and lattice conduction components; at present, estimates vary by one or two orders of magnitude. Quite clearly, attempts should be made to estimate these contributions experimentally in order to pin down false assumptions being made in the theory".

CONCLUSIONS AND RECOMMENDATIONS

The chairman of this subcommittee is anxious to make this subcommittee more useful and has had many discussions with geologists and geophysicists as to how this may be accomplished. Until some policy can be developed, the subcommittee is being kept small.

To be effective, the subcommittee must meet but must have a reason for meeting; it should not meet just to discuss generally geophysical methods applied to geology. The Centennial Conference mentioned earlier provided an objective for the Exploration Geophysics Subcommittee of the Associate Committee on Geodesy and Geophysics and created great interest among mining geophysicists. The subcommittee cannot be associated regularly with any one of the subcommittees of the ACGG because its interests are distributed among several of them.

Periodically, the subcommittee should appoint ad hoc members to meet and prepare reports on gaps in Canadian research in areas of interest to the subcommittee and make recommendations as to how these deficiencies may be corrected. These recommendations should be considered by some group that has funds to make possible their implementation if they are considered to have merit and warrant priority. One way this might be accomplished would be to change the policy of making Geological Survey grants and support "centres of excellence" at geological and geophysical centres of research rather than large numbers of unrelated and uncoordinated research projects.

If these recommendations have merit, meetings to investigate such topics as the measurement of absolute-stress or high-pressure and -temperature phenomena could be held. These are two fields of research that deserve more attention.

REPORT OF THE SUBCOMMITTEE ON MINERAL DEPOSITS

Presented by C. J. Sullivan

Members of Subcommittee

C. J. Sullivan (Chairman)	Kennco Explorations (Canada) Ltd., Toronto, Ontario.
R. L. Cheesman	Department of Mineral Resources, Regina, Saskatchewan.
J. F. Davies	Department of Mines and Natural Resources, Winnipeg, Manitoba.
A. M. Goodwin	Geological Survey of Canada, Ottawa, Ontario.
P. E. Grenier	Department of Natural Resources, Quebec, P. Q.
Walter Holyk	Texas Gulf Sulphur Company, Toronto, Ontario.
C. S. Ney	Kennco Explorations (Canada) Ltd., Vancouver, British Columbia.
J. P. Nowlan	Department of Mines, Halifax, Nova Scotia.
J. E. Riddell	Consulting Geologist, St. Andrews, New Brunswick.

INTRODUCTION

It is perhaps appropriate to review the history of theories in mineral exploration over the past 35 years, the period during which mineral exploration (as distinct from mining geology) has developed. Against this perspective recommendations are made concerning the direction in which research should proceed.

The report also includes a brief review of current trends in research within the mineral-exploration industry, and recent international symposia in the field of mineral deposits.

THE MAGMATIC-HYDROTHERMAL ERA 1930 to 1950

Waldemar Lindgren[6] the father and teacher of many widely held theories on mineral deposits in the English-speaking world during this period, stated (1933): "Each deposit should be considered a problem in physical chemistry." Lindgren created a temperature-pressure classification of mineral deposits and with the underpinning of the theory of magmatic differentiation evolved mainly in laboratories, mining geology like petrology became to a considerable degree a subject for study in the laboratory.

Lindgren himself was somewhat sceptical of the magmatic-hydrothermal origin of many deposits, but others carried these concepts to an extreme, concluding that practically all deposits containing sulphides were of this type. Thus, Bateman[1] (1950) concluded that the Rhodesian copper ores were of hydrothermal origin, though Lindgren (with Schneiderhohn) had doubted this. Bateman considered the favorability of the ore-bearing beds a function of their permeability. However, permeability is common and not much of a prospecting guide. Under the hydrothermal concept, the exploration geologist had to ignore the prospecting significance of intracratonic basins, particular stratigraphic units, basal formations, palaeoclimatic conditions, and a number of other possibly important prospecting criteria.

What Bateman had done for Rhodesia-Katanga, L. C. Graton[5] did for the Rand. He concluded that these deposits were hydrothermal and hence that the beach-pebble conglomerates had no intrinsic prospecting significance. As a consequence, when similar conglomerates containing uranium were discovered many years later at Blind River, Canada, the significance of the conglomerates as indicators of size and continuity of the uranium orebodies was not at first appreciated by some geologists. Some looked for granitic or other intrusions because according to the classical hydrothermal theory ore was unlikely to be present unless an intrusion (preferably granite) was somewhere in evidence.

For the bedded lead-zinc ores of the Missouri-Tristate-Pine Point type, the consensus of opinion as expressed by Bateman (1950) favored a magmatic-hydrothermal origin, thus persuading geologists to downgrade or ignore correlations between these deposits and stratigraphic units, basement highs, reefs, lagoonal facies, dolomitic facies, the presence of unconformities, etc.

Resulting Exploration Criteria

Some geologists continued to observe general geological features that seemed to have a bearing on the occurrence of ore, but, the ruling hydrothermal theory of the genesis of ore had an important bearing on what geologists did in the field because every geologist and prospector has some concept of the genesis of ore in the back of his head which influences his search for mineral deposits. From about 1930 to 1950, under the influence of ruling magmatic-hydrothermal theories, the following exploration criteria were stressed.

Intrusions

It was considered important to have an intrusion somewhere near, preferably a granite. If within a rock sequence no intrusions were present much doubt existed as to the possibility of finding ore. In some areas this negative approach was fatal. On the other hand, the perfectly valid association of particular types of igneous rocks and particular types of ores was carefully studied; this is still a valid prospecting guide.

Structure

Great emphasis was placed on "structure," including faults, "true fissures," drag folds, etc; ore had come from depth, so channelways or, "plumbing" were necessary. This emphasis on structure is strikingly illustrated by the naming of two standard Canadian books on ore deposits: The Structural Geology of Canadian Ore Deposits, Vol. I (1948) and Vol. II (1957). When it was decided to assemble a similar volume on Australian deposits for the Fifth Empire Mining and Metallurgical Congress (1963), it was only after considerable debate that the word "structural" was omitted.

In exploration within a mine, emphasis on structure was often most helpful, but when applied to regional exploration the results were far less satisfactory. When advocates of the importance of structure and regional "lineaments" tried methods useful in mining geology in regional exploration, many a fault was found to be barren, and in a large number of cases faulting and folding showed little correlation with mining districts or metalliferous provinces. In some areas, as for example Bathurst, New Brunswick, exploration geologists who concentrated their efforts along major faults were unsuccessful, as compared with those who concentrated on particular formations.

Alteration

From 1930-1950, much laboratory research was devoted to hydrothermal alteration. Information on the characteristics of alteration along zones of mineralization was collected, and much of this is helpful in exploring known deposits and in evaluating new discoveries; in some instances alteration

zones are useful as guides to buried ore deposits. But hydrothermally altered zones commonly have dimensions only one order of magnitude larger than the deposit itself and in exploration for new deposits the problem of finding an altered zone is much the same as finding a mineralized zone.

Zoning

Early recognition of thermal zoning resulted in extensive studies. Such studies are still proceeding and have definite value, especially in the exploration of already discovered porphyry copper districts. However, in general they are not useful in regional prospecting or exploration in districts where no deposits have yet been found.

Paragenesis

Most descriptions of mineral deposits in this period included studies of the paragenetic sequence. This information, usually obtained in a laboratory, is of scientific interest but not of much help in prospecting and exploration.

Fluid Inclusions

As a logical extension of the magmatic-hydrothermal theory, and the attempt to study the "ore-forming fluid," considerable attention has been paid to liquid inclusions within ore-deposit minerals. Though of scientific interest, the results have proved of little use to the exploration geologist.

Temperature Classification

As a result of temperature-pressure, physical-chemical laboratory studies of ore deposits, much stress was placed on temperature of deposition as indicated by the minerals present. But many deposits appear to have been modified by repeated re-heating and the fact that the present mineral assemblage of a particular deposit leads to its classification as "leptothermal" is of little help to the exploration geologist in his search for others like it.

Summary

The above criteria are characterized by a "scientific," laboratory, instrumentational approach, and a tendency to ignore basic, classical geology. As consequence many exploration and mining geologists made little effort to apply the basic principles of historical geology, sedimentation, palaeogeography and field geology generally. This trend to more and more emphasis on the laboratory-instrumentation approach to geology continues within universities, which is not healthy for either general geology or mineral exploration. In contrast, the more mature oil-exploration industry has obtained rewarding results by applying general geological principles in the search for petroleum

and natural gas. Such successes as the mineral industry has recently had, stem from the same geological approach.

PROSPECTING BY GEOLOGICAL ENVIRONMENT, 1950 TO PRESENT

It would be an exaggeration to say that during a particular period all geologists think and act in a certain way, and that during another period they think and act differently; there is a great deal of overlap in geological theories from one period to another. Also, this outline applies particularly to North American and English-speaking geologists generally; European geologists have had a somewhat different outlook and were not as impressed by the unified hydrothermal-magmatic approach. For example, as noted by Lindgren[6], Hans Schneiderhohn made a broad geological classification of ore deposits in 1925 which would be acceptable to many exploration geologists today. In his classification he included submarine exhalation deposits, the importance of which have been appreciated only in recent years in the English-speaking world.

However, broad trends are apparent, and it is fair to say that during the past decade and a half, which has been the greatest period in history for scientific mineral exploration, an increasing emphasis has been placed on the control of geological environment in the occurrence of mineral deposits. Studies of these relationships, combined with the development of new detection techniques, have led to great advances in mineral exploration.

Some fruitful geological studies are basically empirical in approach, seeking any relationships that may have prospecting significance. Numerous geologists have made contributions to such studies but perhaps most have been attached to the exploration departments of mining companies. Sullivan[8] (1957) pointed out: "Field associations are of great practical importance and must have major genetic significance"; a classification of ore deposits based on geological association was presented. L. J. Miller[7] (1960) pointed out the importance in prospecting of the relation between types of volcanic rocks and types of massive sulphide deposits. These relations were applied successfully by Miller and his associates (Texas Gulf Sulphur deposit, Ontario), and similar concepts were used successfully in the Noranda and Mattagami districts of Quebec by geologists of other companies.

In the years 1954-1956, Anaconda[3], Texas Gulf and Kennco, working independently, discovered massive sulphide deposits in New Brunswick by prospecting the contacts of a porphyritic-acid volcanic unit with airborne systems. The stratigraphic approach was chosen, although at that time "conventional wisdom" would have directed the search to near granite bodies, along faults, etc.

It is not possible to do justice to all who have contributed to modern concepts in exploration over the past 30 years. In Katanga, company

geologists never appeared to depart from sound stratigraphic or other basic geological principles. Union Miniere geologists unravelled the secrets of the Series des Mines, and discovered large reserves of copper, cobalt, uranium; a principal stratigraphic guide was an algal reef formation. In Rhodesia, company geologists searched particular stratigraphic units in intracratonic basins and developed large ore reserves.

In the United States, very important discoveries were made in Missouri by several companies, including Kennecott and St. Joseph Lead, using the stratigraphic and the environmental approach in the manner of oil geologists. At about the same time, Cominco Ltd.[2] by exploring the reef complex at Pine Point, Northwest Territories, outlined major lead-zinc ore-bodies.

In Australia, principles of stratigraphy and sedimentology[4] were applied successfully to make major discoveries near Mount Isa and in the Rum Jungle fields. In Ireland, Canadian geologists, by prospecting the over-lap of the Carboniferous on Devonian sandstones, helped to revive the mining industry of that country. In Europe, substantial exploration is under way in about the same time unit – the Visean – were widespread mineralization is associated with particular volcanic and sedimentary rocks. In this work, palaeophysiographic maps are an important guide to prospecting (S. W. Holmes, personal communication).

SUMMARY OF REGIONAL GEOLOGICAL GUIDES TO ORE

The following notes describe some of the relationships that appear to be emerging between general geology and the occurrence of ore deposits. All suggest lines of fruitful research, although some may prove to be invalid.

Sedimentary Environment

Many important sulphide-mineral deposits occur in the intracratonic basins which have developed within continents, as opposed to basins formed on the continental shelves. In the intracratonic metal-bearing basins dips may be gentle; there may be no intrusions; there are suggestions of slow sinking, deep weathering, dry climate and a fluctuating water table; evaporites may be present; probably no high mountains bounded these basins.

The geosynclines developed on the edges of continents, possibly bounded by high mountain ranges. They have been formed from material provided by rapid erosion, allowing little time for deep weathering and solu-tion; vulcanism is common and sinking has been rapid. Ultimately, deep depression of the basin into the crust has been followed by granitization and intrusion.

Certain time units are generally important, and copper deposition may exist in such a time unit, as in Rhodesia-Katanga, even though the sedimentary environment may change.

There appears to be no sulphide deposition in redbeds or in aeolian environments.

Various metals tend to accumulate under slightly different conditions. Sedimentary copper may be found in quartzites or shale, less commonly in carbonates. Lead and zinc favor the carbonate (especially the dolomitic) environment, particularly in the vicinity of reefs, many of which are of algal origin. Some copper is found in the reef environment also. Lead, apart from its occurrence in carbonates, favors carbonaceous sandstones. Uranium favors an epicontinental environment which is not favorable for copper. Uranium may also be found in fossil beach deposits as at Blind River, Ontario and on the Rand, South Africa.

The palaeogeography of sedimentary basins is extremely important in prospecting – including the position of former shorelines, islands, lagoons, deltaic deposits, etc. In general, the exploration geologist should study sedimentation as carefully as the oil geologist.

The metal association in sedimentary deposits may be anomalous as compared with that in deposits formed under thermal conditions. The cobalt-uranium-copper association is common and mercury sulphide may occur with copper sulphide. Silver-copper ratios may be higher than in thermal deposits. The mineral association is suggestive of precipitation by hydrogen sulphide.

Volcanic Environment

Perhaps the best-known volcanic association is that between basalts and native copper-chalcocite-bornite deposits. Most are patchy, but interesting deposits occur in amygdaloid flows such as those of the Keweenaw Peninsula and Coppermine River. In some cases there may have been reconcentration by metamorphism.

The relationship between massive copper-zinc sulphide ores and extrusive acidic rocks is more widespread and so far more interesting economically. The sulphides are commonly found at the contact between rhyolitic tuffs or breccias, and overlying andesites or basalts. These deposits may be zoned, with pyrite-chalcopyrite replacing or immediately overlying brecciated rhyolite, and dominantly pyrite-sphalerite ore overlying the copper ore.

The presence of ore is associated with thickening of the acidic fragmentals. Thin beds of tuff or graphitic slate may be deposited at the ore

horizon or, in some cases, chert or iron formation. Near many deposits, especially in the Canadian Shield, basic intrusions may show a close relationship to the ore, and magnesium metasomatism, represented by cordierite-anthophylite-chlorite alteration, may be developed. Areas in which such prospecting guides apply include the Mattagami and Noranda districts of Quebec, the Texas Gulf discoveries near Timmins, Ontario, and the Bathurst district of New Brunswick. The Palaeozoic Bathurst ores contain zinc, lead and copper in that order of abundance, while the ores of the Shield, associated with Precambrian lavas, are commonly richer in copper and zinc and poor in lead. Numerous deposits of this type are known outside Canada. They include the massive sulphide ores of Rio Tinto, Spain, which are characteristic of a volcanic environment rather than the intrusive porphyry environment of the western Cordilleras of North and South America. The Rio Tinto porphyries are probably not intrusions, and this suggests possibilities for stratigraphic prospecting.

An association between Lake Superior-type iron ores and volcanic activity has long been suspected.

In most of the examples indicated above, the volcanic flows appear to be of submarine origin, but some ore deposits may be found that are associated with subaerial vulcanism. Probably many ore deposits with volcanic associations remain to be discovered and described.

The Basic Igneous-Rock Environment

The association of particular ores with particular types of basic and ultrabasic igneous rocks is well known, and has been used as a guide to prospecting for several decades. Such ores exhibit similar metal ratios as those in the associated basic rocks. Peridotites produce asbestos or nickel deposits; gabbros are associated with copper-nickel deposits, cobalt deposits and cobalt-silver deposits.

Such rocks may occur along regions of major faulting, such as the edges of the Superior Province of the Canadian Shield; at Sudbury, Ontario, and Thompson, Manitoba, basic rocks are closely associated with some of the world's greatest nickel ore deposits. In the Thompson area, granitization appears to have occurred subsequent to the intrusion of peridotite, and major deposits lie essentially in granitic gneiss. However, the presence of peridotites marks the belt as a whole, and remnants of peridotites are closely associated with the deposits[11]. At Sudbury, many of the copper-nickel deposits are closely associated with the dioritic facies of norite, which again suggests subsequent granitization.

In some copper-rich areas, such as Arizona, there may be an abundance of basic rock, much of it pre-granite in age. This suggests that at some point in time in this area the crust was thin and that basic rocks brought

in the copper, some of which was later concentrated into ore deposits. In any case, the presence of abundant basic rock, even where pre-granite and pre-ore, must be considered a favorable indicator for copper.

The Porphyry Copper-Molybdenum Environment

These deposits occur mostly in Mesozoic and Tertiary mountain terrains where metamorphism is local, and erosion has not exposed the deeper, more highly metamorphosed rocks characteristic of Shield areas. The deposits are nearly always associated with porphyry stocks which are important prospecting guides. The recent tendency to apply the name "porphyry copper" to any large copper deposit that can be open pitted, is not only absurd geologically but misleading to the prospector.

The porphyry-copper ores may lie within the stock, or in skarn replacement or veins around its periphery. In this environment, skarn ores may be of great importance; commonly the grade of ore in the skarn is somewhat higher than the grade of ore in the porphyry itself. A single stock may give rise to a complete, zoned district, the zoning being dependent on the reactivity of the surrounding rocks and upon the grade of metamorphism peripheral to the stock[9]. It also depends on the tendency of ore minerals to be segregated in various temperature zones.

Copper-bearing porphyries commonly occur in geosynclines characterized by abundant volcanics of andesitic type, although there are exceptions. Thus, both in Canada and in South America, porphyry-copper and porphyry-molybdenum deposits are far more common within the Mesozoic volcanic-rich geosynclines than the Palaeozoic, dominantly sediment-rich geosynclines. The Palaeozoic-Appalachian geosyncline of North America has not been very productive in relation to its size, although the Gaspé copper deposit is of the porphyry type. Similarly, moderate-sized porphyry-copper deposits occur in the Palaeozoic geosyncline of eastern Australia.

In general, the porphyry-copper belts follow Mesozoic or Tertiary island arcs, and palaeogeography is as important in porphyry-copper exploration as in the search for the other deposits mentioned above.

GENERAL CONCLUSIONS AND RECOMMENDATIONS

For many years the largely laboratory-based, physical-chemical approach to research on mineral deposits has been stressed; we conclude that the results have been comparatively unrewarding. This approach continues and is being expanded in many universities with installation of expensive instruments. As a consequence geologists in universities and research institutions tend to be preoccupied with the tools and instruments of physicists and

chemists. These are important to geology and must not be neglected, but neither should they be allowed to downgrade sound field facts and fundamental geological reasoning.

Most advances in mineral exploration have resulted from field work and the study of the geological environment as related to mineral deposits. We recommend re-emphasis of the field approach to mineral exploration in particular and to geological research in general.

An apparent tendency within universities to consider mineral exploration as merely a technique of secondary interest is regrettable. Research should be encouraged in the broad relationships between general geology and ore deposition. These relationships will not be found unless the approach is based on fundamental principles of geology-sedimentation, vulcanism, metamorphism, intrusive activity etc.

APPENDIX

Comments of Subcommittee Members

1. J.P. Nowlan writes as follows: "In Nova Scotia, shoreline studies of sedimentary basins from the Mississippian on still rank as one of our most important needs. However private companies are now waking up to the inherent possibilities from such work and several geologists representing industry are conducting such studies in one or more basins.

   "We are sponsoring one graduate student who is working on the relationship of limestone compositions to ancient shorelines in one basin of Cape Breton.

   "The second urgent need is for the dating of intrusions to permit sorting out their various ages from earliest Ordovician to (probably) post-Horton. This in turn will help us outline the various orogenic cycles in this part of the country."

2. C.S. Ney writes: "I suggest that the magnetization of intrusive or intrusive-like porphyries and granitoid rocks should be investigated for possible correlation with mechanism of intrusion and association with mineral deposits. W.G. Wahl wrote a paper[10] a few years ago in which the magnetic effects in and around three intrusive stocks were compared and related to the occurrence of mineral deposits in their vicinity. It seems to me that such an investigation would be worth pursuing on a more comprehensive scale.

"A few years ago one of our geologists mentioned that in aeromagnetic surveys of the Great Basin, the Nevadan intrusions presented little magnetic effects, whereas the Laramide intrusions were strongly indicated. Perhaps this fact indicates something more than magnetite content; it may well reflect mechanism of intrusion, cooling rate, magma source, etc.

"The striking difference between the Hanover stock and the Santa Rita stock at Silver City, New Mexico, both in magnetic effects and in associated mineralization always has seemed to me a significant clue to ore formation. I would think that the two stocks followed different lines of intrusive evolution.

"In some of the regional aeromagnetic maps of British Columbia and Yukon, I note that many mapped granitoid stocks fail to show up conspicuously in the magnetic pattern, while others not separately indicated in the map legend, and apparently surrounded by the same rocks, stand out boldly on the aeromagnetic map. Analysis of the remnant as well as the induced magnetization, by study of oriented cores, might yield valuable data, as it has in recent years for the extrusive rocks. The excellent aeromagnetic maps of the Cordillera in British Columbia, Yukon and Northwest Territories provide a great volume of data for research into the relations between magnetization, intrusive history, and mineralization."

3. J.F. Davies writes: "During the past few years we have seen some remarkable changes in emphasis in our ideas about the occurrence and origin of certain types of sulphide deposits. In particular, we note increasing attention to strata-bound sulphide deposits. Both syngeneticists and epigeneticists are among those concerned with strata-bound deposits. Amongst the syngeneticists are those who admit of redistribution or concentration of sulphides during metamorphism. Some of the epigeneticists are traditional "deep-seated" hydrothermalists, others refer to sulphide melts, and still others explain the strata-bound sulphides in terms of volcanic processes. In short, we find all shades of opinion regarding both the interpretation of features displayed by these deposits and their origin.

"We note also an increasing awareness of the relationship between certain kinds of mineral deposits and certain stages of the orogenic cycle; we see regional studies of the relationship between mineral districts and tectonics; and we see a renewed interest in metallogenic studies, and the compilation of metallogenic maps attempting to relate deposits to evolutionary geological processes. We have, then, a range from detailed studies of single deposits to local regional investigations to very broad country-wide metallogenic studies.

"The scope or scale of studies of mineral deposits depend to a large degree on where or for whom one works; it depends on both the geographical areas where one has gained experience, and on whether one works in a mine, in mineral exploration, in a university, or for a government survey. In each case the emphasis is different and this affects the worker's ideas on the occurrence and origin of mineral deposits. I suggest that progress into understanding mineral occurences could be made by teams of researchers composed of economic geologists with different backgrounds and wide experience in different regions who would be concerned with all levels of study from the most detailed to the very broadest.

"I feel that coordinated programs including many levels of research are much more productive than isolated programs limited by the capacity of one or two investigators. The team approach is common in other professions and necessitated by the increasing tendency towards specialization. Here is a situation where a Geological Research Institute could fill a need that no existing institution now fills – where geologists from various sources, including industry, could work together on common problems. There is no reason why such an Institute should limit itself to mineral deposits; it should embrace the whole of geological science, because all aspects are inter-related."

4. Paul E. Grenier makes the following two recommendations:

"1. In the general framework of studies undertaken by the Geological Survey of Canada in the Appalachian Geologic Province within Canada (Quebec, New Brunswick, Nova Scotia, Prince Edward Island and Newfoundland), it would be desirable to drill a certain number of deep bore-holes. This would allow scientists to get a better overall picture of the geology, especially the stratigraphy and tectonics of the Appalachian rocks. In proposing this, we mention the interesting results already obtained from Operation Muskox drilling. Such a study could be very useful also in exploration for petroleum and natural gas, as well as other mineral resources.

"2. It would seem desirable to make a greater number of accurate radioactive age determinations in Precambrian terrain, using various methods for comparison. I realize that this suggestion presents a number of problems, including the collection of suitable samples from the field and adequate laboratory facilities and personnel for making the determinations. To solve such problems, it would be best to combine the efforts of various organizations and institutes. Different groups doing geologic field work could collect samples according to predetermined standard procedures and submit them to

the proper laboratories for analysis. The interpretation of the results could then be made by one, or preferably several, scientists named by a committee.

"The practical applications of this research may not be very evident at present, but we are confident that time will show its true value."

5. Geochemistry

(a) We suggest that the geological Survey of Canada could play an important part in researching and publicizing geochemical exploration methods suitable for the various terrains of Canada. In particular, the application of geochemical prospecting to the Shield of Canada is not effective at present.

(b) Greater knowledge of the distribution of metals in glacial or other Pleistocene deposits might be a useful aid to prospecting.

(c) The comparatively recent development and application in the United States of geochemical methods for the detection of small quantities of gold has been successful in the discovery of finely divided gold, not easily concentrated in a panning dish. It is conceivable that within the greenstone belts of Canada, or in other formations which do not have the traditional appearance of gold-bearing veins or lodes, there may be sufficient quantities of gold for large-scale open-pit mining. With the development of new techniques, some research along these lines seems warranted.

Recent Conferences

1. A symposium on the origin of Strataform Deposits of Lead, Zinc, Barite and Fluorite sponsored by UNESCO and the IUGS was organized by the Society of Economic Geologists in cooperation with the Society of Mining Engineers of the A.I.M.E. in New York City, March 4-5, 1966. The symposium was followed by a field trip to the Mississippi Valley and other representative deposits[12]. Although there was no final agreement on the origin of the deposits, participants were able to observe a substantial number of prospecting criteria which are broadly applicable.

2. The Commission for the Study of Economic Elements in the Earth's Crust of the International Union of Geological Sciences, has been engaged in the construction of metallogenetic maps designed to show the known distribution of metals throughout the world. An attempt is being made to apply statistics to these compilations. A meeting of the committee was scheduled for New York some time in 1967.

3. The International Association on the Genesis of Ore Deposits held a meeting in St. Andrews, Scotland, in September 1967.

In general, it may be noted that the preoccupation of these international organizations is with the genesis of mineral deposits. Genetic understanding is eventually necessary, but for mineral exploration the compilation of the geological associations of the deposits is of primary importance.

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DISCUSSION OF REPORT

In discussion of the report several subcommittee members, although agreeing that field studies and particularly studies of the geological environment of ore deposits were important and perhaps more immediately helpful in mineral exploration, emphasized the importance also of laboratory-based physical-chemical studies. They considered the report unfair in belittling the value of the more academic studies of this type. Although not of as much immediate usefulness in mineral exploration, such studies had much to contribute to our understanding of geology and how ore deposits form. Eventually such studies would lead to important applications in finding new deposits.

Several members stressed that the prime purpose of the university is the teaching of basic science and that universities are not technological schools to train men for particular jobs. The opinion was expressed that although the petroleum industry considered basic training in geology essential, mining companies tended to expect more specialized technological training. It was also pointed out that the laboratory-instrumentation approach to geology was important and that modern geology needs both field and laboratory specialists.

In regard to the suggestion that formation of a geological institute "could fill a need for geologists from various sources to work on common problems" (p. 25), several members suggested that many Canadian universities with recent growth in faculties and facilities could, and were, serving as institutes; federal and provincial surveys could fulfill similar functions.

REPORT OF THE SUBCOMMITTEE ON MINERALOGY, GEOCHEMISTRY AND PETROLOGY

Presented by G. Perrault

Members of Subcommittee

Guy Perrault (Chairman)	Ecole Polytechnique, Montreal, Quebec.
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P. L. Roeder	Queen's University, Kingston, Ontario.
H. P. Schwarcz	McMaster University, Hamilton, Ontario.
A. J. Sinclair	University of British Columbia, Vancouver, British Columbia.

In addition to exchanging correspondence the subcommittee also met on Thursday, March 30, 1967, in Ottawa. Members wish to express thanks to the National Advisory Committee for providing funds for this meeting; it is pleasant to recall that this was one of the recommendations contained in the 1966 report of this subcommittee.

REVIEW OF CURRENT RESEARCH

Current research projects in fields of interest of this subcommittee are tabulated below for the past four years.

Category	Number of research projects			
	1966-67	1965-66	1964-65	1963-64
Mineralogy				
(1) Specific minerals	29	28	30	*
(2) General problems	27	23	41	*
Total	56	51	71	48
Geochemistry	108	116	121	95
Petrology and Petrography	110	113	141	122
Sedimentation	47	42	*	*
Geochronology	20	28	26	25
Grand Total	341	350	359	290

* not reported separately.

There has been no significant increase in the number of research projects over the past four years. However, if we consider the main publication media (Canadian Mineralogist, Canadian Spectroscopy, Canadian Journal of Earth Sciences, C.I.M.M. Bulletin, and Canadian contributions to American and international journals), the volume of reported research has increased appreciably in the current year. The backlog of papers is such that another increase is in sight for the forthcoming year. This improvement no doubt reflects the increased support research projects have been receiving from granting bodies over the past few years.

FUNDS FOR GRANTS

Expenses incurred in Canadian universities for geological research in 1967-68 and succeeding years will increase considerably because:

(1) 1966 and 1967 have been years of extensive acquisition of new equipment including microprobes, X-ray diffractors and fluorescence equipment, pressure-temperature-synthesis units, geophysical equipment, etc.

(2) Faculties in departments of geology have increased more rapidly in the last three years than before.

(3) Whereas a few years ago research was carried on by only a few members of departments of geology in Canadian universities, it is now a criterion of appointment.

(4) A large number of national and international meetings in the geological sciences was and will be held in 1967 and 1968, including the International Geological Congress in Prague in 1968. Funds should be available for the travel expenses of the large number of Canadian university geologists that will wish to attend.

In summary, there will be more research in geology and geological engineering departments of Canadian universities in 1967-1968 and succeeding years. This will call for more funds to support research in geoscience departments throughout the country.

ANALYTICAL STANDARDS

In our 1966 report, we recommended that –

(1) in the field of analytical standards, the efforts of geoscientists in Canada should, at present, be oriented mainly towards the establishment of rock-analytical standards;

(2) one of the responsibilities of this subcommittee should be to establish and maintain an up-to-date list of available standards of geological materials;

(3) Canadian geoscientists fully support the Non-Metallic Standards Committee of the Canadian Association for Applied Spectroscopy in its efforts to prepare, distribute and analyze standards of geological materials;

(4) further analytical standards of Canadian Shield rocks be developed, including an amphibolite facies rock, a greenschist facies rock and a basalt.

Listing of analytical standards

We present hereafter our revised list of standards of geological materials. The presentation has been modified to include additional data. Listing is alphabetical and by country of origin.

Bulgaria

1. Carpatho-Balkan Geological Association.

   B. Aleksiev,
   Carpatho-Balkan Geological Association,
   Bulgarian Academy of Sciences,
   Geological Institute,
   Sofia, Bulgaria.

   G-B. Bulgarian granite.

Canada

1. Canadian Association for Applied Spectroscopy.

   Non-Metallic Standards Committee,
   Prof. R. Webber,
   Supt. of Geological Sciences,
   McGill University, Montreal.

   Sulfide ore -1
   Syenite rock -1 (now exhausted)
   Mount Royal Gabbro, MRG-1 (in process).

East Germany

1. Zentrales Geologisches Institut.

   H. Grassman,
   Zentrales Geologisches Institut,
   East Berlin,
   German Democratic Republic.

   GM granite
   BM basalt
   TB argillite
   KH limestone

France

1. Centre de Recherches Pétrographiques et Géochimiques

   Messieurs H. de la Roche et K. Govindaraju,
   Nancy-Vandoeuvre,
   B.P. 682-54,
   Nancy, France.

GR granite monzonitique (exhausted)
GA granite banal
GH granite leucocrate
BR basalte à olivine
biotite ferrifère (in process)
actinote (in process)

2. Groupe Français des Argiles.

Mlle S. Gaillère,
23, rue de Cronstadt,
Paris 15e, France.

22766 sepiolite
22767 montmorillonite (plus kaolinite)
22769 montmorillonite
22768 polygorskite (plus 10 to 20% montmorillonite)
22770 kaolinite

Great Britain

1. British Chemical Standards.

Bureau of Analysed Samples Ltd.,
Newhall Hall,
Middlesborough, England.

Iron ore, BCS 175-1
Manganese ore, BCS 176-1
Lincolnshire iron ore, BCS 301
Northampshire iron ore, BCS 302
Iron ore sinter, BCS 303
Grecian chrome ore, BCS 308
Sillimanite, BCS 309

Switzerland

1. Schweizerische Arbeitsgemeinschaft für Steine und Erden.

Th. Hugi,
Mineralogisch-Petrographisches Institut der Universität,
Sahlistrasse 6, Bern, Switzerland.

"Liste der Referenzproben der Chemischen Abteilung der Technischen Stelle Holderbank der Bestimmung des Mineral-Bestandes." Offers a wide variety of rocks and minerals: feldspars, silicate minerals, amphiboles, pyroxenes, chlorites and chrysolites, micas, hydrated micas,

candites, smektite, carbonates, hydrated oxides minerals, calcium silicate and other Portland cement clinker materials and others.

Tanzania

1. Mineral Resources Division.

P. Bowlen,
Mineral Resources Division,
P.O. Box 903,
Dodoma.

T-1 Tonalite

Union of Soviet Socialist Republic

1. Zhadnov University

Prof. A. Kuokharenko,
Dept. of Geology,
Leningrad, V164.

Nepheline syenite (khibiny general).

United States of America

1. Frederick Smith Chemical Company.

P.O. Box 23344,
Columbus 23, Ohio.

GFS 450:)	
GFS 451:)	magnetite concentrate (Minnesota).
GFS 452:)	
GFS 453:)	
GFS 454:)	Hematite (Minnesota).
GFS 455:)	
GFS 456 - GFS 490:	magnetite-hematite blends.
GFS 400:	dolomite, Woodville, Ohio.
GFS 401:	limestone, Marble Cliff, Ohio.
GFS 402:	limestone, Spore, Ohio.
GFS 403 - GFS 419:	limestone-dolomite blends.

2. National Bureau of Standards (Washington).

Dolomite 88.
Argillaceous limestone.
Fluorspar.
Opal glass 91.
Feldspar 70.
Glass sands 81 and 165.
Soda Feldspar 99.
Flint clay 97.
Plastic clay 98.
Phosphate rock 120.
Lithium ores 181, 182, and 183.

3. U.S. Atomic Energy Commission.

New Brunswick Laboratory,
P.O. Box 150,
New Brunswick, New Jersey.

Uranium ores.

4. U.S. Geological Survey Rock Analytical Standards.

Mr. F.J. Flanagan,
U.S. Department of the Interior,
Geological Survey,
Washington, D.C., 20242.

a) Being analyzed:
   G-2 : granite, Bradford, R.I.
   GSP-1 : granodiorite, Silver Plume, Colo.
   ACV-1 : andesite, Guano Valley, Lake Co. Oregon.
   PCC-1 : peridotite, Cazadero quadrangle, Sonoma Co., Calif.
   DTS-1 : dunite, Twin Sisters, Washington.
   BCR-1 : basalt, Columbia River (Yakima type), Multnoman Co., Oregon.

b) In process:
   STM-1 : nepheline syenite, Table Mountain, Tidewater quadrangle, Lincoln Co., Oregon.
   SCO-1 : shale, Cody, Edgerton quadrangle, Natrona Co., Wyoming.
   SDC-1 : mica schist, Rock Creek Park, Washington, D.C.
   MAG-1: terrigenous marine mud, Wilkerson Basin, Gulf of Maine, Atlantic Ocean (42°34.6'N, 69°32.6'W).
   ------ : obsidian (field name), Glass Mountain, Calif.
   ------ : quartz latite or dacite (field name), Lake Co., Oregon.

GSM-1: gabbro, San Marcos; Rancho Santa Fe quadrangle, San Diego Co., Calif.
TLM-1: tonalite, Lakeview Mountain, Perris 7 1/2 minute quadrangle, Riverside Co., Calif.
------: quartz, mostly optically clear; shipped from Brazil during World War II.
------: garnet, placer; Hampton Creek, White Pine Co., Nevada.

c) Formerly available:
G-1: granite.
W-1: diabase.

Possible Future Canadian Developments

Various projects to develop more analytical standards are under consideration.

(1) Pyrochlore standard, to be developed by Guy Perrault. This standard might serve as a reference to commercial operations in pyrochlore concentrates. It will be a particularly challenging type of analysis in many respects, because the material contains many rare elements.

(2) Canadian Shield rocks. There is particular interest in development of analytical standards for an amphibolite facies rock, a greenschist facies rock and a basalt.

(3) Volcanic rocks. Members of the Volcanology Subcommittee of N. R. C. Associate Committee on Geodesy and Geophysics plan to develop standards of typical Canadian volcanic rocks, and restrict the circulation of this material to ten or fifteen Canadian laboratories. It is planned to develop approximately six standards of volcanic rocks. These materials will be made available to individual laboratories in lots of 10 to 15 pounds so that the material may be used repeatedly as a constant reference to the performance of analytical instruments.

Microprobe Standards

Canadian university geoscience departments have acquired six microprobes over the past two years. Many other research institutions interested in earth material have also acquired microprobes. Mineral standards would help those using microprobes. A Canadian association of microprobe users is being formed. This group might review and advise on the development of standards, perhaps as an affiliate of the Mineralogical Association of Canada or the Canadian Association of Applied Spectroscopy.

LIAISON WITH SUBCOMMITTEE OF THE N.R.C. ASSOCIATE COMMITTEE ON GEODESY AND GEOPHYSICS

During 1966-67, this subcommittee, through its chairman, established liaison with the Subcommittee on Volcanology and the Subcommittee on Isotope Studies and Geochronology of the Associate Committee on Geodesy and Geophysics. This liaison took the form of attendance at the 47th and 48th meetings of the A.C.G.G. (Oct. 28, 1966, and Feb. 23, 1967), and attendance at the Volcanology Subcommittee meeting (Oct. 27, 1966). It is regrettable that we were unable to attend the Isotope Studies and Geochronology.

The chairman of this subcommittee is now an ex-officio member of the Isotope Studies and Geochronology Subcommittee of A.C.G.G. We recommend, in return, that the chairmen of A.C.G.G. Subcommittees on Volcanology and on Isotope Studies and Geochronology be appointed ex-officio members of Subcommittee on Mineralogy, Petrology and Geochemistry of the National Advisory Committee.

FUTURE MEMBERSHIP OF THIS SUBCOMMITTEE

There are no strict rules as to maximum number of members on N.A.C. subcommittees, but there is an accepted policy that ten is the maximum if the subcommittee is to meet once a year. Present members of this subcommittee feel this policy should be continued.

It may be advisable for the continuity and effectiveness of the work of this subcommittee to formalize the manner of nomination and the term of office of subcommittee members. With special respect to this subcommittee, members recommend that subcommittee members be appointed for three-year terms and that one third of the membership be appointed yearly. With respect to subcommittees as a whole we recommend that the National Advisory Committee consider the advisability of approving appointments to the various subcommittees. This would have certain advantages, in that membership in individual subcommittees would be more widely known in better time. It would thus be easier to relate the work of one subcommittee to that of the other. It might be possible also to distribute the subcommittee work more evenly.

MEETINGS AND SYMPOSIA IN MINERALOGY, PETROLOGY AND GEOCHEMISTRY

The number of meetings and symposia in the fields of this subcommittee held by the various scientific and professional societies is large and

growing with the increasing amount of fundamental and applied research in geological sciences. The following meetings are known to members of the subcommittee:

Canada:

1967:

Aug. 19, Sept. 6:	G. A. C. -M. A. C.: meeting in Kingston, Ont., symposium on age relations in high-grade metamorphic terrains.
Fall:	Microprobe users' meeting.
June 19-23:	XIII International Colloquium Spectroscopium, Ottawa.

1968:

Spring:	C. I. M. M. -M. A. C. -G. A. C. (?), annual meeting in Vancouver.

1969:

June:	Joint meeting M. A. C. -G. A. C., symposium on Monteregian hills alkaline rocks.
	Symposium on Flysch sedimentation, Montreal.
	Possibly another symposium on cherty iron formations (time and place to be determined).

U. S. A.:

1967:

April 28:	Society of Independent Professional Earth Scientists, annual meeting, Dallas, Texas.
May 1-2:	Institute on Lake Superior Geology, East Lansing, Mich.
May 10-13:	Rocky Mtn. Section of G. S. A., annual meeting in Golden, Colo.

May 23-26:	Alaska A.I.M.E., British Columbia C.I.M.M., symposium on the North's Mineral Resources. U. of Alaska, College, Alaska.
August 9-11:	Denver Research Institute, applications of X-ray analysis, Denver.
August 20-25:	Am. Crystallographic Association, symposium on crystal growth, Minneapolis.
August 24-30:	Int'l conference on stratigraphy and structure affecting continental drift in North Atlantic, Columbia U., New York.
August 28-31:	Clay Minerals Society and North American Clay Minerals Conference, Golden, Colorado.
October 1-4:	A.I.M.E. and S.P.E. fall meeting, Houston, Texas.
October 5-7:	Am. Institute of Professional Geologists, Houston.
October 13-15:	New England intercollegiate geological conference and field trips, Amherst, Mass.
October 19-21:	Symposium on exploration drilling, Minneapolis.
November 20-22:	Annual meeting, G.S.A., M.S.A., S.E.G., New Orleans.
December 26-31:	Annual meeting, A.A.A.S. New York City.

1968:

February:	S.E.G., annual meeting, New York.
Sept. 29, Oct. 2:	S.E.G., annual international meeting, Denver.

Other (Europe, Africa, Asia, South America):

1967:

May 8-10:	Int'l Association of Geochemistry and Cosmochemistry, symposium on origin and distribution of elements, Paris.

August 11-15:	Int'l Sedimentological Congress, Reading, England.
September 11-16:	Int'l Union of Geodesy and Geophysics, Zurich, Switzerland.
Sept. 19, Oct. 21:	Symposium on development of water resources, The Hague, Netherlands.
October 1-14:	Field symposium on the granites and basement of NE Brazil and their comparison with those of W. Africa, Recife, Brazil.
October 16-19:	Symposium on continental drift, Montevideo.
1968:	
January 24-31:	Congress of Australian and New Zealand Association for Advancement of Science, Christchurch, N. Z.
August 19-28:	Int'l Geological Congress, Prague.
	Possibly also Int'l Mineralogical Association at the same time and place.

There are no doubt many more symposia and meetings scheduled or to be scheduled in the near future. Mineralogists, petrologists and geochemists are probably closer in their research activities to the fundamental and applied sciences, chemistry and physics, than most other branches of geology, but to enumerate the relevant meetings and symposia in pure and applied physics and chemistry would make the above list considerably longer.

The big event in 1968 will no doubt be the International Geological Congress in Prague. In this respect, this subcommittee recommends that steps be taken to insure that adequate travel funds be available to earth scientists in Canadian university departments to participate in this meeting and represent Canada in the affairs of the International Union of Geological Sciences.

REFEREEING OF APPLICATIONS FOR GRANTS

In general, funds for research in the United States (e.g., National Science Foundation funds) are alloted after some considerable refereeing of applications for grants by scientists most closely associated with the area of research outlined. Our principal granting bodies in geological sciences in

Canada might possibly modify their manner of review of applications for grants in this direction. Members of this subcommittee consider it would be well if responsible officers of the National Advisory Committee studied the manner of allocation of research grants in geosciences in Canada.

SUMMARY AND CONCLUSIONS

1. This subcommittee acknowledges the financial assistance given by the National Advisory Committee for meeting once a year, a recommendation contained in our 1966 report.

2. This subcommittee predicts that there will be more research in the various geoscience departments of Canadian universities, particularly from 1967 to 1970, because faculties have expanded considerably in the last two years; research ability is more now than ever before a criterion of appointment to geoscience faculties; and there has been extensive acquisition of scientific instruments in the last two years.

3. In view of the probable increase in research, and the importance of geological research in training professionals for our mineral industry this subcommittee recommends that the Geological Survey funds for research grants to universities be increased considerably.

4. Progress in the preparation and distribution of rock-analytical standards has been slight in 1966. A revised list of available rock-analytical standards is presented.

5. This subcommittee continues its liaison with subcommittees of the Associate Committee on Geodesy and Geophysics.

6. This subcommittee recommends that members of the subcommittee be appointed for three-year terms; that one third of the membership be appointed yearly; and that the chairmen of the subcommittees on Vulcanology and of Isotope Geology and Geochronology of the N. R. C. Associate Committee on Geodesy and Geophysics be appointed ex-officio members of this subcommittee.

7. This subcommittee recommends that the National Advisory Committee consider the advisability of approving appointments of members to the various subcommittees.

8. This subcommittee recommends that steps be taken to ensure that adequate travel funds are available to earth scientists on the faculties of Canadian universities to participate in the International Geological Congress and the meetings of the International Union of Geological Sciences in Czechoslovakia in 1968.

DISCUSSION OF REPORT

In presenting the report, Perrault emphasized that although many rock-analytical standards were available or being developed in the United States, Canadian rock-analytical standards were also needed and should be developed. Other members mentioned the need for radiometric and microprobe standards.

REPORT OF THE SUBCOMMITTEE ON QUATERNARY GEOLOGY

Presented by W.H. Mathews

Members of Subcommittee

W.H. Mathews (Chairman)	University of British Columbia, Vancouver, British Columbia.
L.A. Bayrock	Research Council of Alberta, Edmonton, Alberta.
I.C. Brown	Water Research Branch, Ottawa, Ontario.
W.D. Brueckner	Memorial University of Newfoundland, St. John's, Newfoundland.
E.A. Christiansen	Saskatchewan Research Council, Saskatoon, Saskatchewan.
C.B. Crawford	National Research Council, Ottawa, Ontario.
A. Dreimanis	University of Western Ontario, London, Ontario.
J.A. Elson	McGill University, Montreal, Quebec.
Lockhart Gray	Water Control and Conservation Branch, Winnipeg, Manitoba.
P.F. Karrow	University of Waterloo, Waterloo, Ontario.
W.O. Kupsch	University of Saskatchewan, Saskatoon, Saskatchewan.
J. Ross Mackay	University of British Columbia, Vancouver, British Columbia.
R.H. MacNeill	Acadia University, Wolfville, Nova Scotia.

Raymond Roy	Department of Natural Resources, Quebec City, Quebec.
A. MacS. Stalker	Geological Survey of Canada, Ottawa, Ontario.
A.K. Watt	Ontario Water Resources Commission, Toronto, Ontario

The chairmanship of this subcommittee was transferred in August, 1966, from W.O. Kupsch, who had served most effectively since 1963, to W.H. Mathews. Membership of the subcommittee is otherwise unchanged.

Business of the subcommittee was carried on entirely by mail; it is discussed below under appropriate headings. This included items passed on from the Ottawa meeting of April 16, 1966; new items requested by the chairman of the National Advisory Committee; and a survey of research in the Quaternary field undertaken during the past year.

N.R.C. ASSOCIATE COMMITTEE ON QUATERNARY RESEARCH

Establishment of an Associate Committee on Quaternary Research of the National Research Council was recommended at the 1966 meeting of this subcommittee and subscribed to by the National Advisory Committee at its annual meeting, April 1966. It was considered and approved by the National Research Council in the fall of 1966.

A preliminary meeting of the new associate committee was held in February, 1967, to consider its scope, objectives, and activities, as well as its full membership and relationships with other organizations. This initial meeting was held under the chairmanship of J.G. Fyles, Geological Survey, and included also R.J.E. Brown, National Research Council, J.D. Ives, Geographical Branch, W.E. Taylor, National Museum, and W.H. Mathews, University of British Columbia. W.T. Meyer-Oakes, University of Manitoba, the sixth appointee, was unable to attend. Additional appointees were recommended to bring the associate committee to approximately 16 members and to represent Quaternary research in the fields of botany, zoology, geology, geography, archaeology, palaeoclimatology, pedology, and geocryology. Final recommendations on activities and relationships with other committees, however, were deferred until the additional members are approved by National Research Council and have an opportunity to meet.

The formation of this new organization will, we hope make Quaternary geological research more fruitful in Canada, both by increasing the awareness of geologists to the needs, problems, and accomplishments of other disciplines, and vice versa. It may prove desirable that the annual

summary of Quaternary geological research, appearing as an appendix to this report, be incorporated in a broader interdisciplinary report published by the new associate committee. We believe, however, that the more specialized problems of promoting purely geological research in the Quaternary should continue as the prime responsibility of the present subcommittee, albeit with encouragement from the associate committee as well as from the National Advisory Committee.

DISSEMINATION OF INFORMATION

Dissemination of information on opportunities in Quaternary geology has been placed in the hands of a small subcommittee consisting of A. MacS. Stalker (chairman), P. F. Karrow, and L. A. Bayrock. This problem seems, however, to be one best undertaken in conjunction with the Subcommittee on Scholarship and Research Training of the National Advisory Committee, and to this end we have been in touch with R. Sabourin who is requesting material for a booklet covering opportunities in all geological fields in Canada. Some information has already been sent to him, but no doubt other submissions would be welcomed.

URBAN GEOLOGY

Urban geology, a topic which engaged considerable attention in last year's discussions of the subcommittee, has not progressed at all satisfactorily. Only in Edmonton, Saskatoon, and St. John's has there been an adequate effort to keep up with developments and provide some synthesis of observations. Elsewhere the urban studies are insufficient to meet needs and opportunities or are completely lacking.

The ruling that urban geology is regarded by the Federal Government as a provincial or municipal responsibility has not, it seems, promoted any significant new activity by the latter two levels of government. It appears that the responsibility is not one to be passed on, but rather one to be shared cooperatively according to the distribution of qualified personnel. Most municipal organizations lack any geological workers and could, at least to start with, provide only raw data such as drill logs. Provincial as well as federal surveys or research councils can provide continuous and effective technical assistance only when they have qualified men in residence in the urban centres in question.

Civil engineering and geological consultants can provide a great deal of help in urban studies, but all too many fail to appreciate the advantages of interchange of information and of filing records in a central office accessible to all. A great deal of missionary work is still required to overcome the suspicions and professional jealousy at this level.

GREAT LAKES GEOLOGY

Mapping of geology under the Great Lakes, another recommendation arising from last year's meeting, will, we hope, be undertaken in conjunction with other Great Lakes studies being planned by the Inland Waters Branch, Department of Energy, Mines and Resources, with assistance from the Geological Survey.

MARINE GEOLOGY, WEST COAST OF CANADA

The chairman of the NAC has solicited the views of this subcommittee and the Subcommittee on Stratigraphy, Palaeontology, and Sedimentation on marine geology studies on the west coast. This question has arisen in part because no government agency has yet undertaken serious studies in marine geology on the Pacific Coast of Canada, notwithstanding extensive work on the Polar Continental Shelf, the Atlantic Coast (particularly out of the Bedford Institute) and shortly, we trust, in the Great Lakes. Interest in West Coast studies is being spurred by the petroleum exploration there by such companies as Shell Oil, British-American Oil and Pan-American Oil, all of which hold both federal and provincial permits on the continental shelf or in inshore marine waters. It was further stimulated by the discovery last year of a mantle of manganese nodules in a small area of the floor of one of the west cost fiords. Finally, it should be added, rival claims by provincial and federal governments to the rights over offshore oil and mineral deposits have aroused much public interest.

To date marine geology on the west cost has been undertaken almost exclusively by members of the University of British Columbia, with field support provided by the Federal Government. Studies have included reconnaissance surveys of bottom deposits in Dixon Entrance, the Strait of Georgia, Queen Charlotte Sound, and the west coast of Vancouver Island as well as more detailed surveys in several inlets and off the delta of Fraser River. Sparker and seismic surveys in the Straits of Georgia and Juan de Fuca have also been carried out.

In response to the request for suggestions we offer the following topics for research:

(1) A study of marine processes, including the evolution of deltas, the influence of organisms on sedimentation, the effects of pollution and (if this is considered a marine feature) the character and origin of the strandflat. The discrimination of tectonic, volcanic, sedimentary, and erosional processes on the topography of the sea floor may also be considered.

(2) An investigation of the Pleistocene record of the sea bottom: the correlation of bottom deposits with terrestrial beds on the nearby land;

the placing in proper sequence and, if possible, the dating of distinctive ash beds which might aid in terrestrial stratigraphy; the establishment of the offshore limits of glacial erosion and of ice rafting; the continued study of magnetic reversals and of ocean-floor spreading along the presumed crest of the east Pacific Rise west of British Columbia; a study of the magnetic, lithologic, and palaeontologic record near the Pliocene-Pleistocene boundary.

(3) A comparison of the geology of the seabed with that of the adjacent land, including: an analysis of source disposition of key minerals derived from the land and accumulated in the marine sediments; the tracing of map-units from the land out under the sea; mapping the extent and character of the east Pacific Rise northward under the continental margin.

Continued expansion of its marine-geology program is planned by the University of British Columbia for the inland waterways and the continental shelf. The studies will, however, be confined to areas less than one day's ship travel time from Vancouver and to problems with scope appropriate for Master's and Doctor's theses. The more distant, extensive, and time-consuming problems in marine geology, particularly those in deep water off the continental slope, will not soon be solved unless full-time personnel, such as could be provided by the Federal Government, is assigned to the task. Such personnel should work in close contact with geologists studying the adjacent land areas. Your subcommittee chairman suggests that to achieve maximum effectiveness in studies such as are proposed here this personnel should share office quarters with the land-based geologists rather than with physical and biological oceanographers in an oceanographic institute.

RECENT INTERNATIONAL MEETINGS

Among recent international meetings of concern to Quaternary geology the San Francisco meetings of the Geological Society of America (November, 1966) were outstanding. Subjects of particular interest discussed at this conference include: the three-million year old date for an early glaciation in the Sierra Nevada, the palaeomagnetic time scale in late Tertiary and Quaternary time, and the hypothesis combining magnetic reversals with ocean-floor spreading to account for the magnetic patterns on the sea floor west of British Columbia and southwest of Iceland.

CURRENT RESEARCH IN QUATERNARY GEOLOGY

The attached appendix lists activities in the Quaternary field which have been brought to the attention of the subcommittee. Because of a change in the chairmanship of the subcommittee, probable inconsistencies with former procedures in classifying projects, and possible changes in the diligence of the subcommittee in seeking out projects, no statistical comparisons with

those of the past few years seem justified. Notwithstanding this word of caution, it does seem that the total manpower spent in Quaternary research has increased significantly in the past few years, particularly in the field of hydrogeology.

APPENDIX

REVIEW OF CURRENT RESEARCH, 1966

The following presents brief statements of research work being undertaken in the various territories and provinces during 1966, based in large part on submissions from members of the Quaternary subcommittee. Though the list covers much of the work in Quaternary geology, members of the subcommittee may not have been advised of all projects, hence no claim of completeness can be offered.

Northwest Territories

J.G. Fyles, geological Survey of Canada, continued Quaternary stratigraphic studies in the Mackenzie-Delta-Arctic Coast region (N.W.T. and Y.T.), made a brief study of the Winter Harbour moraine of Melville Island with logistic support from the Polar Continental Shelf project, and, jointly with B.G. Craig, carried out a preliminary reconnaissance of eskers in the Dubawnt-Thelon area west of Hudson Bay.

J. Ross Mackay, University of British Columbia, went down the Mackenzie River by boat in the first two weeks of June and continued his observations on boulder pavements, flooding, terraces, and permafrost. He spent the rest of the summer at Barry Island. A lake 500 by 1,000 feet was lowered three feet to examine the lake bottom. The deformation of ground in an ice-wedge area was measured by precise surveying of deformed tubes. Heat-balance studies of hummocks were carried out. Estimates of permafrost depth from Arctic Red River north were made from measurements of temperatures in nine 50-foot holes, two 200-foot holes, and one 250-foot hole.

D.E. Kerfoot, University of British Columbia, continued his previous studies, already reported for 1964 and 1965.

D. Gill, University of British Columbia, started detailed investigations of flooding and sedimentation near Reindeer Station, Mackenzie Delta.

O.L. Hughes, Geological Survey, made a brief examination of an archaeological site at Fisherman Lake near Fort Liard.

Z. Hog, University of Alberta, is investigating the Pleistocene stratigraphy of the Pine Point Area, under the supervision of J. Westgate.

Samples were obtained for a dendroclimatological study supported by the Geological Survey from a northern tree-line location east of Great Slave Lake.

O. Løken continued the Geographical Branch glaciology program on the Lewis and Decade Glaciers, Baffin Island, with emphasis on mass balance and glacier processes.

M. Church, University of British Columbia, began a study of geomorphology and sedimentation on sandurs in the Ekalugad Fiord area on the east coast of Baffin Island in a project supported by the Geographical Branch.

W. Blake, Jr., Geological Survey, prepared a preliminary report on end moraines and deglaciation chronology of Southern Baffin Island.

B.G. Craig, Geological Survey, is preparing a memoir on the surficial geology of northwestern Baffin Island.

R. King, Ph.D. candidate at the University of Saskatchewan, initiated a study of periglacial features and origin of soils in the vicinity of the Cape Sparbo camp of the Arctic Institute on Devon Island.

J.R. Weber, Observatories Branch, remeasured the relative positions of 14 poles across the crest of the Penny Icecap, Baffin Island, and measured differences in gravity between the poles and "Gravity Base." Snow characteristics were measured at the centre station and 15 stakes across the outlet glacier were relocated for measurement of movement and ablation.

G. Hattersley-Smith, Defence Research Board, is continuing his glaciological studies in northwestern Ellesmere Island.

Yukon Territory

O.L. Hughes, Geological Survey, continued investigating the limits of successive glaciations and other aspects of Quaternary geology in southwest Yukon, concentrating in the Aishihik Lake map-area.

V. Rampton, Geological Survey, continued investigation of Quaternary geology in the Snag area, involving a transect from the present glacier terminus to the all-time limit of glaciation. This study, under the supervision of O.L. Hughes, will be used for a Ph.D. thesis at the University of Minnesota.

K. Ricker, University of British Columbia, continued compilation of his data on the glacial geology of the North Klondike-Blackstone Valley.

O. L. Hughes collected samples for a dendroclimatological study in central Yukon Territory.

J. F. Lerbekmo, University of Alberta, and F. A. Campbell, University of Calgary, are continuing a study of size distribution and composition of the Recent White River ash deposit.

The Icefield Ranges Research Project, Arctic Institute of North America, continued work in S. W. Yukon with the following studies:

(1) A reconnaissance of a medial moraine of Kaskawulsh Glacier, including measurements of profiles and ablation stakes, and air photography.

(2) A morphological analysis of streams on a glacier surface, including the pattern and evolution of streams as related to weather, ice structure, etc.

(3) A reconnaissance of beach morphology along 1,000 metres of shoreline of Kluane Lake adjacent to the base camp to determine changes in the location of the shoreline and transport of beach materials over a period of years.

(4) An examination of four rock glaciers, with stations marked and located relative to a local survey net, the dating of trees on and adjacent to three of the glaciers, and an investigation of block orientation on two.

(5) Collection of snow and ice samples for analysis of Ca, Na, Mg, K and Pb-210.

(6) Establishment of seven photogrammetric bases and nine camera stations around the terminus of Kaskawulsh Glacier to permit future monitoring of changes in its shape and drainage.

(7) An investigation of the surge of Steel Glacier which apparently started in 1965 and was continuing into 1967. With cooperation from the Surveys and Mapping Branch, air photography was undertaken in August and September 1966 and continued through the autumn and early winter.

British Columbia

J. W. Murray and D. Tiffin, University of British Columbia, undertook sparker surveys of the floor of the Strait of Georgia which are providing new information of distribution, thickness, and structure of Pleistocene and postglacial sediments.

J. W. Murray and R. Macdonald initiated a survey of bottom deposits of Jervis Inlet which, among other things, produced the first known occurrence of manganese nodules within a west coast fiord.

P. Kellerhals and J. W. Murray completed a survey of the ecology and sedimentation of the intertidal zone of Boundary Bay, on the southern inactive side of the Fraser River delta. Results were presented in a paper read to the AAAS in December 1966.

J. W. Murray also completed work on the bottom deposits of Howe Sound, including, with H. V. Warren and R. Delavault, an analysis of the distribution of certain trace elements within the sediments.

H. Nasmith, Thurber and Associates, Victoria, W. H. Mathews and G. E. Rouse, University of British Columbia, completed a study of the distribution of the postglacial Bridge River ash in South-central British Columbia. Results are published in the February 1967 issue of the Canadian Journal of Earth Science.

G. E. Rouse is also studying the postglacial pollen stratigraphy of Marion Lake, near Heney, and A. W. L. Stewart, University of British Columbia, working with Rouse, is analyzing fungal remains in the postglacial Camosun bog at Vancouver.

K. Piel, University of British Columbia, is continuing work on Tertiary and Pleistocene pollen near Prince George.

Miss J. Ryder and Miss L. Anderton, University of British Columbia, have been mapping postglacial terrace deposits and alluvian fans in the Thompson River valley between Lytton and Ashcroft.

J. R. Mackay and W. H. Mathews, University of British Columbia, are continuing studies on soil movement and snow creep in the Garibaldi Lake and Mount Seymour areas.

W. H. Mathews has also continued studies on glacier budgets and the catastrophic drainage of an ice-dammed lake in the Stewart area.

Quaternary research undertaken by the Water Investigations Branch of the British Columbia government include the following projects:

(1) The drilling of five deep rotary holes to Tertiary bedrock in the Cloverdale area, supervised by J. C. Foweraker.

(2) The drilling of one rotary hole to 1,215 feet near Armstrong, supervised by E. Livingstone.

(3) The drilling of five rotary holes south of Creston, supervised by E. Livingstone.

(4) The drilling of a cable-tool as a test hole and test well at Malcolm Island, supervised by J.C. Foweraker.

(5) Geological mapping and the drilling of four test wells into Quaternary and Tertiary deposits southeast and southwest of Prince George, supervised by J. McCallum.

(6) The drilling of shallow rotary drill holes in the search for aquifers along the east side of Okanagan Valley between Okanagan Falls and Oyama, yielding some interesting data on Pleistocene deposits up to elevations of about 2,300 feet, supervised by E. Livingstone.

Other local mapping projects were carried out in the Okanagan Valley near Creston, in the western Peace River block, near Ashcroft, and around Mission.

Quaternary research undertaken by the Inland Waters Branch, Department of Energy, Mines and Resources included:

(1) Drilling of a 987-foot test hole in the Nicomekl-Serpentine Valley for stratigraphic interpretation of the flow systems. Three piezometers were installed in an upper clay unit. Flow systems are being studied in relation to tidal and flooding effects. E.C. Halstead was in charge.

(2) A small drainage basin on top of Mount Kobau, the site of the Queen Elizabeth Observatory, was being studied to learn about groundwater recharge on the mountain top. E.C. Halstead was in charge.

(3) In the Trapping Creek basin additional piezometers and water-table wells were installed to study underflow near the mouth of the basin and to start a study of groundwater flow in shattered bedrock on the mountainsides near the outlet. Mapping of surficial deposits was done and water-quality and stream-flow measurements taken. D.W. Lawson was in charge.

(4) Glacier studies across the Cordillera were expanded to include three glaciers in British Columbia – the Sentinel, Place and Woolsey – and two in Alberta – the Peyto and Ram. Readings were made to allow for calculation of the mass balance by several different means; instruments are being designed for further studies of glacier environment and processes. A.D. Stanley was in charge.

R. J. Fulton, Geological Survey, continued investigations of Quaternary geology in the Columbia River valley in areas to be affected by the Columbia Treaty dams. Much of the work was concentrated in the vicinity of Duncan dam.

M. J. Pullen, Geological Survey, a graduate student working under R. J. Fulton, completed field work for a study of sedimentation at the head of Upper Arrow Lake.

G. W. Smith, Geological Survey, began a Ph. D. thesis project in the Mable Lake-Shuswap River area on Quaternary geology to supplement Fulton's earlier work to the west.

Seismic investigations of drift thicknesses in valleys in the southern interior of British Columbia have been undertaken through the Geophysics Division of the Geological Survey in support of Fulton's program.

Fulton has continued petrographic investigation of volcanic-ash samples from the southern Cordillera, has submitted final maps of the Vernon area for publication, has completed a paper on interglacial stratigraphy at the Duncan dam and is preparing a memoir on the Vernon and Nicola areas.

S. F. Leaming, Geological Survey, commenced an inventory of surficial deposits and landforms in the Prince George area to meet a request from the British Columbia ARDA committee. This work is under the supervision of J. E. Armstrong.

N. W. Rutter, Geological Survey, commenced a reconnaissance of the Quaternary geology of the Peace, Parsnip, and Finlay valleys to obtain information in advance of flooding by the Peace River dam.

J. Terasmae, Geological Survey, undertook a study of modern pollen deposition in relation to present vegetation in south-central British Columbia. With H. C. Fritts of the Laboratory of Tree-Ring-Research, University of Arizona, he also initiated a dendroclimatological study in the Kamloops-Vernon area.

D. C. Ford, McMaster University, is continuing a study of the characteristics and history of the Nakimu Caves, in the Glacier National Park.

R. M. Quigley, University of Western Ontario, has been working on the clay mineralogy, physico-chemistry, and consolidation properties of fresh water and marine clays near Prince Rupert.

Alberta

Field mapping has been carried out in many parts of the province by different agencies during 1966. The Geological Survey of Canada continued mapping of surficial deposits in the Iosegun area (83 K – D. St-Onge) and easterly into the Whitecourt area, including the Swan Hills. It also supported work on the surficial deposits of the Bow River valley west of Calgary (82 D – N. Rutter). The Research Council of Alberta concentrated its main endeavor in mapping of the Medicine Hat sheet (72 L – T. Berg) and completing the mapping of the Edson-Hinton area (83 F – D. Roed). Field checking of previously mapped but unpublished areas was also carried out. East half of the Wainwright area (73 D – L. Bayrock) was in final stages of preparation for publication.

Groundwater investigations, although not primarily concerned with Quaternary deposits, in many cases involve an evaluation of surficial deposits. The Grinshaw area (SW 1/4 of 84 C – O. Tokarsky) was mapped in some detail. D.R. Stevenson continued a groundwater study of the Marmot Creek basin for his M.Sc. thesis as well as undertaking similar studies elsewhere in Alberta for the Alberta Research Council. Other aquifer studies were carried on for the Research Council by J. Toth, in the Three Hills area, by W. Turner near Red Deer, and by A. Vandenberg near Redcliff and in the Hand Hills.

Subsurface mapping of the area of the City of Edmonton was continued in cooperation with the City Engineering Department.

A study on the composition and variations of composition of surface tills of the Province of Alberta was in final stages of compilation (S. Pawluk, University of Alberta, L.A. Bayrock, Research Council of Alberta). Maps of the following parameters have been constructed with the help of IBM 1640 and 1620 computers: Content of Fe, CaO, Zn, Cu, Mg, Mn, Co, B, soluble salts, and clay minerals. Studies of the engineering properties of till, such as liquid limit, plastic limit, and plasticity index, have been carried out. It is significant that most of the distributions of the above-mentioned parameters are related to the immediately underlying bedrock.

Periglacial structures in pre-glacial but Pleistocene deposits (Saskatchewan Gravels and Sands) are being studied by T. Berg, Research Council of Alberta. Preliminary results, based on fossil sand wedges, indicate that the climate of Central Alberta was cold and arid before the advance of the continental glacier.

The study on sedimentation of Saskatchewan Gravels and Sands has been completed (A. Allong, University of Wisconsin, M.Sc. thesis).

Vertebrate palaeontology of the Quaternary has received considerable attention during the past year. J. Hillerud, University of Nebraska, completed

the study of the Duffield site. His major conclusion is that Bison occidentalis should be classified as a subspecies of Bison antiquus, i.e., B.a. occidentalis. T. Reimchen made a large collection of fossil vertebrates from Saskatchewan Gravels and Sands. Currently he is engaged in speciation of the finds. A. Mac.S. Stalker, Geological Survey, and R. Churcher, University of Toronto, conducted extensive excavations for Quaternary vertebrate fossils in southern Alberta in conjunction with Pleistocene stratigraphic studies of southeastern Alberta and are working on papers dealing with Bow River terraces at Cochrane and mid-Wisconsin early man at Medicine Hat. Stalker also completed a memoir on the surficial geology of the Drumheller area and is working on papers on surficial geology of the Kananaskis Forestry Station and on the Saskatchewan Gravels and Sands.

During 1966 the Groundwater Division, Research Council of Alberta, continued work on buried channels under glacial drift in a number of localities, including Stavely, Edmonton, Two Hills, Edson, High Prairie, Lethbridge, Devon, Crawling Valley and Keg River. Bedrock topography mapping is under way in the following areas: Edmonton, Drumheller, Peace River and Edson.

M.J.J. Bik, Geographical Branch, Department of Energy, Mines and Resources, has been conducting research on the origin of "prairie mounds" or doughnut-shaped hills in southern Alberta.

J. Westgate, University of Alberta, is currently engaged in a number of projects concerning Quaternary deposits of Alberta. In conjunction with A. Dreimanis, University of Western Ontario, he is studying Quaternary volcanic-ash deposits of Alberta. Dreimanis also began till-fabric studies in the recent flutings of moraines of the Saskatchewan Glacier. The Saskatchewan Gravels and Sands of the Peace River area are being investigated by J. Westgate and R. Green, Research Council of Alberta. Under the supervision of J. Westgate, J. Ramsden is investigating Pleistocene stratigraphy of the Edmonton area. The lithology of tills in southeastern Alberta is being studied by J. Westgate.

D.L. Delorme, Inland Waters Branch, continued his studies of Pleistocene and postglacial ostracods in Alberta.

P. Meyboom, Inland Waters Branch, installed instruments to start measuring evapotranspiration from a mountain bog and collected data for construction and interpretation of water-table maps as part of the Kananaskis wet-land study.

L.V. Hills, University of Calgary, is continuing a quantitative study of Alpine landforms for his M.Sc. thesis.

Saskatchewan

J. E. Wyder, University of Saskatchewan and Geological Survey, continued to study geophysical methods in locating gravel deposits in glacial successions and to delineate the contact between glacial and pre-glacial sediments. A map of the location of the pre-glacial Missouri River channel has been prepared as part of his work.

J. A. Vonhof, University of Saskatchewan and Geological Survey, is investigating characteristics of pre-glacial stream deposits of Western Canada. He also published his work Water Quality Determination from Spontaneous-Potential Electric Log Curves, undertaken while employed by the Saskatchewan Research Council.

R. W. Klassen, Geological Survey, continued investigations of the Quaternary history of the Assiniboine River valley and its tributaries in Manitoba and Saskatchewan.

R. J. Mott, Geological Survey, completed field work on late-glacial and post-glacial pollen in Saskatchewan designed to provide information on vegetation and climatic changes.

E. A. Christensen, Saskatchewan Research Council, reports that a major test-drilling program, supported by the Research Council, A. R. D. A. and N. R. C., is under way, with 50,000 feet of drilling completed in a 20,000-square-mile area. Location of the pre-glacial Tyner and Battleford valleys has been completed and a pre-glacial Swift Current valley discovered. Bedrock-surface and geology maps on a scale of 1:250,000 are being compiled for some 40,000 square miles of southern Saskatchewan. He adds that the test-drilling program for the urban geology of Saskatoon has been completed, and that with help from R. Byers, University of Saskatchewan, the City of Saskatoon and the Saskatoon Geotechnical group, maps and a three-dimensional model are being compiled.

Five observation wells with automatic water-level recorders were installed by the Saskatchewan Research Council in 1966.

W. A. Meneley, Saskatchewan Research Council, completed the test drilling of the Tyner-Delisle aquifer on a contract for Cominco Ltd.

R. O. van Everdingen undertook work for the Inland Waters Branch on the influence of the South Saskatchewan Reservoir on Upper Cretaceous bedrock aquifers. He also assembled 13,000 chemical analyses from the Prairie area for tracing deep regional groundwater-flow systems.

R. A. Freeze, Inland Waters Branch, installed additional instruments in the Good Spirit Lake drainage basin to determine soil moisture and to assist computer modelling of the basin. He completed field work and mathematical

models of the type areas of the Old Wives Lake drainage basin and also developed general mathematical models to study saturated and unsaturated systems, transient water tables and conditions and effect of well fields.

R. L. Herr, Inland Waters Branch, installed seven piezometers at three sites in cooperation with the Department of Engineering, University of Saskatchewan, for the Bad Lake study.

P. Meyboom, Inland Waters Branch, made mass-transfer studies of sloughs in the Moose Mountain area to determine the part that such topographic features play in the overall hydrogeology of a Praire area.

A. Rozkowski, N.R.C. postdoctoral fellow with the Inland Waters Branch, studied the hydrochemistry of the Moose Mountain groundwater flow system in conjunction with Meyboom's study.

The National Research Council, Division of Building Research, reports mapping of potential sulphate hazard to concrete in soils in an area in central Saskatchewan. Groundwater levels are being recorded in Saskatoon to assess the effect of urban development, irrigation, weather, and drainage.

R. M. Quigley, University of Western Ontario, has been working with J. J. Hamilton, N. R. C., Saskatoon, on clay mineralogy of 12 samples from Western Canada.

J. A. Elson, McGill University, carried on field studies of the strand lines of Lake Agassiz, finding a high probability that this body of water discharged northwestward via Clearwater River into the Mackenzie system, as well as south to the Mississippi, during the Campbell phase.

Manitoba

M. J. Taplin, University of Manitoba, carried on a search for prehistoric occupation sites in the Swan River valley. The Anthropology Laboratory also sponsored a conference on environmental studies of Lake Agassiz and vicinity on Nov. 3-6, 1966, involving discussions of deposits, limits, and drainage history of the lake, and the vegetation history, palaeoclimatology, and palaeoecology of the region, together with the record of human occupation.

Z. C. Zoltai, Department of Forestry and Rural Development, continued his studies of the shores of Lake Agassiz in southeastern Manitoba and the northern Interlake areas.

R. A. McPherson, D. T. Anderson, and E. I. Leith, University of Manitoba, worked on the Pleistocene deposits of the Gull Lake-Winnipeg River area.

Barbara A. Kennedy, University of British Columbia, studied valley asymmetry in relation to microclimate, vegetation, and stream positions to compare small east-trending valleys in southwest Manitoba and southeast Wyoming. One of the aims of this study is to establish the degree of relict influence of late Pleistocene cold climates.

R. W. Klassen, Geological Survey, continued investigations of the Quaternary history of the Assiniboine River valley and its tributaries in Manitoba and Saskatchewan. He also completed a preliminary map and report on the Waterhead-Grand Rapids area in connection with a study of the Manitoba Interlake area requested by A. R. D. A. Klassen also completed a paper on interglacial stratigraphy and palaeontology of the Roaring River jointly with D. Delorme and R. J. Mott.

M. Hoque, University of Saskatchewan, commenced a study of the gypsum deposits near Gypsumville, with special reference to the deformation of the deposits caused by overriding glacier ice.

A. Lissey, Inland Waters Branch, reports that the instrumentation of the Oak River drainage basin is essentially complete, with some 77 piezometers installed. A method of mapping groundwater recharge and discharge areas from surface features and ecology of sloughs was developed and checked against the piezometer observations.

G. H. Johnston and J. M. Blackwell, National Research Council, continued terrain studies and subsurface investigations on anchorage for power-transmission-line towers near Thompson and Gillam. Associated with this work was Fetulah Aysan, University of Manitoba, who studied the effects of freezing on Lake Agassiz clay, with special reference to anchor pullout for his M. Sc. thesis.

J. S. Scott, Geological Survey, studied hydrologic factors affecting stability of slopes in Saskatchewan, Alberta and Manitoba.

G. A. Russell and Imantz Deme, University of Manitoba, undertook investigations of the effects of varying lime and moisture contents on stabilization of Lake Agassiz clays.

Russell also worked on airphoto analysis of a research drainage basin in permafrost for the International Hydrologic Decade.

Ontario

B. G. Craig, Geological Survey, prepared for a 1967 reconnaissance of the Quaternary geology of the Hudson Bay Lowland as part of "Operation Winisk." During the 1966 field season he took part in a trip through the lowlands. S. H. Richard has been involved in airphoto interpretation as part of the same project.

E. P. Henderson, Geological Survey, continued investigation of the surficial geology in the Gananoque-Brockville area. His map on the surficial geology of Gananoque-Wolfe Island was published as Map G. S. 13-1965.

H. A. Lee, Geological Survey, continued investigation of mineral-exploration techniques, using distribution of mineral indicators in an esker in the Kirkland Lake district. He completed a report on the Quaternary history of the Hudson Bay region for the Centennial volume on Hudson Bay.

N. R. Gadd, Geological Survey, is preparing a memoir on the surficial geology of the Ottawa area.

Capt. J. LeMenestral of the Scientific and Technical Unit of the French Military Service was associated with the Geological Survey of Canada and completed a geomorphological map of Blackburn, Ontario, and Quebec, covering the eastern part of Ottawa.

C. F. M. Lewis, Geological Survey, continued study of tilt and lake-level change during the last few thousand years in the northern part of the Lake Huron basin, and was involved in planning and reconnaissance for the Great Lakes study being undertaken by the Inland Waters Branch, Department of Energy, Mines and Resources; N. Rukavina participated in the latter work. The sedimentation study has been complemented by a sparker survey organized by the Geophysics Division, Geological Survey.

J. Terasmae, Geological Survey, continued investigation of post-glacial climatic trends in the Great Lakes region as shown in bog, pond, and lake deposits. Terasmae and R. J. Mott cored ten lakes for geochronological studies in the North Bay and Kingston areas in support of mapping projects by Lewis and Henderson. Stratigraphic drilling of deposits in the buried St. David's Gorge at Niagara Falls was completed, as was a similar project at Woodbridge. The former project revealed plant-bearing beds below glacial deposits; the latter disclosed unconsolidated Quaternary sediments beneath what is the oldest known till in the Toronto region. Bottom sediments were also collected in three lakes in the Trenton-Belleville area to obtain further data on the age of Glacial Lake Iroquois.

U. J. Vagners, University of Western Ontario, completed a Pleistocene map of the Fort St. Marie area, and a M. Sc. thesis on lithologic relationship of till to carbonate bedrock in southern Ontario. He also continued investigation of the terminal grades of minerals in tills for a Ph. D. thesis.

A. Dreimanis, University of Western Ontario, completed a review on mastodons in Ontario and concluded an environmental hypothesis on their extinction.

F. Mayr, with Dreimanis, found several new beach deposits in southwestern Ontario, most of them older than Lake Maumee. Most significant is a buried low-level beach of probable Plum Point Interstadial age. Mayr is working on principles of fabric analysis with emphasis on till fabric.

A.A. Berti, University of Western Ontario, continued palynologic investigations of the Port Talbot Interstadial deposits; C.B. Gunn on the possible origins of diamonds in glacial drift; J. Craft on the relationship of mountain and continental glaciations in the Adirondacks, and B.H. Feenstra on tills at the Conestogo dam, all as Ph.D. or M.Sc. thesis projects.

P. Jensen, University of Western Ontario, investigated the Pleistocene deposits of the university campus as a senior thesis project.

R.W. Packer, University of Western Ontario, continued to direct the collection and interpretation of data on natural slope angles in southwestern Ontario, with support from the Geological Survey.

V.W. Sim, University of Western Ontario, supervised a continuing study of bluff recession along the Lake Erie shoreline near Sparta with support from the Geographical Branch. Sim has also continued work on the relationship between winter soil-temperature and ground-frost heave on the University of Western Ontario campus.

Graduate theses projects being undertaken at the Department of Geography at University of Western Ontario include the descriptive geomorphology of Beaver Valley (D.J. Davis), freeze-up and break-up of Dingman's Creek, Middlesex Co. (T. Spence), and hydrophysical characteristics of Bronte Creek (R. Dolling).

Master's thesis projects being undertaken in the Faculty of Engineering, at University of Western Ontario, include a study of the influence of swelling clay minerals on the permeability of Leda clay from Ottawa (C. de Wit), residual-strength properties of Pleistocene clays in Toronto and the role of clay fabric (R. Horvath), and a Ph.D. thesis project on engineering properties of the Tilbury till and settlement history of a bridge structure built on this particular soil (Y.D. Kim).

P.F. Karrow, University of Waterloo, continued mapping the Stratford-Conestogo area for the Geological Survey. Three to four till sheets are found throughout much of the map area. Several holes were drilled for stratigraphic records.

O.L. White and P.K. Lee, University of Waterloo, are studying engineering properties of Waterloo county soils in cooperation with the Department of Agriculture.

H. T. Hui has begun a study of a microfauna from the Toronto interglacial beds under the direction of C. H. Fernando, University of Waterloo. H. C. Duthie, University of Waterloo, is continuing study of diatoms from the same beds.

W. M. Tovell, Royal Ontario Museum, is continuing his studies of raised glacial lake beaches in the vicinity of Sault Ste. Marie.

The Division of Building Research (N. R. C.) is continuing investigation of natural slopes in sensitive clay in the Ottawa area. Computer programs were developed for the analysis of slopes. Two minor slides in the Ottawa area were given detailed study. Near Ottawa an extensive piezometer installation has been made to measure groundwater flow in a system of clay terraces adjacent to the Ottawa River.

M. L. Parsons, Inland Waters Branch, mapped surficial geology and undertook a drilling program to obtain subsurface information in a study of the hydrology of eskers at Iroquois Falls. Piezometers were installed along and between two topographically high eskers running through the Barlow-Ojibway clay belt. Fluid potentials indicate that the eskers are recharge areas. Groundwater temperatures will be used as a major criterion.

C. E. Buchwald, McMaster University, started a study of shoreline processes at Long Point, Lake Erie.

W. A. Gorman, Queen's University, studied size changes with distance in Precambrian debris carried from the Shield into the Palaeozoic Lowland and the palaeogeography of the Champlain Sea in southern Quebec and eastern Ontario.

The Division of Water Resources of the Ontario Water Resources Commission was active in 116 studies involving groundwater in 1966, in addition to activities in six International Hydrologic Decade projects. Of these, 13 were municipal groundwater surveys; 13 were test-drilling or well-construction projects for municipal water works or provincial water-supply systems; 17 were investigations of waste-disposal sites or pollution problems; 8 were investigations of municipal water-supply problems; 2 were reports for the surveys of the water resources of the Big Creek and Big Otter Creek drainage basins; 4 were regional assessments of water-supply and waste-disposal facilities and water resources; 50 were investigations of well-interference problems; 7 were investigations of well-construction problems; 1 was a geophysical investigation utilizing seismic and resistivity methods; 1 was a continuation of the collection of synoptic hydrometric measurements in eight drainage areas in southern Ontario; and 1 was a preliminary reconnaissance survey of hydrologic conditions in the river basins draining northern Ontario to Hudson and James Bays.

Work in the representative basin studies being carried out under the International Hydrologic Decade was concentrated on the installation of observation wells and streamflow-gauging stations. Observation wells were installed as follows: Bowmanville, Soper and Wilmot Creeks – 21; Blue Springs Creek – 16; East and Middle Oakville Creeks – 7. Mapping of Quaternary deposits was carried out in the Bowmanville, Soper and Wilmot Creeks basin. Thorough pumping tests to determine the hydraulic characteristics of sand and gravel deposits were carried out at observation wells in the township of Colchester South near Harrow and in the town of Bothwell as part of an I.H.D. program for groundwater assessment.

Nine other observation wells were added to the Commission's regular network, bringing the network total to 105, and the assembly, analysis and distribution of hydrogeologic data was continued.

Quebec

J.A. Elson, McGill University, is continuing projects on the role of needle ice in slope movement in the Montreal area and the weathering and mass wasting on a small limestone cliff that can be observed several times a week; definite cycles in the shift of points of groundwater discharge through joints occur through the winter, related to the accumulation of ice on the rock face.

K. Mallick, McGill University, in the course of a geochemical study on Mt. St. Hilaire for his M.Sc. degree, has acquired interesting data on the movement of the regolith on various slopes.

R.D. Thomas, McGill University, is evaluating the amount of denudation on Mt. St. Hilaire since it was deglaciated.

H.J. Gwyn, McGill University, is studying the effects of freeze-thaw and wetting-drying cycles on the movement of the regolith on Mt. St. Hilaire.

H.R. Grice, McGill University, has been setting up an N.R.C. project on engineering geology in the Montreal subway and the collection and storage of geologic data in a computer store.

The Division of Building Research (N.R.C.) reports that deformation gauges have been installed in very long piles at Berthierville to measure the loading due to negative skin friction caused by a subsiding clay layer. One friction pile has been instrumented to measure the distribution of positive and negative friction along its length.

N. R. Gadd, Geological Survey, has completed the selection and editing of parts of an unpublished memoir manuscript by J. W. Goldthwait for inclusion as an appendix to his memoir on the St. Lawrence Valley.

B. C. McDonald, Geological Survey, completed his Ph. D. thesis project on the Richmond-Sherbrooke area, joined the Geological Survey and started a new areal study of deglaciation and Quaternary geology in the adjoining area to the east. A short paper by McDonald on auriferous till in the Eastern Townships has been published in G. S. C. Paper 66-2, and preliminary maps illustrating his investigations on the Richmond-Sherbrooke area as G. S. C. Maps 4-1966 and 5-1966

M. Tiphane, University of Montreal and Quebec Department of Natural Resources, continued study of the behavior of beach material in the Gaspesian coast to establish the effects, if any, of the exploitation of sand and gravel from nearby pits.

J. Y. Chagnon, Quebec Department of Natural Resources, continued research on clays and ground slides.

R. L. Ledoux, Université Laval, is continuing mineralogical, mechanical and physico-chemical studies of quick clays.

J. C. Dubé, McGill University and Quebec Department of Natural Resources, continued work on Quaternary geology of the Arthabaska region.

T. Koulomzine, Ecole Polytechnique, with graduate students, made a systematic study of unconsolidated sediments on the St. Lawrence lowlands.

P. Lasalle, Quebec Department of Natural Resources, worked on the late Quaternary vegetation and general history of the St. Lawrence lowlands and Pleistocene geology in the Beloeil and Lac St. Jean areas.

G. Tremblay, Quebec Department of Natural Resources and Université Laval, continued his study of the Quaternary geology of the Isle-Maligne-St. Ambroise area.

M. Roy, le directeur du Servide hydrologique, Ministère des richesses naturelles du Québec a rapporté:

Projet No 1: aide à 26 municipalités de la province.

Nos études portent essentiellement sur l'inventaire des formations aquifères propices au développement de puits. Pour faciliter nos recherches nous faisons des levés séismiques, nous pratiquons des forages et nous effectuons des épreuves de pompage.

Projet No 2: étude hydrogéologique dans la région des lacs Aylmer-St-François.

Cette région est sise à environ 70 milles au sud de Québec. Les calculs théoriques des débits basés sur la superficie des bassins de drainage ne correspondant pas aux mesures de jaugeage des deux lacs. A certaines périodes de l'année, il semblerait qu'environ 100 p.c.s. s'écoulent du lac St-François vers le lac Aylmer sans emprunter la décharge naturelle. Une étude hydrogéologique de la région, commencée cette année, devrait nous permettre d'expliquer cette anomalie.

Projet No 3: aménagement de puits d'essai et d'observation aux Isles-de-la-Madeleine et dans 11 municipalités de la province.

Ces études sont financées par l'ARDA. La première consistait à faire l'inventaire des puits dans les principaux centres habités des Isles, à amenager 8 puits d'essai et 15 puits d'observation. L'an prochain il est proposé de compléter les épreuves de pompage et d'installer des limnigraphes. La deuxième étude dont la réalisation est en cours, concerne l'aménagement de puits d'essai dans 11 municipalités rurales qui ont déjà fait l'objet d'un levé hydrogéologique. On effectuera également des épreuves de pompage et on installera des limnigraphes pour suivre de plus près les fluctuations de la table d'eau.

Projet No 4: étude hydrogéologique dans le bassin de la rivière Eaton, dans le cadre de la décennie hydrologique internationale.

Près de la moitié du bassin a été couvert par la méthode séismique. Ceci nous a permis de déterminer l'épaisseur du mort-terrain et de connaitre l'importance des paramètres géologiques. Afin de voir si les formations géologiques influencent l'écoulement de base au point de vue hydrologique, nous avons établi un système d'échantillonnage dans différents ruisseaux du bassin et quelques puits de la région. Les résultats obtenus jusqu'à ce jour nous portent à croire que l'écoulement de base est en rapport direct avec les alluvions. Avant de prouver cette hypothèse, il sera nécessaire de ramasser un plus grand nombre de données.

Maritime Provinces

J.E. Charron, Inland Waters Branch, undertook a cooperative study of the North Nashwaaksis drainage basin along with the University of New Brunswick and New Brunswick Mines Branch. This included mapping of surficial deposits, bedrock, springs, and installation of observation wells.

P.A. Carr, Inland Waters Branch, completed the initial piezometer network for a study of saltwater-freshwater relationship in Prince Edward Island.

D. R. Grant, Geological Survey, began a Ph. D. project dealing with coastal submergence in Nova Scotia and Prince Edward Island under the supervision of V. K. Prest.

L. V. Brandon, New Brunswick Department of Natural Resources, obtained 300 water samples for chemical analysis and initiated a complete analysis of baseflows of rivers for assessment of groundwater contributions.

Field parties of the Nova Scotia Research Foundation were busy mapping Pleistocene deposits, or Quaternary deposits, in parts of Cumberland, Colchester, Pictou, Antigonish and Guysborough counties, as well as carrying out check work in other parts of the province. The Federal Department of Agriculture, working out of Truro, conducted a soil survey of Cumberland county. Members of the Dalhousie geology staff carried on work on sedimentation in the bay areas of the province, as well as some work offshore, where samples of the sediments were taken. The Research and Productivity Council of New Brunswick carried out reconnaissance mapping of the surficial geology of the Bathurst area. The Bedford Institute of Oceanography studied the sedimentation and sediments on the shelf and in the Gulf of St. Lawrence, these sediments being largely Pleistocene, or certainly Quaternary.

Without listing the agencies doing the work, the following are some of the studies carried out in laboratories or office areas. The heavy mineral content of the tills was examined; laboratory analyses of some Annapolis and Cumberland County soils were carried out; sieve analysis was carried out on a considerable number of Quaternary deposits in the Annapolis Valley with respect to hydrology programs; offshore grab samples were analyzed for their grain size and composition; a study was made of a fossil proboscidean tooth from the Continental Shelf area; and some till analysis was done on some Nova Scotia tills.

Newfoundland

Miss E. L. Brown, Memorial University of Newfoundland, undertook a study of a Foraminifera fauna from a raised beach or sublittoral deposit near St. Anthony, working under the supervision of R. D. Hughes.

J. M. Shearer, Memorial University of Newfoundland, completed field work in a study of bottom sediments of Port au Port Bay, with support from the Bedford Institute and supervision by W. D. Brueckner. Shearer is now working on mineralogy and size analysis of a number of selected samples for comparison with subaerial Quaternary formations around the bay.

General

The Division of Building Research (N. R. C.) reports the following general activities:

Permafrost Distribution

Ground-temperature measurements were continued in the Inuvik vicinity and at Thompson, Manitoba.

Frost Action

The pressures exerted by the growth of ice lenses in various media are being measured in the laboratory. Materials used include sorted glass beads, brick, mortar, sandstone, and natural soils.

A new technique for investigation of frost susceptibility based on the intrusion of air into soil, which is analogous to the freezing of soil, is being pursued.

Muskeg Studies

Some tests have been conducted on frozen peat samples to give an indication of the rheological properties. Apparatus has been constructed to conduct plate loading test on peat.

Soil Moisture and Volume Change

Work continued on the correlation between climate, soil moisture and soil-volume changes at Winnipeg, Regina, Eston and Melfort in Western Canada. Development of equipment and techniques for field calibration of nuclear moisture and density probes continued.

Consolidation Studies

Studies on the consolidation swell of heavy clay soils in the consolidometer and suction-plate apparatus were continued. Further investigations of the effect of the rate of loading on the preconsolidation pressures of Leda clay were continued.

Shear Strengths

Triaxial and direct shear tests were continued on Leda clay. The concept of residual shear strength is being examined. Using high-air-entry porous stones, negative pore-water pressures were measured and attempts made to correlate these values with swelling pressures on two clays from Western Canada.

The Geological Survey notes the following additional items of interest:

(1) The completion of the new Glacial Map of Canada and text for Quaternary of Canada by V.K. Prest.

(2) Study of structure of varved sediments by N.R.C. post-doctoral fellow, I. Banerjee.

(3) Development of new electrical methods of geophysical mapping of surficial deposits and sulfide conductors.

(4) An investigation of the amplitude and frequency of seismic waves in groundwater problems (K.B.S. Burke).

(5) An investigation of circular features in organic terrain by Lily Usik.

The Inland Waters Branch adds as general activities the following studies:

J.A. Gilliland (observation-well program) the completion of installations at Delta, Manitoba, and at Ottawa, to determine the best construction for observation wells and the relation of groundwater levels to meteorologic factors. Observation wells were also installed in crystalline rocks at Ottawa, at Val d'Or, Quebec, at Kapuskasing, Ontario, and at Sandilands, Manitoba. Various types of instruments are being tested for the observation-well program and development is in progress of a long-period (one year) digital recorder capable of receiving input from meteorological and groundwater instruments at the same site.

Gilliland has also been working on data storage and retrieval, a program designed to handle all observation-well data obtained by the Inland Waters Branch and to be compatible with pre-existing programs in water chemistry set up by the branch as well as with Geological Survey programs.

A.D. Stanley has been supervising the compilation of all available data on the inventory of Canadian glaciers, a study which was expected to be completed by mid-1967.

I.K. Crain, McGill University, has started a study of the influence of post-Wisconsin climatic changes on thermal gradient for his M.Sc. thesis.

P.P. David, University of Montreal, is continuing a study of selected sand-dune areas in Canada.

G.K. Billings and B. Hitchon, University of Calgary, are working on trace-element composition of subsurface brines.

REPORT OF THE SUBCOMMITTEE ON SCHOLARSHIP AND RESEARCH TRAINING

Presented by Robert Sabourin

Members of Subcommittee

Robert Sabourin (Chairman)	Université Laval, Quebec, P.Q.
W.H. Mathews	University of British Columbia, Vancouver, British Columbia.
Guy Perrault	Ecole Polytechnique, Montreal, Quebec.
J.S. Stevenson	McGill University, Montreal, Quebec.
J.T. Wilson	University of Toronto, Toronto, Ontario.
C.G. Winder	University of Western Ontario, London, Ontario.

A memorandum has been sent to Canadian university departments of geology and geophysics requesting offers to contribute brief summaries of Canadian projects for inclusion in a booklet Careers in Geology.

The following offers have been received and will be followed up:

Professor J.M. Nielson, Queen's University – Engineering Geology.

Professor W.H. Mathews, University of British Columbia – Underwater Mineral Deposits.

Professor J.T. Wilson, et al., University of Toronto – Geophysics, Isotope Geology and Ocean-Floor Spreading.

Professor C.G. Winder, University of Western Ontario – Computerization of Well Data.

A.M. Stalker, Geological Survey of Canada – Quaternary Geology.

This should be considered an interim report because barely 25 per cent of the university departments consulted have answered. We hope that a few more offers to contribute summaries will be forthcoming.

DISCUSSION OF REPORT

Sabourin emphasized that the report was interim. The subcommittee proposed to go ahead with the preparation of a booklet on careers in geology which it was hoped would be completed by the spring of 1968. It would be modelled after the A. G. I. booklet but would use Canadian material and examples.

REPORT OF THE SUBCOMMITTEE ON STRATIGRAPHY, PALAEONTOLOGY AND SEDIMENTATION

Presented by C. W. Stearn

Members of the Subcommittee

C. W. Stearn (Chairman)	McGill University, Montreal, Quebec.
W. G. E. Caldwell	University of Saskatchewan, Saskatoon, Saskatchewan.
J. W. Kerr	Institute of Sedimentary and Petroleum Geology, Calgary, Alberta.
Jean Lajoie	Université de Montréal, Montreal, Quebec.
D. J. C. Laming	University of New Brunswick, Fredericton, New Brunswick.
R. G. McCrossan	Imperial Oil Enterprises, Ltd., Calgary, Alberta.
G. V. Middleton	McMaster University, Hamilton, Ontario.
J. W. Murray	University of British Columbia, Vancouver, British Columbia.
C. G. Winder	University of Western Ontario, London, Ontario.

INTRODUCTION

Before 1966, subcommittees of the National Advisory Committee on Research in the Geological Sciences formulated their annual reports by correspondence. The subcommittees could hardly discuss the problems of their disciplines, plan, or reach decisions by correspondence alone; they could only compile opinions and report on research in the country. In 1966 for the

first time the Geological Survey of Canada made funds available to allow the various subcommittees to meet. This has changed the functions of the Subcommittee on Stratigraphy, Palaeontology and Sedimentation, allowing its members to discuss and reach recommendations and suggest ways whereby these three disciplines canbe advanced. Funds for travel are not large, and the membership of the subcommittee had to be reduced. However, the composition of the present committee remains representative of the three disciplines of sedimentary geology and of the geographic regions of Canada.

The members of the subcommittee met on December 28, 1966, at the Geological Survey of Canada in Ottawa. A considerable part of the meeting was concerned with defining more precisely the function of the subcommittee as an advisory group to promote the advance of sedimentary geology in Canada. This report consists of a summary of the decisions reached at this meeting, with comments on important advances in stratigraphy, palaeontology, and sedimentology over 1966-67.

SURVEYS OF RESEARCH

At present both the National Advisory Committee[1] and the National Research Council[2] publish surveys of research in Canadian Universities. The latter covers only research projects in the universities and is unannotated; the former is more complete, encompasses government research institutions, and contains bibliographic material and annotations. Use of the National Advisory Committee compilation would be made easier by the codification of research projects so that each received a number, perhaps as in the American Geological Institute scheme. Such a numbering scheme should not displace the present practice of listing by disciplines and areas but would supplement it. Indexing by key words, so that indexes could be compiled by computer, would increase the usefulness of the current listings. The subcommittee considers these listings important in preventing the duplication of geological research in various institutions in Canada; they are complete enough to eliminate the need for any additional listing in this report.

The subcommittee decided not to suggest further specific research topics for investigation because geologists can define far more problems than they have time to undertake. However, the subcommittee will continue to draw attention to major fields that are neglected in sedimentary geology in Canada and suggest ways in which this can be remedied.

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[1] Current Research in the Geological Sciences in Canada, 1966-67, National Advisory Committee on Research in the Geological Sciences, Ottawa, 1967. Geol. Surv. Can., Paper 67-58, 1967.

[2] Canadian Universities: Research in Science and Engineering, 1965, National Research Council, Ottawa, N.R.C. No. 8840.

N.A.C. GRANTS AND THE SUBCOMMITTEES

At present applications for Geological Survey research grants are reviewed by a five-man Projects Subcommittee of the National Advisory Committee which consults geologists across the country before making its decisions. The Projects Subcommittee does not use the expertise of the subcommittees of the National Advisory Committee directly in assessing grant applications. Some way should be found to refer applications to members of subcommittees for rating without greatly increasing the paper work, or delaying the awarding of the money. The subcommittee members could not, of course, fix the value of the awards, because the total budget must be divided among the major disciplines of geological science by the Projects Subcommittee; but they could complete a standard rating form for proposals submitted to them, and assign priorities.

The Subcommittee on Stratigraphy, Palaeontology and Sedimentation therefore suggests that a sufficient number of copies of the applications be made to provide each member of the relevant subcommittee with copies. The applicant would be asked to indicate on his application which of the subcommittees he wishes to assess his project. The applications would then be rated A, B, C, D, by each subcommittee member or reported on more completely on an evaluation sheet such as is used by other granting agencies. These evaluations should be of assistance to the Projects Subcommittee when it assesses the applications.

In order that this procedure not delay the awards, a strict deadline would have to be maintained on the return of the evaluations by subcommittee members. The Projects Subcommittee could make its recommendations immediately after the deadline without waiting for responses from the whole subcommittee. The opinions of the subcommittee members would not be binding on the Projects Subcommittee.

SEMINARS AND STUDY GROUPS

The organization of seminars and workshops is not the function of the subcommittee, but it may urge societies to sponsor such meetings and suggest ways in which seminars may be arranged. We hope that the Geological Association of Canada will acept our suggestion to hold a symposium on "The Offshore Geology of the West Coast" at its Vancouver meeting (1968). The G.A.C. executive has approved this proposal, but arrangements with the local committee are not complete. This subcommittee hopes to promote seminars in fields of its interests at future meetings of national societies.

"SKIN-OF-THE-EARTH" PROJECT

During the early and middle sixties the Upper Mantle Project held seminars on and published summaries and coordinated investigations of the upper layers of the mantle and the lower layers of the crust of the earth. The aims of the project are not easily defined but are mainly to study, by any means possible, the nature and influence of the upper mantle. Although a few of the disciplines of sedimentary geology could fit into one or another of the working groups of the Upper Mantle Project, not many research workers in these disciplines have participated. The project may have seemed so far removed from sedimentary geology that few sedimentary geologists became concerned; probably some were not even aware they might participate.

J. W. Kerr has suggested that sedimentary geologists should unite in a concerted project to study geological mechanisms that operate in the upper layers of the crust and at the surface. Whereas the Upper Mantle Project is concerned with processes at depth, the "Skin-of-the-Earth" Project would be concerned with processes which controlled the deposition of the sedimentary column and shaped the surface. "Skin of the Earth", "Crust of the Earth", and "Face of the Earth" have all been suggested as names for the project. If such a project were organized, its working groups might be concerned with basement influences; geological time scale; the correlation of events; biological, sedimentary, and tectonic evolution; palaeoecology; palaeoclimatology; sedimentary geochemistry, etc. Kerr suggests that as a result of such a cooperative project, (1) studies that have contributed to the understanding of geological processes operating near the surface would be more specifically communicated; (2) geologists could be stimulated to form more basic conclusions from their data by being invited to summarize their contribution to the understanding of geological processes and conditions on a broad scale; and (3) geologists would be stimulated to summarize their work and to suggest ways in which specialists in other fields might use it.

This imaginative project has been discussed and endorsed by the Research Committee of the Alberta Society of Petroleum Geologists. This subcommittee is also enthusiastic and suggests that it be discussed by the National Advisory Committee with a view to presentation at the International Geological Congress in 1968 or the American Association of Petroleum Geologists meeting in Calgary in 1970. Obviously, to be successful the project must be welcomed by a wide segment of the geological profession and be backed by professional societies of international scope.

REFERENCE COLLECTIONS OF SEDIMENTARY ROCKS

Sets of typical Canadian sedimentary rocks would be useful additions to teaching collections of universities across the country, especially at the advanced undergraduate and graduate levels. Examples of such collections would be 50 specimens from the Devonian of Alberta or from the Permian of

British Columbia. The subcommittee believes that if such sets could be made available at cost they would be purchased by institutions and possibly by companies, particularly now that many new geology departments are being equipped. Probably the Geological Survey of Canada could best administer the selection and distribution of the suites.

Neither the Canadian Stratigraphic Service nor the Alberta Research Council appears to be in a position to undertake the project. The project has been discussed with the Alberta Society of Petroleum Geologists and their cooperation has been requested. A committee with representatives of the N. A. C., the A. S. P. G. and the G. S. C. would have to decide on the make-up of the suites and survey the universities to find out the potential demand for teaching collections of this type. The members of this subcommittee hope to persuade some agency to initiate this project.

MARINE GEOLOGY ON THE WEST COAST

Oceanographic research on the west coast is at present carried out by the Pacific Naval Laboratory, Esquimalt, by the biological and oceanographic groups of the Fisheries Research Board, Nanaimo, and by the Institute of Oceanography at the University of British Columbia, Vancouver. Only the latter is concerned with marine geology. The subcommittee urges the Geological Survey and the Marine Sciences Branch of the Department of Energy, Mines and Resources to assign marine geologists immediately to the Naval Laboratory, Fisheries Research Station, or the Geological Survey office in Vancouver so that marine-geological work by the Federal Government can start now, instead of being delayed until the establishment of the West Coast Oceanographic Institute proposed a few years hence. We hope that funds can also be provided now to bring visiting marine geologists to these laboratories, pending the start of full-scale work. The subcommittee also urges that the proposed West Coast Oceanographic Institute be established as soon as possible and that additional funds be made available by the Federal Government for the expansion of marine-geological work at the University of British Columbia.

WATER RESOURCES SUBCOMMITTEE

The Research Committee of the Alberta Society of Petroleum Geologists has suggested to this subcommittee that the National Advisory Committee set up a Subcommittee on Water Resources. Such a subcommittee would give geologists, who will probably be a minority in the new Water Resources Branch of the Department of Energy, Mines and Resources, a vehicle for expressing their views on the development of Canada's water resources. The position of the proposed subcommittee with respect to the hydrology group of the National Research Council would have to be carefully considered.

STABLE ISOTOPES AND PETROLEUM

R.G. McCrossan suggests that a massive research program is needed to study the occurrence of stable isotopes of carbon, sulphur, and oxygen in petroleum; it might throw light on the origin of petroleum. He envisages an institute supported by federal, industrial, and perhaps provincial funds. As an initial step funds might be made available to expand the stable-isotope work now in progress at the Alberta Research Council and at McMaster University. Although the subcommittee approves, in general, the proposed institute, it is unable to suggest specifically how it might be realized.

NAME AND COMPOSITION OF THE SUBCOMMITTEE

This subcommittee considers that the fields covered by it are better described as Stratigraphy, Palaeontology, and Sedimentology than Stratigraphy, Palaeontology and Sedimentation and recommends that the name of the subcommittee be so changed. We suggest also that the membership of the subcommittee be regularized by giving each member a three-year term and retiring three members each year. Such rotation would be exclusive of the chairman who is appointed by the National Advisory Committee.

CURRENT RESEARCH

For a detailed summary of current research the reader is referred to Current Research in the Geological Sciences in Canada, 1966-67 (G.S.C. Paper 67-58). This report lists 91 research projects in stratigraphy and palaeontology, 51 in palaeontology and 48 in sedimentation – a total of 190 projects. This compares with a total of 219 projects reported in these categories in the final report for 1965-66 (see Table 1).

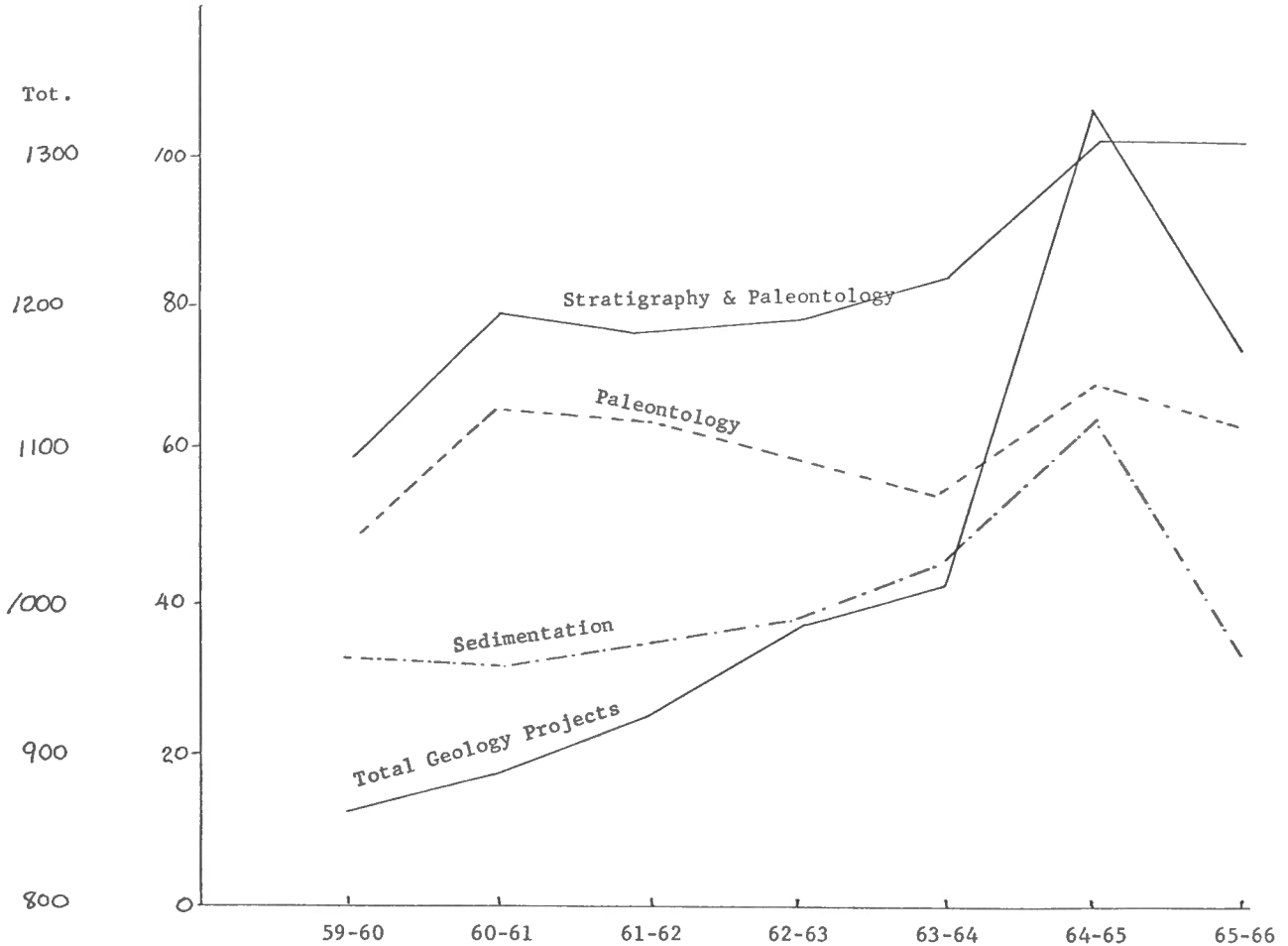
Table 1

Number of research projects listed in Current Research etc. 1966-67

YEAR	Stratigraphy & Palaeontology	Palaeontology	Sedimentation	TOTAL
1965-66	118	65	36	219
1966-67	91	51	48	190

Some investigators are "lumpers" and report their research under a single all-inclusive title; others are splitters and prefer to list four or five aspects of the general problem as separate research projects. In addition,

FIGURE 1 - Projects reported to N.A.C.



some projects which cross disciplinary boundaries appear in more than one list and so are counted twice in such a compilation. The plausible conclusion that there has been an overall drop in research in stratigraphy and palaeontology is probably false. The number of projects in the three disciplines for the last seven years is plotted in Figure 1. It indicates a general increase in stratigraphy and stratigraphic palaeontology since the beginning of the decade, interrupted by a plateau between 1961 and 1964. With some oscillation, the number of projects in pure palaeontology has remained essentially unchanged. Sedimentation, which suffered an apparent decline a year ago, seems in the process of recovery.

To single out certain projects as more significant would be an unprofitable task and would merely reflect the interests of the selector. On the international scale the advances in stratigraphy and sedimentation have recently been reviewed in Geotimes by Pierce, Gross and Stanley (January, 1967) and in Palaeontology by Dutro (February, 1967).

In stratigraphy and stratigraphic palaeontology interest continues to be greatest in the late Palaeozoic systems which supply most of Canada's oil. However, the compilation for 1966-67 lists an almost equal number of research projects in lower Palaeozoic and Mesozoic stratigraphy. Research into Precambrian stratigraphy and palaeontology seems to be increasing in Canada, particularly in the relationship of stratigraphy to mineral deposits (see also pp. 18-21). Most of this work being carried out at the Geological Survey and at the University of Western Ontario is concerned with rocks of the Shield and the Appalachians. The thick Proterozoic sequences of the Cordillera are under investigation at the University of Alberta and by the Geological Survey. However, the number of specific projects on the Cordilleran Proterozoic still seems to be smaller than this important sequence deserves. The Geological Survey of Canada continues to be the centre of stratigraphic research outside the oil companies. A third of the Palaeozoic research projects and two thirds of the Mesozoic projects are under the direction of Survey personnel.

Although the listing of research projects seems to indicate that research in sedimentation is confined almost entirely to the universities, many of the projects listed in stratigraphy by Geological Survey personnel are closely related to sedimentation. The publication Maritime Sediments continues to supply useful summaries and indexes to research in both modern and ancient sediments for the provinces bordering the Atlantic. The October 1966 issue contains a twenty-page summary "Research on Recent and Pleistocene Sedimentary Deposits in the Atlantic Provinces and Adjacent Areas: Current and Recently Completed Work", by Brenda Laming. The release this year of G. V. Middleton's film on his experiments on turbidity current flow and the publication of several papers analyzing the results of these experiments are worthy of note.

Exploration and development of the Keg River reefs and exploration of the continental shelf by the petroleum industry occupy a great deal of attention. Recruitment of students this year for permanent positions in industry has been intense, and the present graduating classes will not fill the demand. The Athabasca Tar Sands project which came into production in 1967, is an important development in the petroleum industry in Canada.

A dozen continuing projects in invertebrate macropalaeontology are being carried out across Canada. The palaeoecology of Devonian rocks and graptolites in Ordovician rocks seem to be the most popular fields of research. In vertebrate palaeontology five projects are listed in the survey of current research, 1966-67 ranging from the ostracoderms of the early Palaeozoic to the edentates of the late Pleistocene. For those interested in further details on this aspect of palaeontology F. L. Staplin's summary for 1967 of micropalaeontological activity in Canada will as usual be published in the journal Micropalaeontology, his last report appeared in Micropalaeontology in October 1966. Notable is the meteoric rise of palynology, particularly Palaeozoic palynology. Several papers by Canadians were presented to the Second International Conference on Palynology at Utrecht in 1966. Research projects in this field are being carried out at the Geological Survey, the Universities of Alberta, British Columbia, Calgary, McMaster, Saskatchewan, and Trent, the Alberta Research Council, Imperial Oil Ltd., and Shell Canada Ltd. Interest in the conodonts remains high among projects at the Geological Survey, Quebec Department of Natural Resources, the Universities of Ottawa, Waterloo and Western Ontario. Foraminiferal micropalaeontology is under investigation at the Bedford Institute of Oceanography, Alberta Research Council, the Universities of Calgary, Montreal, Saskatchewan, and at British-American and Chevron Standard oil companies.

In Canada events of importance in the past year in disciplines of this subcommittee include the Lower Palaeozoic Symposium at Edmonton, organized by Denis Jackson for the Edmonton Geological Society and the University of Alberta and published in the December 1966 issue of the Bulletin of Canadian Petroleum Geology. The Banff conference in 1966 was concerned with evaporites and was led by L. V. Illing, L. L. Sloss, and G. Richter-Bernburg; the 1967 conference will be on the topic "Petroleum". A Reef Symposium was held under the auspices of the University of Calgary in December 1966. Many sedimentary geologists in Canada were involved with the organization of the International Devonian Symposium in Calgary in September, 1967; the editorial committee hoped to have more than 200 papers published before the conference. The Royal Society of Canada Symposium on the Appalachians which took place in June 1966 and was scheduled for publication in the fall of 1967, includes several papers of stratigraphic interest. During 1966, the Royal Society's symposium on continental drift was also published. The Canadian Institute of Mining and Metallurgy's volume Tectonic History and Mineral Deposits of the Western Cordillera contains several

papers of interest to the stratigrapher. The Ontario and Quebec Biostratigraphy Seminar met in the spring of 1966 at Queen's University and in March 1967 at the University of Ottawa.

DISCUSSION OF REPORT

The proposed "Skin-of-the-Earth" (p. 73) program was discussed at some length. It was pointed out that in many ways the project resembled the proposed IUGS-UNESCO International Program for Geological Correlation which is presently under active discussion. The subcommittee was asked to study the IUGS-UNESCO project to see what the two have in common.

With respect to the need for reference collections of sedimentary rocks (p. 73) it was felt that much more detailed information is required on the need and what would be involved before asking the Geological Survey to become involved in the project.

With respect to the suggestion that a Subcommittee on Water Resources be formed (p. 74), several members pointed out that the Quaternary Subcommittee included coverage of hydrogeology, and that pollution was not the concern of the National Advisory Committee.

The recommendation that the name of the Subcommittee on Stratigraphy, Palaeontology and Sedimentation be changed to Stratigraphy, Palaeontology and Sedimentology was accepted.

REPORT OF THE SUBCOMMITTEE ON STRUCTURAL GEOLOGY

Presented by James T. Fyles

Members of the Subcommittee

James T. Fyles (Chairman)	Department of Mines and Petroleum Resources, Victoria, British Columbia.
Alex Baer	Geological Survey of Canada, Ottawa, Ontario.
R. L. Brown	University of New Brunswick, Fredericton, New Brunswick.
H. A. K. Charlesworth	University of Alberta, Edmonton, Alberta.
K. Barron	Mines Branch, Department of Energy, Mines and Resources, Ottawa, Ontario.
Pierre St-Julien	Quebec Department of Natural Resources, Quebec, Quebec.
W. H. Poole	Geological Survey of Canada, Ottawa, Ontario.
R. A. Price	Geological Survey of Canada, Ottawa, Ontario.
J. V. Ross	University of British Columbia, Vancouver, British Columbia.
J. O. Wheeler	Geological Survey of Canada, Vancouver, British Columbia.
H. R. Wynne-Edwards	Queen's University, Kingston, Ontario.

The trends in structural research in Canada established in the past few years continued through 1966. Field studies which form the greater part of the research are becoming more detailed and specific. Structural studies, integrated with other geological and with geophysical work which aim at determining the tectonic history of a region, are continuing. An increased number of theoretical and experimental studies are being made.

Opinions vary as to whether or not satisfactory progress is being made. Over the last 10 years or so a remarkable increase in the number and the calibre of structural studies is apparent (see Fifteenth Annual Report). Some members of the subcommittee feel, however, that "structural geology in Canada could be progressing farther and more rapidly than it is at the present."

SUMMARY OF STRUCTURAL RESEARCH

As in previous reports, the structural studies will be considered in three categories:

(a) Field studies, regional and detailed.
(b) Integrated studies involving other branches of the geological sciences, mainly geophysics.
(c) Theoretical and experimental studies.

An idea of the number and scope of current studies in structural geology can be gained from Current Research in the Geological Sciences in Canada, 1966-67 (G.S.C. Paper 67-58). Members of the subcommittee, from their own experience and from correspondence, have provided a summary of significant studies which have come to their attention; these are discussed below.

Field Studies

As an introduction to a review of field studies the following comments by Baer are appropriate; they represent an ideal for structural geologists which will never be outdated.

> "Field geology has been the bread and butter of most geologists since the beginning of our science, but techniques and methods of approach have changed little between 1850 and 1950. In recent years, laboratory and experimental studies have gained importance, and some of us go so far as to predict the eventual downfall of field geology. I disagree, but I believe that we should give some serious thought to our approach towards field geology (including, of course, structural geology).

"The basic rules of the game have been set over a century ago, and everybody is familiar with the classical tools of the profession, the hammer, hand-lens, compass and notebook. These tools, however, do not make a geologist, as students soon find out on their first field-trip.

"If field studies are going to maintain their importance they must produce more and better results. Toward that goal, two approaches are possible.

"The first, possibly the more obvious, is to load the geologist with more sophisticated equipment by taking part of the laboratory in the field. The second, and to my mind the better one, lies in an exhaustive inspection of the outcrops, particularly in large-scale studies, where most stations will never be re-occupied. Thirty minutes well spent on an outcrop are far more important to the final result that sophisticated equipment carried along. We should pay greater attention to the quality and amount of observations and not delude ourselves with the idea that laboratory analysis will make up for what we fail to observe. All of us have missed valuable information because we were not aware of its importance at the time. Kink-bands, for instance, have been seen by a structural geologists all over the world but few have thought of measuring them until experimental data became available (Paterson and Weiss, 1966, Geol. Soc. Am., Bull., vol. 77, p. 343).

"By necessity, each time we leave an outcrop, we leave some untapped information behind. Let us make a conscious effort to cut down on these losses, particularly on large-scale mapping. Before taking a whole arsenal with us into the field, we should get as much as we can out of our observational powers. This means training students to observe and never to treat field work as routine. It also means we must keep abreast of all methods of quantifying structural observations and see if we can apply them to our own studies (see for instance attempts by E.H.T. Whitten, 1966, Jour. Geol., vol. 74, p. 744).

"In approximately the words of Leopold von Buch, father of German geology over 150 years ago: 'Three things are necessary to make a good geologist. The first one is a keen sense of observation, the second one is a keen sense of observation, and the third one is... a keen sense of observation!'"

Regional Field Work

Much of the systematic four-mile and one-mile mapping of the Geological Survey of Canada is directed to an understanding of the regional structure, or results indirectly in an understanding of the structure. These studies also provide a background for detailed work that is essential both in selecting areas for detailed study and making meaningful interpretations.

In the west, Baer calls attention to a large nappe-like structure with a core of quartz diorite discovered by Hutchinson in the Skeena map-area of the northern coast of British Columbia (see Geol. Surv. Can., Paper 67-1, p. 63). Changing fold styles in the Kaza (Late Precambrian) Group have been defined by Campbell in McBride map-area (see Geol. Surv. Can., Paper 67-1, p. 53). As an outcome of Campbell's work on the Canoe River map-area a detailed study of the structural relationships of metamorphic rocks along the Rocky Mountain Trench was started in 1966 by Giovanella as a Ph. D. thesis project. Regional mapping on Vancouver Island by J.E. Muller has extended and clarified many aspects of a regional pattern of faulting. In the Rockies, field work on operation Bow-Athabaska under the direction of Price has been completed (see Geol. Surv. Can., Paper 67-1, p. 106) and this, together with the regional mapping to the south (see Leech, Geol. Surv. Can., Paper 67-1, p. 72) and detailed studies under the direction of Price, is a major advance in the understanding of the regional structure of the Rockies. These projects fulfil some of the preliminary objectives of the Cordilleran Structure Project (see p. 93).

As concerns the Northwest Territories, Poole points to mapping of Thubun Lakes area by Reinhardt (see Geol. Surv. Can., Paper 67-1, p. 40) in which an analysis was made of the MacDonald and subsidiary faults which lie near the boundary of the Slave and Churchill structural provinces.

Mapping by De Romer in the Gaspé Peninsula and by Hubert along the south shore of the St. Lawrence from Kamouraska to Levis for the Quebec Department of Natural Resources is producing much interesting information on the regional structure of the Appalachian province in Quebec. Mapping by Dimroth to decipher the regional structure of the Labrador trough continues.

Concerning the Atlantic provinces, Poole reports on the structural significance of several one-mile mapping projects. In the McKendrick Lake area of central New Brunswick, Anderson has begun a study of the structure of folded Lower Palaeozoic volcanic and sedimentary rocks cut by two ages of Palaeozoic granite and overlain by flat-lying Carboniferous sediments (see Geol. Surv. Can., Paper 67-1, p. 168). In the St. Stephen-Mount Pleasant area of southern New Brunswick, Ruitenberg has begun a study of the structure of folded Lower Palaeozoic rocks cut by Ordovician ultramafic bodies and Devonian granites (see Geol. Surv. Can., Paper 67-1, p. 169). In both these studies the structural history will be integrated with metallic mineralization. Mapping by Kelley in the Cobequid Mountains of northern Nova Scotia has led to an understanding of the structure and stratigraphy of folded Silurian and Devonian rocks intruded by Devonian granites (see Geol. Surv. Can., Paper 67-1, p. 186).

In the Northern Peninsula of Newfoundland Stevens is making a regional study of structure and stratigraphy in a large klippe of Ordovician sedimentary and volcanic rocks enclosing ultramafic bodies (see Geol. Surv. Can., Paper 67-1, p. 186).

Detailed Field Work

Detailed field studies are being made in increasing numbers. As indicated in last year's report, most are aimed at determining the structure and structural history of an area, and relatively few at determining a structural principle or developing a new technique. But the two go together, and new techniques and new principles are being developed as field studies of geometry and tectonic history become more searching and numerous. Many of the detailed field studies in British Columbia are directly or indirectly part of the Cordilleran Structure Project described later in this report (p. 93). In addition to these, several others should be mentioned. At the University of British Columbia, Ross and Kellerhals began work north of the Nelson batholith between Kootenay and Slocan Lakes as part of a study of the regional structure of the Columbia Mountains. Data on the batholith which will be of tectonic significance are being gathered by Sinclair and Libby. Studies of the Shuswap gneiss domes by Reesor are continuing under the "Granite of Canada" program of the Geological Survey. Farther south Preto has completed a structural analysis of the gneisses near Grand Forks (see Geol. Surv. Can., Paper 67-1, pp. 84-86).

Small-scale structures in the Moose Mountain area in the Rocky Mountain Foothills and Front Ranges of Alberta southwest of Calgary have been studied by Simony. At the University of Alberta studies of jointing and cleavage are being made by Charlesworth. He points to three specific studies, one of jointing and microjointing in the Cardium Sandstones of the foothills by Boetzkes (see Muecke and Charlesworth, Can. J. of Earth Sc., vol. 3, p. 579), another of cleavage in Precambrian metasedimentary rocks near Jasper by Zaturecky, and a third on stratigraphy and structure of Precambrian rocks near Lake Louise.

Charlesworth draws attention to local field studies at the University of Manitoba of the structure of the San Antonio Formation and underlying volcanic rocks in the Rice Lake area; lineament analysis in Gundy and Broderick townships, Ontario; pebble deformation in the San Antonio conglomerate; and folding in Ewart township, Ontario.

Wynne-Edwards reports on structural studies in the universities of Ontario:

> "Active work on structural problems has been reported from the universities of Carleton, McMaster, Toronto, Ottawa, Queen's and Western Ontario. About 25 separate projects are under way. As before, field studies predominate, but there is growing emphasis on detailed studies and less on descriptive mapping. Of interest in this respect is an evaluation by Janes, Currie, and Moorehouse, University of Toronto, of the geological map as a means of conveying information.

"All but a few of the projects are concerned with the Grenville province, and combine structural investigations with petrology. Work by Clifford, Kwak, and Henderson along the Grenville front near Sudbury is well advanced. At Carleton, Queen's and Toronto, detailed structural studies of faults or folds within the Grenville province are in hand, and are being started at the University of Ottawa."

Wynne-Edwards is also directing three projects in the Grenville province of Quebec.

From Quebec, St-Julien, Quebec Department of Natural Resources, describes his own projects as:

"a) an east-west section in the southeastern part of the Quebec Appalachians, from Logan's line at Drummondville to the Connecticut Valley-Gaspe Synclinorium, south of St-Georges-de-Beauce; b) a detailed tectonic study of the refolded similar folds of the Sherbrooke area; and c) a structural, stratigraphic and sedimentological study of the Cambro-Ordovician in the Quebec-Levis area. The third project is being done in conjunction with F. Osborne, Laval University."

He also draws attention to two projects at the University of Montreal:

"The first deals with the tectonics of the Grenville Katazone between the Morin massif and the St-Maurice river; Professor Martignole and Michel Hocq are engaged in that study. The second concerns the structural study of the Lemieux Dome in Lemieux township, Gaspe; Professor J. Beland and Francisco Gentile are carrying out this study."

For the Maritimes, Brown points to the work of Helmstaedt, a Ph. D. candidate who is in his second year of research in the Southern New Brunswick project:

"The geometry of his thesis area (St. George-Bay of Fundy) is now fairly well understood. He is at present carrying out a detailed analysis of quartz deformation lamellae, calcite lamellae, and microfractures in order to compare late-stage dynamics with the earlier 'plastic' kinematic picture."

Brown's work with Dalziel in the Boothia arch of Somerset Island, Northwest Territories, is being prepared for publication.

Poole draws attention to the continuing regional work of Neale and the detailed studies of Kennedy on the Burlington Peninsula of northern Newfoundland (see Geol. Surv. Can., Paper 67-1, pp. 180 and 183). The objective of the work has been to study the detailed structural and metamorphic history of the Fleur de Lys Group and to determine the stratigraphy for comparison with Dalradian rocks in Ireland and Scotland.

Integrated Studies Involving Other Branches of Geology

Under this heading may be considered three poorly defined groups of research projects which grade from one to another; (1) regional projects using geophysics in the study of deep crustal structures; (2) compilations; (3) studies in which there is dual emphasis.

Regional Projects Using Geophysics

Several deep crustal studies using geophysics have started recently or are continuing. For example, at the University of Alberta:

> "The deep crustal structure of the Cordillera and Plains is being investigated by D.I. Gough and J.S. Reitzel (Graduate Research Center of the Southwest, Dallas, Texas) using magnetic deep sounding; by D. Rankin through telluric and magnetotelluric studies; by G.L. Cumming, E.R. Kanasewich, R.M. Clowes and N.N. Chandra, using seismic refraction and reflection methods; and by E.R. Kanasewich using gravity and magnetometer surveys."

In Manitoba, Project Pioneer, a joint project of the University of Manitoba and the Manitoba Department of Mines in the Rice Lake-Beresford Lake volcanic-sedimentary belt, was started in 1965 and several facets of the project are listed in Current Research in the Geological Sciences in Canada, 1966-67 (G.S.C. Paper 67-58). A regional structural analysis of the Superior province involving the correlation of several types of geological and geophysical observations is being carried out by H.B.D. Wilson, W.C. Brisbin et al. at the University of Manitoba. Another study by L.J. Kornik and W.C. Brisbin is using gravity, aeromagnetic, and geological data to outline major structural features and their relation to surface geology in the Churchill Province in northwest Manitoba and northeast Saskatchewan.

Regarding this type of study in universities in Ontario, Wynne-Edwards writes:

> "Regional studies, often with the help of geophysical information, are important parts of structural geology. In this category is an investigation by Clifford at McMaster of the tectonics of greenstone belts and from this, of the behavior of the Archaean crust; a study by Wynne-Edwards of superimposed tectonic events in the central part of the Grenville Province, which has revealed a history extending back to the Archaean; and an investigation of the regional structure of the Lake Superior area by Halls, West, and Currie at Toronto."

Compilations

Studies in which data accumulated over a period of years by various agencies are put together with a specific purpose and may or may not be supported by regional field work by the compiler are becoming increasingly important. Price emphasizes this:

"In appraising the current status and future requirements of research in structural geology we must place adequate emphasis on the fundamental importance of those comprehensive studies, such as regional geological syntheses, in which large volumes of data drawn from the various fields of specialization in the geological sciences are integrated in terms of the fundamental objectives of structural geology – the what, how, when, and why of the deformation of the earth's crust. These comprehensive studies draw upon a broad spectrum of interdependent specialized fields of investigation that includes, among others: structural analysis, physical stratigraphy, geochronology, sedimentology, rock mechanics, igneous and metamorphic petrology, geophysics, and geomorphology. They constitute the most fundamental category of research in structural geology and provide a logical framework within which the individual structural research projects of more limited scope that lie within the various fields of specialization can be formulated, executed, and appraised. The continuing trend toward progressively more narrow specialization may be a necessary expedient in view of the ever widening scope of structural geology, but inherent in it is the risk of specialized research that progressively becomes diverted from the fundamental objectives of structural geology into some other field of endeavor. For example, in appraising sophisticated analyses of structural geometry or comprehensive studies of the mechanical behavior of geological materials under laboratory conditions we must operate within the context of the fundamental objectives of structural geology lest these specialized studies be considered as ends in themselves. Diversity in our analytical approach in structural geology is desirable, but agreement on our fundamental objectives, and the integration of the fruits of those diverse studies in terms of these objectives, is essential.

"The most significant recent advance in our understanding of the geological structure of the Canadian Rockies was marked by the publication during 1966 of a comprehensive synthesis of the structure and orogenic evolution of the southern Canadian Rockies by Bally, Gordy, and Stewart of Shell Canada Limited (Alberta Society of Petroleum Geologists, vol. 14, pp. 337-381). The presentation of the basic results of several decades of intensive seismic exploration in the southern Canadian Rockies and Foothills has provided a new dimension in the synthesis of the large volume of structural, stratigraphic, and petrologic data available from surface-geological studies throughout the southeastern Canadian Cordillera and from deep drilling in the eastern Rocky Mountains. The result is a basic

model for structural geometry and evolution of the Canadian Rockies that should exert a fundamental influence on the interpretation of the foreland zones of other orogenic belts throughout the world.

"An overall synthesis of the geology of Canada being prepared by the Geological Survey of Canada under the direction of R. J. W. Douglas can be expected to play a role that is similar in character but broader in scope. Some of the preliminary results of this project as it applies to the western Cordillera were incorporated in the C. I. M. M. symposium on the tectonic history of the western Cordillera published during 1966. Current investigations in the Canadian Rockies that are pertinent to research in structural geology include regional geological studies, several detailed studies of particular aspects of local geological structure, and a seismic reflection study."

Special Volume No. 8 of the Canadian Institute of Mining and Metallurgy Tectonic History and Mineral Deposits of the Western Cordillera, complements the Alberta Society of Petroleum Geologists' Atlas on the Geological History of Western Canada and somewhat changes the perspective of the tectonic history of the area west of the Rocky Mountain Trench.

Regarding the Tectonic Map of Canada, Poole writes:

"Compilation of the Tectonic Map of Canada by a committee chaired by C. H. Stockwell is a project of major importance. In 1965, the Geological Survey of Canada published a preliminary tectonic map of the Canadian Shield in several colours. Stockwell reports that compilation of the tectonic map of the rest of Canada is complete and final review and correction well advanced. The final Tectonic Map of Canada will be published in color on a scale of 1:5,000,000 (about 1 inch to 80 miles)."

Projects with Dual Emphasis

Projects in which the emphasis has been partly structural and partly petrologic or stratigraphic have been mentioned in the foregoing discussion of field studies.

Poole stresses the dependence of structural analysis on stratigraphy:

"Almost all projects by the Geological Survey are predominantly stratigraphic, and structural analysis takes a subsidiary role. Clearly, structural studies must follow and be thoroughly integrated with stratigraphic studies. In most areas, study of stratigraphy and distribution of rock-units need be accompanied by only first-stage structural analysis to be worthwhile. This is not to say that the stratigraphic or regional study would not benefit from a more thorough structural analysis. However, structural analysis, to be meaningful and valuable in terms of the common goal of the evolution of the rocks, must be keyed to the stratigraphy."

As indicated last year, very few structural studies of mineral deposits are reported. Some structural studies are being done by mining companies but are not reported, although a few of these have appeared as published papers. This was discussed in last year's report, and this year Wynne-Edwards, in reviewing university research in Ontario, comments:

> "Although they may be reported elsewhere and thus have escaped our attention, there appears to be an astonishing lack of the previously traditional types of structural study of a mine or mineralized area. This must reflect an increasing preoccupation with pure scientific research, but perhaps more seriously it may indicate a lack of liaison between the mining industry and the staff of the universities of Ontario. The structural study of controls of mineralization is a field to which Canada has contributed tremendously, and one which should not be allowed to die out."

Theoretical and Experimental Research

Experimental Studies

As in past years, experimental structural studies are mainly in rock mechanics. K. Barron, secretary of the Canadian Advisory Committee on Rock Mechanics, has provided the following report:

(a) Rock Mechanics at the Mines Branch, Department of Energy, Mines and Resources

> "A monograph by D.F. Coates of the Fuels and Mining Practice Division, Mines Branch, Department of Energy, Mines and Resources, has been published outlining basic rock-mechanics principles. Coates is also the author of a series of Mines Branch Research Reports concerned with various aspects of mine-pillar loading and has proposed a system of rock classification tailored to rock-mechanics requirements.
>
> "As part of the study on rock classification, a group headed by R. C. Parsons is conducting uniaxial compressive tests on a wide spectrum of rocks to determine the range in values of strength, deformability, pre-failure deformation and its variation with time, and the proportion of plastic strain occurring in the substance before failure. Coates and M. Gyenge have conducted in situ plate-load tests to determine the strength and deformation properties of rock.
>
> "Studies of some of the factors influencing rock-slope stability are continuing, and a series of reports by Coates and Gyenge has been published. Of particular interest in slope stability is the establishment of stress distributions in typical slopes. Gyenge has been conducting a

program of photoelastic studies to determine such stress distributions. To augment this bench study, K. Waranica has used the finite-element method developed at Berkeley to determine the stress distributions in typical rock slopes. Independently, N. Toews is considering an analytical approach to determine stress distributions in typical rock slopes, using as a basis the functions (infinite in number) which are solutions to the biharmonic equation in polar coordinates. The desired solution would be approximated by taking a linear combination of the above functions and finding the coefficients that give the best least-square fit to the boundary conditions. Toews is also applying numerical methods to calculate the stress distributions associated with slopes of cuts in material under gravity loading. The exact conformal mapping is approximated by a power series. In the case of a straight finite slope an adequate representation would require sixteen or more terms.

"Measurements which allow determination of field stresses have been made by the Mines Branch at a number of Canadian mines. These field measurements have been a part of the investigations concerned with pillar and abutment load studies. Primitive as well as mining-induced stresses have been determined. Stressmeters, developed at the Mines Branch, U.S. Bureau of Mines Deformation Meters and South African CSIR "Leeman Cells" have been used.

"At the request of the University of Sheffield, K. Barron, acting for the Mines Branch, has made an appraisal of the glass-insert stressmeter as a means of determining field stress. Barron and Toews have shown from measurements made within an unlined salt shaft that radial displacement at depth is consistent with the assumption that the shaft is subject to a uniform all-round pressure and that the creep of the salt is solely due to shear creep (i.e., dilatational creep is negligible).

"G.E. Larocque has developed a sonic unit to determine the extent of the fracture zone around mine openings. Some relationships have already been established between fracture zones and the extent of mining. Attempts to relate existing stress to microseismic activity at a number of Canadian mines have been unsuccessful. A commercially available unit "Seismitron" has been used in these studies.

"Blasting studies are being carried out at the Mines Branch to establish coupling and transmission relationships for rock materials under explosive attack. The common object of these studies is to predict field crater dimensions on the basis of computed stress distributions and established rock and explosive dynamic properties. Rock-plate tests by K. Sassa and Coates have determined plane-wave-attenuation factors, crushing strength and the Hugoniot for the rock material under study. This study has also indicated that the standard acoustical coupling relationship is adequate in establishing the transmitted pressure into the rock mass at the rock-explosive interface. G.E. Larocque has determined the dynamic

tensile strength of the rock material by means of Hopkinson bar tests. Field-ground-motion studies have also been completed. Good agreement has been realized between the actual dimensions of field-crater tests and those predicted on the basis of analysis. Larocque, F. Kapeller and J.A. Darling have developed a system for measuring the detonation velocity of large explosive charges. Larocque has reported a method of simulating the direct-stress distribution resulting from detonation of a column charge on the basis of knowledge of the stress conditions resulting from a small charge element. M. Terada is continuing the earlier work of Sassa and Coates on rock plates. The study has been extended to consider stress-wave shape and the effects of spherical attenuation. K. Waranica is presently considering adaptation of the "Tensor" code to describe the one-dimensional attenuation of the shear wave resulting from explosive attack of rock plates.

"K. Lyall has continued the study initiated by P. LeComte of the mechanical properties of rock through the transmission of vibrations in laboratory specimens. Measurements of internal friction are being made to study the deformation mechanisms in rocks and minerals, commencing with two relatively pure marbles, galena and halite. H.R. Hardy, until his departure in 1966, continued his study of the time-dependent deformation of geological materials. Initial incremental creep measurements have been carried out with specimens of Wombeyan marble. It has been found that the resulting data fit the incremental form of the Burgers mechanical model.

(b) Rock Mechanics at Canadian Universities

"C.L. Emery, University of British Columbia, is investigating the thermal conductivity of rocks under various stress conditions. At Laval University, B. Ladanyi is investigating the stress-strain behavior of rock after failure. The purpose of this research is to acquire more information on the true state and strength of rock in failure zones around mine openings. M.S. King, University of Saskatchewan, is continuing a study of the mechanical properties of salt and potash rocks that was initiated by W.M. Schwerdtner. P.M. Clifford, McMaster University, is conducting laboratory studies on rock deformation. The object is to establish the precise relationships which exist between deformational behavior and grain and cement characteristics of the rock. R.G.K. Morrison, McGill University, is reviewing the test work conducted at that institution on the physical properties of rock as to procedure, usefulness and possible future test programs. J.E. Udd, also at McGill, is continuing mathematical and photoelastic studies of stress distributions around simulated mine openings. The research is currently being extended to include multiple, interacting openings. W.M. Telford, McGill University, is investigating the possibility of detecting rock instability in rock structures by means of seismic or acoustic techniques. E.J. Lajtai, at the University of New Brunswick, is

using structural models to study the shear strength of jointed rock masses. Similarly, D. E. Gill at Ecole Polytechnique is using structural models in an investigation of the influence of geological structure on the stress distributions in a mine roof and the effect on the strength of a mine roof. A. Bauer, Queen's University, is initiating a study to develop scaling laws for use in blasting. A. V. Pegler, also at Queen's, is directing a study concerned with the fracture of rock by fatique."

The need for liaison between workers in rock mechanics and structural geology has been emphasized in previous reports of this subcommittee. Some of the projects mentioned in the foregoing such as those of Schwerdtner, Clifford, Lajtai, Currie, and others are being done by geological departments. A workshop to be held in Ottawa in March 1968 on "Kink Bands and Brittle Deformation" (p. 6) is an important step in bringing together workers in the two fields and one in which this subcommittee is taking an active part.

From the viewpoint of a field geologist, P. S. Simony, University of Calgary, makes the following comment: "...Field geologists should be encouraged to make greater efforts in establishing probable upper and lower limits on the main parameters operative during a particular tectonic event, that is, pressure, temperature and strain rate. This would greatly help in making meaningful correlations with the rapidly developing experimental field."

Techniques and Theoretical Studies

In addition to rock mechanics and related experimental work, some studies of structural techniques and principles are reported. They are few but extremely important. No doubt many projects of this sort are not reported and many never succeed to the extent that they will be reported.

One of the most important developments of techniques has been the application of computers to the processing of structural-orientation data. In connection with Project Pioneer, W. C. Brisbin, I. Haugh and A. Turek, University of Manitoba, have made up and tested a structural-field-data sheet from which complete structural observations can be readily transferred to punch cards[1]. They are developing computer programs for data retrieval and processing. In their study of jointing in the Cardium Sandstones of Alberta, Muecke and Charlesworth used computer programs in the preparation of pole-density diagrams. R. A. Price recorded field data on coded cards in connection with some structural studies in Operation Bow-Athabasca; these data are currently being processed. It is expected that such techniques will be applied increasingly to projects in which large masses of numerical data must be

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[1] Haugh, I., Brisbin, W. C., Turek, A., A Computer-Oriented Field Sheet for Structural Data, Can. Jour. Earth Sciences, vol. 4, No. 4, 1967, pp. 657-662.

analyzed. There are many pitfalls in selecting and recording the data, but if they are overcome and the machines and programs become readily available, the methods will stimulate work in quantitative structural analysis.

Attention should be drawn to other theoretical studies, including the work of Stauffer on the geometry of folded linear orebodies, Schwerdtner and Ahmad on hornblende fabrics, Starkey on the application of X-ray techniques to petrofabric analysis, and King on the rheological properties of evaporites.

Southern Cordilleran Structure Project

A third season of field work was completed in 1966 on the Southern Cordilleran Structure Project, initiated at the suggestion of the Structure Subcommittee under the chairmanship of K. C. McTaggart in 1962. Field work on a few of the projects is complete or nearly complete, and detailed reports are being prepared. An informal field conference for participants in the project and others interested was held in Revelstoke, June 9 and 10, 1966. A progress report is expected to form the basis for a symposium at the meeting of the Geological Association of Canada in Vancouver in April 1968.

The following summary has been provided by Project Coordinator J. O. Wheeler.

The southern Cordilleran Structure Project is guided by a committee set up at the beginning of the project (1962) and chosen from people who at that time were familiar with one or more of the structural sub-provinces of the southern Cordillera. The members are J. O. Wheeler (Geological Survey of Canada), director, K. C. McTaggart (University of British Columbia), James T. Fyles (British Columbia Department of Mines and Petroleum Resources), J. E. Reesor (Geological Survey of Canada) and R. J. W. Douglas (Geological Survey of Canada). In three field seasons a great deal of work has been done, financed by the Geological Survey of Canada, by G. S. C. grants recommended by the National Advisory Committee, and by the British Columbia Department of Mines and Petroleum Resources. Much of the work has been carried out by university professors and their students. Compilations of present knowledge have been made and new ideas have stimulated a great deal of interest in the structure of the southern Cordillera and in structural geology. A progress report will be presented at the proposed Geological Association of Canada symposium on Cordilleran structure in Vancouver in 1968. The completion of the first stage of the project, involving determination of the geometry of the structure of the belt, will probably require a dozen or more man-seasons of field work. To be successful in its first objective, the project requires continued support for several years after 1968.

SOUTHERN CORDILLERAN STRUCTURE PROJECT (C.S.P.)

The following summarizes field projects undertaken in 1966 related to the Structure Project.

AREA	WORKER	FINANCIAL SUPPORT	ORGANIZATION AND PROJECT
CASCADE MOUNTAINS			
(a) Manning Park	J.A. Coates	G.S.C.	Ph.D. Thesis, U.B.C.-C.S.P. Structure of Lower Cretaceous Rocks
(b) East of Harrison Lake	B.E. Lowes	G.S.C.	Ph.D. Thesis, University of Washington under Prof. P. Misch-C.S.P. Structure and metamorphism in northern continuation of Cascade orogen
(c) Central Cascade Mountains, Chilliwack Lake area	T. Richards	N.A.C.	Ph.D. Thesis, U.B.C.-C.S.P. Study of Chilliwack batholith and environs
INTERIOR PLATEAU			
(a) Nicola Lake area	N. Schau	N.A.C.	Ph.D. Thesis, U.B.C.-C.S.P. Structural studies in the Nicola Group
(b) Shuswap Lake	W.K. Fyson	N.A.C.	University of Ottawa-C.S.P. Structure of Mount Ida Group and relationship to Shuswap gneisses (Monashee Gr.).
MONASHEE MOUNTAINS			
(a) Ratchford Creek	W.J. McMillan	G.S.C.	Ph.D. Thesis, U.B.C.-C.S.P. Structure of core and enveloping metasedimentary gneisses on west side of Frenchman's Cap Dome
(b) Mount Copeland North of Revelstoke	J.T. Fyles	B.C. Dept. Mines & Petroleum Resources	Lead-zinc deposits in Shuswap rocks – on south side of Frenchman's Cap Dome
(c) South of Revelstoke	J.E. Reesor	G.S.C.	G.S.C. Granites in Canada Program – Thor-Odin gneiss dome
DOGTOOTH MOUNTAINS			
Northern part	P.S. Simony and G. Wind	N.A.C.	University of Alberta (Calgary) – C.S.P. Structure of northern Dogtooth Mountains

ROCKY MOUNTAINS			
(a) Operation Bow-Athabaska	R.A. Price E.W. Mountjoy	G.S.C.	G.S.C. – Helicopter-supported reconnaissance between Jasper and Banff
(b) Operation Bow-Athabaska	D.G. Cook	G.S.C.	Ph.D. Thesis – Queen's University. Study of Stephen-Dennis fault zone
(c) Rocky Mountains	H.V. Bielenstein	G.S.C.	Ph.D. Thesis – Queen's University. Structural analysis of Rundle Thrust Sheet
(d) Foothills L. Minnewanka map-area	N.C. Ollerenshaw	G.S.C.	Structural studies of "Panther Dome"

Preliminary results of all the above projects, except those of Richards, Schau, Fyson, Fyles, and Simony, are reported in Geol. Surv. Can., Paper 67-1. Coates, McMillan, Fyles, Reesor, Cook, Bielenstein, and Ollerenshaw have completed field work on their projects. Schau and Price and Mountjoy have nearly completed their field work.

Field projects reported on earlier that have been written up include:

W.J. McMillan (1966), Geology of Vedder Mountain near Chilliwack, B.C. M.A.Sc. Thesis, U.B.C.
J.W.H. Monger (1966), Stratigraphy and structure of the type-area of the Chilliwack Group, southwestern B.C. Ph.D. Thesis, U.B.C.
K.C. McTaggart and R.M. Thompson, "Geology of Cascade Mountains near Hope, B.C." Manuscript completed for paper in Can. Jour. of Earth Science.
J.V. Ross has nearly completed his report on Mount Revelstoke area

A seismic refraction profile was run across the southern Cordillera from the mouth of Fraser River to near Revelstoke, B.C., by the Observatories Branch under W.R.H. White.

COMMUNICATIONS

Considerable concern has been expressed by members of this sub-committee and others regarding the lack of communication between structural geologists in Canada.

Of necessity, many structural geologists work in one geological environment. Many have little opportunity to discuss their findings and techniques with others, particularly with experts from other parts of the country. In the words of J.V. Ross:

> "The very distribution of individuals interested in structural geology precludes them from working in anything but a vacuum. This, of course, is an extreme statement, but I am sure that it has a large element of truth. For example, where do you see 'Cordilleran' geologists discussing, knowledgeably, problems with 'Shield' geologists? Each regards his own domain as something very special, and in some sense, inviolable. This regional attitude is rife in Canada, and anything we can do to dispel it is for the good of our science.
>
> "If any of the above is true, then one way to alleviate the problem is to have frequent (?) informal discussions (workshops) where all disciplinary interested parties attend and participate. Such meetings could have a central theme, which should be fundamental and not determined geographically. They could be held at different universities across Canada, and the proceedings published in a very simple offset format.
>
> "Gatherings such as these should be supported and controlled entirely by the universities themselves, possibly with the help of N.R.C. (in the same manner that the National Science Foundation in the U.S.A. sponsors courses instituted by the American Geological Institute at various colleges). Eventually an autonomous Society of Structural Geology and Rock Mechanics may be formed, possibly as a sub-group of the Geological Association of Canada."

A more concrete proposal is made by Charlesworth:

> "With regard to comments relating to structural research in Canada, I think it's true to say that structural geologists at the Prairie universities feel somewhat isolated and would support Ross's plea, expressed in the 1966 report, for more meetings with other structural geologists. Specifically we suggest (1) that a week-long meeting of structural geologists in Western Canada (including those in federal and provincial surveys, in industry, and in universities) be held once a year or every other year; (2) that these meetings be held on a rotational basis in (a) Vancouver (or Victoria); (b) Calgary (or Edmonton), and (c) Winnipeg (or Saskatoon); (3) that each meeting consist of an informal symposium to be held in the appropriate city, and a field trip into the appropriate

structural area (Western Cordillera, Rockies and Shield); (4) that every third or fourth year structural geologists from Eastern Canada be asked to participate, and (5) that American structural geologists working in Montana, Idaho and Washington be invited to attend every meeting."

A somewhat different approach has led to a plan for a workshop to be called "Kink Bands and Brittle Deformation" to be held in Ottawa in March 1968. Such a workshop was planned originally for the spring of 1967 and grew out of a proposed meeting of the Structural Subcommittee. The need to bring together the overlapping parts of rock mechanics and structural geology has been stressed in previous reports, and this workshop as originally planned and in part as presently conceived, should fulfil this need. It also fulfils the desire expressed above for communication between structural geologists by means of workshops or symposia.

RECOMMENDATIONS

(1) In view of the foregoing discussion regarding communications, the subcommittee strongly recommends that the National Advisory Committee support the proposed "Kink Bands and Brittle Deformation" workshop. Funds are required to bring key speakers to the workshop. We request that $3,000 of the National Advisory Committee funds for subcommittee meetings be used to bring in these consultants.

(2) Since the present subcommittee has reached the end of its term, we recommend that the new subcommittee meet during the workshop and attempt to arrange, through the universities, periodic meetings of structural geologists as suggested by Ross and Charlesworth.

(3) We recommend that the National Advisory Committee continue to support the Southern Cordilleran Structure Project at least until the first phase of the study is complete.

DISCUSSION OF REPORT

In presenting this report, Fyles pointed out that although the Structural Subcommittee would continue to report on the Southern Cordilleran Structure Project (p. 93), the direction of the project should be left to the coordinator and steering committee.

Financial support of the workshop on "Kink Bands and Brittle Deformation" (Tectonics Research Conference, p. 6) to be held in Ottawa on March 14-15, 1968, by up to $3,000 was approved, provided this amount is available after expenses of subcommittees meetings in 1967-68 have been covered.

RESEARCH IN THE OIL INDUSTRY IN CANADA IN 1966

Presented by G.G.L. Henderson

The National Advisory Committee on Research in the Geological Sciences publishes annually a summary "Current Research in the Geological Sciences in Canada" (G.S.C. Paper 66-53 for the year 1965-66). With few exceptions the summary does not include research by mining and oil-industry geologists and geophysicists. In order to obtain some estimate of research in the geological sciences in the petroleum industry, a survey was conducted in early 1967. Thirty questionnaires were distributed and twenty were returned, including those of all the major petroleum exploration organizations. The responses covered 964 man-years of geological and geophysical work during 1966. Since there are approximately 2,000 geologists and geophysicists in the petroleum industry in Western Canada that are members of various professional groups, it is felt that the responses cover a representative sample. For the purpose of comparison, there are about 877 research workers recognized in G.S.C. Paper 66-53.

The survey requested that each organization estimate its total man-years of geological and geophysical work in Canada during 1966, subdivided into administrative, operational and technical work. The administrative category included those geologists and geophysicists employed in supervision, business administration and personnel work, whereas the operational category included those whose primary duties were wellsite work, supervision of geophysical field crews, etc. The technical category was further subdivided into "Applied Research" and "Fundamental Research", using as definitions "the application of existing tools, techniques and concepts" and "the search for new tools, techniques or concepts". The questionnaire also requested the responding oil companies to distribute their applied and fundamental research into essentially the same subjects as are used in the National Advisory Committee survey of non-industrial organizations. Where a detailed breakdown was considered to violate company security the companies were requested to show a total figure for the subject rather than no figure at all. Many companies exercised this option and gave figures for the broad subject (e.g. geophysics) but no detail for the sub-divisions of this subject (e.g., electrical, magnetic, etc.).

The general results of the survey showed that of the 964 man-years reported on by the responding companies, 176 man-years (18.3%) were in administration, 165 man-years (17.1%) in operations and 623 man-years (64.6%) in technical work. Of the technical work 549.5 man-years were distributed as applied research and 73.5 man-years as fundamental research. Assuming that this survey covered a large enough sample to be representative, approximately 65 per cent of the geological and geophysical work performed by the oil industry can be classified as research. Applied to the whole petroleum industry, this percentage would suggest that at least 1,300 man-years

of industrial research were completed in Canada during 1966. It is apparent that a large amount of this work is duplicated, since more than one company is gathering data on the same problem, which is generally not common to public research. This disadvantage, however, is balanced by the advantage of having different groups, with different backgrounds and different approaches, searching for solutions in competition.

In order to keep individual replies confidential, only the industry totals are being published. The data were compiled by J.D. Aitken of the Geological Survey of Canada, Calgary, and are summarized in the following tabulation:

1. Total man-years of geological and geophysical work by responding oil companies in Canada during 1966 — 964 man-years

2. a) Administrative — 176 (18.3%)
   b) Operational — 165 (17.1%)
   c) Technical — 623 (64.6%)

Applied Research 549.5

Fundamental Research 73.5

Distribution by Subject of Technical Work in Man-years

Subject (See GSC Paper 66-53)	Applied (Man-Years)	Fundamental (Man-Years)
1. Areal Geology	39	2.0
2. Engineering Geology	10	-
3. Geochemistry	2	3.4
4. Geochronology	-	-
5. Geophysics	176	35.9
Electrical	-	-
Gravity	8	0.25
Heat Flow	-	-
Magnetic	3	-
Radioactive	-	-
Seismic	145	9.25
General	1.5	0.25
6. Geomorphology and Glaciology	2	-

Subject (See GSC Paper 66-53)	Applied (Man-Years)	Fundamental (Man-Years)
7. Mineral Deposits	70	3.5
Base Metals	-	-
Ferrous Metals	-	-
Radioactive Deposits	-	-
Other Metals	-	-
Industrial Minerals	.9	-
Petroleum	66	3.5
Coal and Peat	-	-
General	1.5	-
8. Mineralogy	.5	0.5
Specific Minerals	.25	-
General	.25	0.25
9. Palaeontology	14	3.0
Macropalaeontology	.25	-
Micropalaeontology	6	2.0
Palynology	4	1.0
10. Petrology and Petrography	10	4.0
11. Pleistocene and Groundwater	-	-
12. Sedimentation Processes	12	3.0
13. Stratigraphy	73	3.0
14. Structural Geology	19	0.2
15. Computer Applications	25	7.5
Geology	8	3.0
Geophysics	15	3.5
16. Economic Geology	12	-
17. Hydrodynamics	4	0.5
18. Petroleum Engineering	67	5.0
19. Petrophysics (Formation Evaluation)	14	2.0
TOTAL	549.5 Man-Years	73.5 Man-Years

DISCUSSION OF REPORT

In presenting this report, Henderson pointed out that more fundamental research by the petroleum industry was in progress than indicated, because several of the larger companies used the large research establishments of their parent companies in the United States for this type of work. This is particularly true of research in structural geology; practically all high-pressure laboratory research of this type is being done in U.S. centres. In the future, laboratories of this type might be established in Canada, although to move such centres once they were established was difficult and costly. Several members remarked that although most of the results of research by the petroleum industry are not released at time of completion, a large amount is released and published eventually by the authors or the companies.

APPENDIX

GEOLOGICAL SURVEY OF CANADA RESEARCH

GRANTS TO CANADIAN UNIVERSITIES

1967-68

Name University	Title of Project	Amount
Ambrose, J.W. Queen's Univ.	Examination of the major fault structure extending northeast from Madoc, Ontario.	$2,030
Bérard, J. Ecole Polytechnique	La porosité des roches et facteurs d'altérabilité.	1,760
Brisbin, W.C. Univ. of Man.	A study of deformation environments within the granitic crust.	1,000
Brueckner, W.D. Memorial Univ. of Nfld.	Southern Avalon geology.	1,000
Burley, B.J. McMaster Univ.	Phase equilibria of the systems: (1) $NaAlSiO_4$-NaCl; (2) $NaAlSiO_4$-NaOh-H_2O; (3) $NaAlSiO_4$ – NaCl-H_2O; (4) $CaMgSi_2O_6$-CaF_2.	1,760
Caldwell, W.G.E. Univ. of Sask.	The Cretaceous "Belly River" Formation in Saskatchewan.	5,000
Cameron, R.A. Nova Scotia Technical College	Statistical study of minor and trace elements analyses of Upper Mississippian carbonate rocks in the Antigonish basin, Nova Scotia.	1,500
Chao, G.Y. Carleton Univ.	Studies of minerals from the Desourdy Quarry, Mt. St. Hilaire, Quebec.	1,760
Charlesworth, H.A.K. Univ. of Alta.	Anisotropy of magnetic susceptibility. Analysis of folding in the Interior Plains of Western Canada.	3,360

Name University	Title of Project	Amount
Clifford, P.M. McMaster Univ.	Precambrian studies.	1,760
Colwell, Jane Univ. of Alta.	Late Cretaceous and Early Tertiary micro-mammals from southeastern Alberta.	3,160
Crocket, J.H. McMaster Univ.	Some aspects of the genesis of strata bound sulfide deposits.	1,740
Danner, W.R. Univ. of B.C.	Stratigraphy and palaeontology of the Cache Creek Group and correlated sequences in southwestern British Columbia.	1,200
Dineley, D.L. Univ. of Ottawa	Heterostraci from the Read Bay and Peel Sound Formations, Somerset and Prince of Wales Islands, N.W.T.	2,100
Doig, R. McGill Univ.	Isotopic and petrologic studies of: (a) Late Precambrian Intrusive rocks of the Chatham-Grenville type, (b) Anorthosites and related rocks.	1,760
Deutsch, E.R. Memorial Univ. of Nfld.	Palaeomagnetism and Application of Rock Magnetism to Geological Structure in the Springdale-Whalesback Area of North-Central Newfoundland.	1,000
Elson, J.A. McGill Univ.	Problems of Glacial Lake Agassiz.	1,760
Eydt, H.R.N. Univ. of Waterloo	Pollen analysis of peat bogs from Prince Edward Island.	1,400
Farquhar, R.M. Univ. of Toronto	Age determinations and isotope studies of Precambrian Terrains in the Canadian Shield.	3,360
Farrar, E. Queen's Univ.	Potassium-argon and fossil fission track age determination.	1,760

Name University	Title of Project	Amount
Fox, R. C. Univ. of Alta.	Early Tertiary microvertebrates from southern Alberta.	1,760
Fritz, Madeleine A. Univ. of Toronto	Geology of the Maritime Provinces.	4,000*
Fyson, W.K. Univ. of Ottawa	Relation of minor to major structures in the Maritime Provinces.	1,760
Geldart, L. P. McGill Univ.	Gravity investigation of faults and dykes.	1,760
Greenwood, H. J. Univ. of B. C.	High pressure-high temperature mineralogic phase equilibria.	1,760
Greggs, R.G. Queen's Univ.	Upper Cambrian trilobite faunas of southwestern Alberta.	3,660
Gregory, A. F. Carleton Univ.	Investigations of the geophysical and geological environment of selected mineral deposits in the Grenville Province.	4,000
Grice, R.H. McGill Univ.	A quantitative method for estimating groundwater flows in a three dimensional system of aquifers.	1,000
Gross, W.H. Univ. of Toronto	Origin of the silver-bearing veins at Cobalt, Ontario.	1,000
Harriss, R. C. McMaster Univ.	Geochemical studies of Lake sediments.	3,600
Hogarth, D. D. Univ. of Ottawa	Igneous history of rocks of the southern Gatineau region.	2,660
Hooper, K. Carleton Univ.	Studies of Precambrian microfossils.	1,000
Hutchinson, R. W. Univ. of West. Ont.	Comparative studies of lithium-bearing pegmatites.	1,700

* Support for publication of symposium volume.

Name University	Title of Project	Amount
Jones, D.L. Univ. of Alta.	Palaeomagnetic study of Waterberg system of South Africa.	1,700
Karrow, P.F. Univ. of Waterloo	Study of fossil remains in interstadial and interglacial deposits of the Toronto district, Ontario.	5,000
Keen, M.J. Dalhousie Univ.	A study of deep reflections from within the crust and upper mantle.	1,760
Kennedy, M.J. Memorial Univ. of Nfld.	Structural study of the Fleur-de-Lys group near Mings Bight and Pacquet Harbour, W.B., Nfld.	1,900
Knop, O. Dalhousie Univ.	Sulphide minerals.	2,100
Kupsch, W.O. Univ. of Sask.	Ecology of Sturgeon Lake marl deposits.	1,500
Lajtai, E.Z. Univ. of N.B.	The petrology of glacial sediments in New Brunswick.	1,000
Laming, D.J.C. Univ. of N.B.	Sedimentology of Devonian and Carbonaceous rocks, Gaspé Peninsula, P.Q., and the upper Bay of Fundy region, N.B. and N.S.	600
Leblanc, G. Laval Univ.	Etude préliminaire de la microséismicité de la région située au nord-ouest de la ville de Québec.	700
Ledoux, R.L. Laval Univ.	Caractérisation minéralogique des argiles des régions de glissements de terrain de la province de Québec.	1,000
Leith, E.I. Univ. of Manitoba	Pleistocene stratigraphy and sedimentation of southeastern Manitoba.	3,360

Name University	Title of Project	Amount
Libby, W.G. Univ. of B.C.	A tectonic study of the Wark and Colquitz gneiss Complex of southern Vancouver Island.	1,600
Liberty, B.A. Univ. of Guelph	Kingston area, Ontario, Memoir.	600
MacNeil, R.H. Acadia Univ.	Till fabric analysis in Drumlins and tills of Nova Scotia. C^{14} dating of selected plant materials.	2,600
Mathews, W.H. Univ. of B.C.	Sedimentation in Pitt Lake, British Columbia.	2,000
McAllister, A.L. Univ. of N.B.	Study of Bathurst ores-Heath Steele Mines Ltd.	5,160
McGugan, A. Univ. of Calgary	Permian Stratigraphy and Palaeontology, S.E. and N.E. British Columbia, Yukon and N.W.T.	1,760
McNutt, R.H. McMaster Univ.	Genesis of anorthosite: Field and Rb-Sr isotopic studies.	1,760
McTaggart, K.C. Univ. of B.C.	Reconnaissance of glaucophane schist belt, north-central British Columbia.	250
Middleton, G.V. McMaster Univ.	Multivariate statistical techniques in geology.	1,760
Milligan, G.C. Dalhousie Univ.	Investigations in George River Series, Cape Breton.	1,000
Moore, J.M. Carleton Univ.	Structure and petrology of the Ratchford Creek map-area, British Columbia. Petrology of Macauley Creek ring complex, B.C.-Yukon.	1,760

Name University	Title of Project	Amount
Moore, R.G. Acadia Univ.	Biostratigraphic units in the upper part of the Windsor Group, Nova Scotia.	3,660
Moorhouse, W.W. Univ. of Toronto	Studies of basic rocks.	1,760
Morton, R.D. Univ. of Alta.	Electron-probe microanalytical studies on minerals and rocks from Canada, Great Britain and Norway.	3,000
Mountjoy, E.W. McGill Univ.	Petrography and stratigraphy of Upper Devonian Reef complexes, Alberta Rocky Mountains.	1,760
Murray, J.W. Univ. of B.C.	Purchase of a Pinger System to position an underwater camera used in marine geological research on the West Coast.	2,300
Nelson, S.J. Univ. of Calgary	Permo-Carboniferous faunal zones.	1,500
North, F.K. Carleton Univ.	The Cambrian system in Canada.	500
Pajari, G.E. Univ. of N.B.	The mineralogy and petrochemistry of the St. George Complex, New Brunswick.	1,760
Perrault, G. Ecole Polytechnique	(1) Mineralogy and petrography of the Oka Alkaline intrusives. (2) Mineralogy of Mount St. Hilaire.	1,760
Philpotts, A.R. McGill Univ.	Investigation of Monteregion rocks.	1,760
Rankin, D. Univ. of Alta.	Magnetotelluric studies of deep crustal structure in southern Alberta.	1,760
Ravindra, R. Dalhousie Univ.	A study of near-vertical deep reflections from the crust-mantle boundary.	1,760

Name University	Title of Project	Amount
Rust, B.R. Univ. of Ottawa	The sedimentology and palaeogeography of the Peel Sound Formation, Somerset and Prince of Wales Islands, N.W.T.	1,760
Sauvé, P. Laval Univ.	Etude géochimique de certaines laves de l'Abitibi.	1,100
Schwarcz, H.P. McMaster Univ.	Extinct aluminum-26 in meteorites.	3,200
Schwerdtner, W.M. Univ. of Toronto	Kinematic significance of hornblende lineations in metamorphic tectonics.	3,000
Shaw, D.M. McMaster Univ.	Trace element geochemistry.	1,760
Simony, P.S. Univ. of Calgary	Geology of Dogtooth Mountains. British Columbia.	2,400
Skippen, G.B. Carleton Univ.	Calibration of the quartz-fayalite-magnetic oxygen buffer assemblage.	1,760
Smith, F.G. Univ. of Toronto	Grain growth in metamorphic rocks.	2,600
Smith, D.G.W. Univ. of Alta.	A preliminary investigation of the Beaver River syenite body, Yukon, Canada.	1,760
Smitheringale, W.G. Memorial Univ. of Nfld.	Geology and secondary dispersion pattern of a Newfoundland base metal deposit. The distribution of trace elements in the mineralized volcanic rocks of the Notre Dame Bay area of northeastern Nfld.	1,760
Steeves, M.W. Univ. of Sask.	Palynology and stratigraphy of the Jurasso-Cretaceous boundary beds in southern Saskatchewan.	3,660

Name University	Title of Project	Amount
Stelck, C.R. Univ. of Alta.	Palynology of micro-vertebrate beds.	1,760
Stevens, G.R. Acadia Univ.	Analysis of texture and petrologic variability in Triassic basalt flows and Devonian granites of Nova Scotia.	3,160
Turnock, A.C. Univ. of Manitoba	Igneous intrusion and metamorphic facies in the Precambrian of eastern Manitoba.	1,760
Waterhouse, J.B. Univ. of Toronto	Permian brachiopod faunas of the Arctic and Yukon.	1,760
Watkinson, D.H. Univ. of Toronto	Experimental study of relationships between niobium mineralization and carbonatites.	1,800
West, G.F. Univ. of Toronto	Lake Superior seismic survey.	1,760
Williams, G.D. Univ. of Alta.	Groundwater geology of Alberta and adjacent areas.	1,760
Wilson, H.D.B. Univ. of Manitoba	The composition, age, and low grade metamorphism of the "Keeweenawan" basalts.	1,760
Wilson, J.T. Univ. of Toronto	Study of date of opening of North Atlantic Ocean.	1,760
Wynne-Edwards, H.R.	Age relations in high-grade metamorphic terrains. Geochemical correlation across the Grenville fault.	5,000* 2,160
Young, G.M. Univ. of West. Ont.	Stratigraphy, structure and sedimentology of the Precambrian rocks of Harrow and McKinnon townships, Ontario.	1,760

* Support for publication of Symposium volume.