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Canadian Geoscience Council

The Geosciences in Canada 1976
A status report

Prepared by
The Canadian Geoscience Council

Edited by: C.R. BARNES

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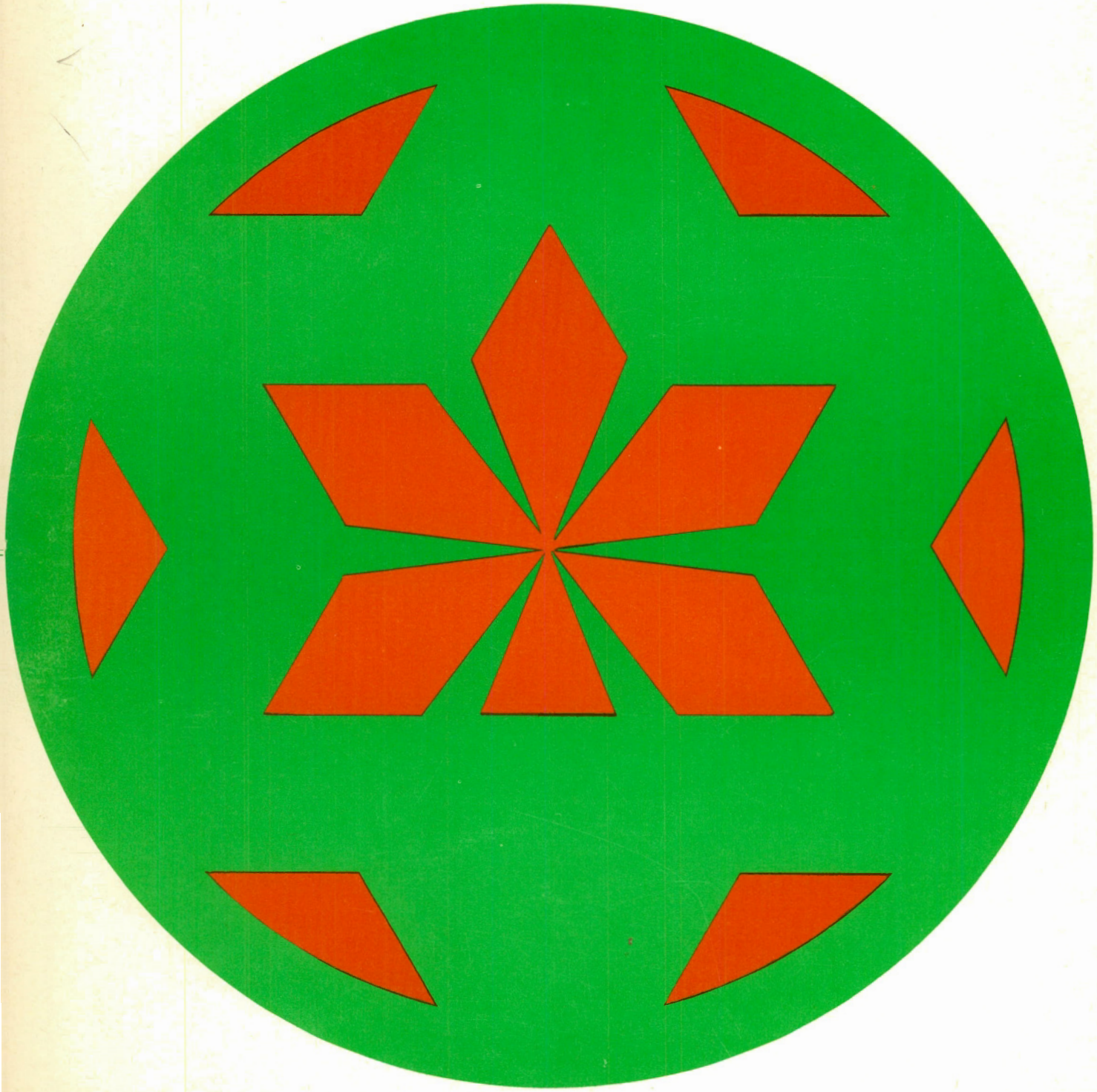

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THE GEOSCIENCES IN CANADA-1976
A STATUS REPORT

PREPARED BY
THE CANADIAN GEOSCIENCE COUNCIL

Edited by
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RATIONALE

The Challenge

Few Canadians realize the immense importance of geoscience to the Canadian economy. Canada ranks third in total world mineral production and first in terms of production on a per capita basis. Canada is the leading producer of nickel, zinc, silver and asbestos; the second largest producer of potash and uranium (in the Western world); the third largest producer of copper; and the fourth of lead.

The minerals and fuel industry (including indirect effects) contributes about 14 per cent of the Canadian gross national product and is responsible for about 8 per cent of employment. The mineral sector alone amounts to one-third of all Canadian exports.

In 1975, the mineral industry directly contributed 13.4 billion dollars to the Canadian economy. The direct investment in Canadian geoscience research by the Geological Survey of Canada, the Earth Physics Branch, and through research supported in universities by the National Research Council is 35.9 million dollars. This represents only 0.27 per cent of the value of the Canadian mineral industry. This clearly is a woefully inadequate investment in a discipline that contributes so much to the Canadian economy.

To meet projected requirements over the next 25 years expenditures will have to increase by a factor of 3 in real terms (Department of Energy, Mines and Resources, 1975). Mineral deposits are becoming increasingly difficult to find, therefore investment in research to provide the techniques will have to increase by substantially more than 3 times. Less easy to quantify is the additional cost of developing an adequate knowledge-base to assess the impact of resource development on the Canadian environment and to manage the expanded offshore regions of Canada.

To give some idea of the magnitude of the task facing Canada in the resource sector, it is estimated that to meet energy and mineral demands to 1990 exploration and development will cost approximately: 15 to 40 billion dollars for oil and gas, 3.2 billion dollars for coal, and 4.9 billion dollars for metallic minerals (Department of Energy, Mines and Resources 1975, 1976). This level of expenditure demands that the private sector be assured of appropriate economic incentives. Whereas there is little doubt of the technical ability of Canadian geoscientists to overcome the problems, it is less certain that the magnitude of the problem will be recognized in time and the necessary financial support given to research and development.

Problems and Priorities

The first Status Report of the Canadian Geoscience Council (Neale **et al.**, 1975) pointed out many highlights and defects in Canadian geoscience; its tone, however, was critical. Its most important achievement was to convey the message that Canadian geoscience has enormous potential for attaining national social and economic goals, but that this was not being fully realized. The present Status Report emphasizes changes in attitude, re-evaluation of our progress and significant improvement in communications. There continues to be some major advance in research and development, but the level of financial support and industrial incentives are inadequate to meet the challenges outlined above.

Many individual scientists writing on their subdisciplines in Part II of this report are concerned about the slow response to previously documented needs (Neale **et al.**, 1975). For example, the report on Coal Geology shows that Canadian universities continue to be oblivious to the growing need for specialists in this field, despite warnings from many sources. Also, in the previous Report it was recommended that Canadian universities revise their curricula to meet the rapidly increasing need for geoscientists to manage and assess natural resources. Although there has been some progress, most universities have ignored this strong recommendation.

The Analysis and Recommendations that follow point to inadequate funding as the most critical problem in both governmental and university geoscience research. The ultimate answer to this problem is an overall increase in funds allotted to geoscience and this can only be attained by thoroughly convincing the public and governments that our programs are essential to maintain economic and social well being. The Council has already addressed itself to the task and must continue to do so with even more vigour. One of its associated groups, the Council of Chairmen of University Geoscience Departments, has embarked on an aggressive pursuit of increased funding of intermediate-range, mission-oriented research subject to a peer review system.

One potential source of conflict within our member societies is the need to establish priorities for dividing our inadequate supply of funds. Some of those reporting on the various subdisciplines such as hydrogeology make praiseworthy attempts to specify certain fields that merit attention to the days ahead. The section on Analysis and Recommendations has pointed to certain disciplines (e.g. northern studies) where efforts should be concentrated because the national environment may help foster excellence and may result in substantial benefits.

Priorities cannot be set lightly as we pointed out in our last report (Neale **et al.**, 1975, p. 3) "It is difficult to see which of the geoscience disciplines listed can be done without in Canada because this is a nation that depends heavily on the development of its natural resource and frontier areas for which the geosciences are indispensable". For example, in the 1950's the basic work of J. Tuzo Wilson and others produced a division of the Precambrian Shield into provinces based on age and structure that led to an effective guide for the exploration for metals. Similarly, in the 1960's preliminary oceanographic data gathered to investigate the concepts of spreading oceans and drifting continents were used by petroleum geologists to test the hydrocarbon potential of the Labrador Sea.

An Outward Look

Canadian geoscientists are clearly broadening their outlook. Membership in our member societies has increased by 30 per cent in the past two years reflecting both an increase in the profession and a growing interest

in the benefits of information exchange and group action. The societies which adhere to our co-ordinating Council are co-operating effectively in many ways. Newly organized groups such as the provincial geoscientists and the Council of Chairmen of University Geoscience Departments now have an associate status in the Council and work together with the discipline-oriented societies to break down barriers to effective action. Although initially slow to co-operate with other scientific groups, geoscientists are now among the leaders in joint endeavours. Through SCITEC our representatives are helping to establish a joint association of parliamentarians and scientists and to organize forums dealing with some of the most pressing problems that confront us, such as the hazards and potentials of nuclear power. Long silent on issues that reached beyond their own interests, individual geoscientists, with their perspective of geological time and processes, now speak out on science policy and provide leadership and guidance as Canada tries to cope with the crises of our times.

Most encouraging is the invitation of the Department of Energy, Mines and Resources to our Council to establish a Committee to scrutinize the activities of the Geological Survey of Canada, and to report the findings to the geoscience community. This is the first committee of its kind established in Canada and its formation and mandate is an example of openness which other scientific establishments should follow. Our Council is increasingly assuming the management of Canada's international geoscience commitments on behalf of the community, a task formerly undertaken by government. The Association of Geoscientists for International Development, which includes hundreds of members from developing countries, grew out of a meeting two years ago sponsored by this Council. Its headquarters remain in this country and stands as a working symbol of the new outward look in Canadian geosciences.

The Growth of Excellence and the Response to the Challenge

In each of the past two years, geoscientists have received the Steacie Award of the National Research Council – the highest national prize for a young Canadian scientist. These are the first Steacie Awards to geoscientists. In the Atlantic region, the APICS medal for the outstanding young scientist of the year has been won three times by geoscientists in the first four years of the award. These are only a few recent examples of active Canadian geoscientists winning national and international awards in competition with scientists from other disciplines.

This Status Report also documents the development of excellence in many fields such as Appalachian and Cordilleran geology; deep seismic crustal studies; environmental geoscience-geochemistry; geophysical, geochemical and petroleum exploration; marine geoscience; metallogeny; and Precambrian paleomagnetism. Few of these developments are the products of long-range planning and many are financially undernourished. They grew in response to the new intellectual challenges and opportunities in the geosciences.

The ability of Canadian geoscientists to apply the new development of knowledge cannot be doubted. For example, half of the 37 major mines discovered in the Western world over the past quarter century were found in Canada (Miller, 1976), illustrating the competence of Canadian geoscientists.

Hope rises from the fact that we are now in a position to respond rationally to the challenges outlined above. Our Council has already started to act and will continue in the year ahead with a forum on "The Earth Sciences Serving the Nation" and a symposium on "Exploration – '77". Further evidence of rational responses from Canadian geosciences is contained in Part II of this report and we are greatly indebted to the 90 researchers who carefully summarized the status of their disciplines. They show beyond a doubt that Canadian geoscience is prepared to serve some of our most worthy national aspirations.

The Canadian Geoscience Council

EXPOSÉ DES FAITS

Le défi

Peu de Canadiens réalisent la grande importance des sciences de la Terre dans l'économie canadienne. Le Canada se place au 3e rang dans le monde pour la production minérale et au 1er pour la production per capita. Il est le premier producteur de nickel, zinc, argent et amiante, le deuxième de potasse et d'uranium (dans le monde occidental); le troisième de cuivre, et le 4e de plomb.

L'industrie des minéraux et des combustibles (y inclus les effets indirects) contribue pour environ 14% au produit national brut et fournit 8% de l'emploi. Le secteur minéral à lui seul est responsable du tiers des exportations canadiennes.

En 1975 l'industrie minérale a contribué 13.4 milliards de dollars à l'économie canadienne. L'investissement direct dans la recherche géoscientifique par la Commission géologique du Canada y compris la recherche financée par le CNR dans les universités est d'environ 28.5 millions de dollars, ce qui représente seulement 0.21% de la valeur de l'industrie minérale du Canada. Cette proportion est nettement insuffisante pour une discipline qui apporte autant à l'économie canadienne.

Pour satisfaire aux besoins des 25 prochaines années, il faudra augmenter les dépenses d'au moins 3 fois en valeur réelle. Les gisements minéraux deviennent de plus en plus difficiles à trouver et par conséquent, l'investissement dans la recherche de techniques nouvelles devra dépasser substantiellement le triple du montant actuel. Il est plus difficile de déterminer le coût additionnel nécessaire à l'acquisition d'une connaissance de base adéquate pour apprécier l'effet de la mise en valeur des ressources sur l'environnement et à la gestion des territoires canadiens au large des côtes.

Pour donner une idée de l'ampleur de la tâche dans le secteur des ressources, on estime que pour répondre à la demande d'énergie et de minéraux au Canada jusqu'en 1990, il en coûtera environ 15 à 40 milliards de dollars pour le pétrole et le gaz, 3.2 milliards pour le charbon et 4.9 milliards pour les minéraux métalliques. Pour en arriver là, il faut assurer des stimulants économiques appropriés au secteur privé.

L'aptitude des géoscientifiques canadiens a résoudre ces problèmes n'est pas en cause; ce qu'on doit craindre c'est qu'on ne se rende pas compte à temps de l'ampleur du problème et qu'on n'attribue pas les fonds nécessaires à la recherche et au développement.

Problèmes et priorités

Le premier rapport du Conseil géoscientifique Canadien (Neale **et al.** 1975) signalait plusieurs points forts et quelques points faibles dans la géoscience au Canada; le ton en était cependant critique. Il transmettait surtout le message que la géoscience canadienne avait un potentiel immense pour atteindre des objectifs nationaux, sociaux et économiques mais qu'on ne se rendait pas parfaitement compte de ce fait. Le présent rapport préconise des changements d'attitude, une ré-évaluation de nos progrès et une amélioration appréciable dans la communication. Des progrès notables sont toujours réalisés dans la recherche et le développement, mais le soutien financier et les stimulants industriels ne sont pas suffisants pour répondre aux défis décrits ci-dessus.

La réaction lente aux besoins exprimés antérieurement (Neale **et al.**, 1975) inquiète plusieurs des auteurs de textes sur leur sous-discipline, dans la partie II de ce rapport. On apprend par exemple dans le rapport sur la géologie du charbon que malgré des avertissements provenant de plusieurs sources, les universités canadiennes ne tiennent pas compte des besoins grandissants de spécialistes dans ce domaine. De plus, dans notre précédent rapport, nous recommandions que les universités canadiennes révisent leur curriculum pour satisfaire au besoin toujours plus pressant des géoscientifiques pour la gestion et l'évaluation des richesses naturelles. Malgré quelques progrès, la plupart des universités ont ignoré cette recommandation.

Dans le chapitre Analyse et recommandations qui suit on signale que le problème le plus critique dans la recherche géoscientifique aux niveaux gouvernemental et universitaire c'est le manque de fonds. La solution à ce problème est une augmentation globale des fonds alloués à la géoscience; on ne pourra l'obtenir qu'en convainquant le public et les gouvernements que nos programmes sont essentiels au maintien du bien-être économique et social. Notre conseil s'est déjà attaqué à la tâche et doit continuer avec encore plus de viguer. L'un des groupes associés le comité des présidents des facultés des sciences de la Terre, s'est engagé dans une campagne agressive pour recueillir plus de fonds en faveur de recherche commandée, de portée intermédiaire et sujette à un système d'examen entre pairs.

Une source possible de conflit parmi les sociétés-membres est l'établissement de priorités pour répartir notre réserve insuffisante de fonds. Les auteurs des rapports des diverses sous-disciplines comme l'hydrogéologie, font des efforts louables pour indiquer certains domaines prioritaires pour les jours à venir. Le chapître Analyse et recommandations signale certaines disciplines (e.g. études nordiques) qui exigent une concentration de nos efforts parce que notre environnement national s'y prête particulièrement et que des résultats bénéfiques peuvent en résulter.

Les priorités ne peuvent être déterminées à la légère comme on le mentionne dans notre dernier rapport (Neale **et al.**, 1975, page 3). On ne peut écarter facilement l'une ou l'autre des disciplines géoscientifiques au Canada parce que ce pays dépend fortement de la mise en valeur de ses richesses naturelles et des régions frontières pour lesquelles les sciences de la Terre sont indispensables. Dans les années 1950, les travaux de J. Tuzo Wilson et d'autres, ont permis une division du Bouclier Précambrien en provinces selon l'âge et la structure, qui s'est avérée un guide valable pour l'exploration. Les données acquises sur l'extension des océans et la dérive ont incité les géologues du pétrole à vérifier le potentiel de la mer du Labrador.

Regard vers l'extérieur

Il est certain que les géoscientifiques canadiens élargissent leur horizon. Le nombre de membres dans nos sociétés-membres a augmenté de 30% au cours des deux dernières années, ce qui manifeste un intérêt accru pour l'échange d'information et l'action de groupe. Les sociétés qui adhèrent à notre Conseil de Coordination coopèrent efficacement de plusieurs façons. Des groupes nouvellement organisés comme les géoscientifiques provinciaux et les présidents des facultés universitaires de Géoscience ont maintenant un statut d'associé au Conseil et ils travaillent de concert avec les sociétés spécialisées en vue d'en arriver à une action effective. Malgré un départ assez lent dans le domaine de la coopération avec d'autres groupes scientifiques, les géoscientifiques sont maintenant parmi les premiers dans les entreprises conjointes. Par le moyen de SCITEC, nos représentants participent à la création d'une association des parlementaires et des scientifiques et à l'organisation de forums traitant des problèmes les plus pressants comme les dangers et le potentiel de l'énergie nucléaire. Pendant longtemps silencieux sur des sujets qui dépassent leurs stricts intérêts, les géoscientifiques avec leur perspective du temps et des procédés géologiques, exposent maintenant leurs vues sur la politique scientifique et servent de guides pour résoudre les crises de notre temps.

L'invitation à notre Conseil du Ministère de l'Energie des Mines et des Ressources, de former un comité pour évaluer les activités de la Commission géologique du Canada et d'en faire rapport à la communauté géoscientifique est très encourageant. C'est le premier comité du genre formé au Canada. Sa formation et son mandat sont un exemple d'ouverture que d'autres établissements scientifiques devraient suivre. Notre Conseil assume de plus en plus la gestion des engagements géoscientifiques internationaux du Canada, tâche qui était autrefois réservée au gouvernement. L'Association des Géoscientifiques pour le Développement international qui comprend des centaines de membres des nations en voie de développement a été crée à la suite d'une réunion tenue par le Conseil, il y a 2 ans. Son quartier général établi au Canada est un témoignage de l'intérêt des géoscientifiques du Canada pour l'extérieur.

Le croissance de l'expertise et la réponse aux défis

Ces 2 dernières années, pour la première fois le prix Steacie du Conseil national de Recherche, la plus haute distinction pour un jeune scientifique Canadien, a été accordé à un géoscientifique. Dans la région atlantique la médaille APIS pour le jeune scientifique de l'année a été méritée 3 fois par des géoscientifiques pour les 4 premières années d'existence. Ce sont là quelques exemples récents de prix nationaux ou internationaux mérités par des géoscientifiques canadiens en concurrence avec des scientifiques d'autres disciplines.

Le rapport souligne aussi l'excellence de travaux dans le domaine de la géologie des Appalaches et des Cordillères; des études séismiques de la croûte en profondeur; de la géochimie de l'environnement; de l'exploration géophysique, géochimique et pétrolière; de la géoscience de la mer; de la métallogénie; et du paléomagnétisme précambrien. Peu de ces travaux sont le résultat de plans à long terme et plusieurs étaient financièrement sous-alimentés. Ils ont vu le jour en réponse aux défis et problèmes intellectuels dans les sciences de la Terre.

On ne peut mettre en doute l'aptitude des géoscientifiques canadiens à appliquer les nouveaux développements de la science. Par exemple, sur les 37 nouvelles mines importantes découvertes dans le monde occidental au cours du dernier quart de siècle, la moitié le furent au Canada (Miller, 1976); ce qui illustre la compétence des géoscientifiques canadiens.

Nous sommes optimistes, étant donné que nous sommes maintenant bien placés pour répondre de façon rationnelle aux défis décrits ci-dessus. Notre Conseil a déjà commencé à agir et continuera l'année qui vient avec un forum sur "Les Sciences de la Terre au service du pays" et un symposium sur "Exploration '77". On trouvera dans la 2e partie de ce rapport d'autres preuves que les défis sont bien relevés par la géoscience au Canada. Nous remercions les 90 auteurs qui ont rédigé un sommaire sur l'état de leur discipline. Ils montrent sans équivoque que la géoscience au Canada est au service de nos aspirations nationales les plus valables.

Conseil Géoscientifique Canadien

INTRODUCTION

The Canadian Geoscience Council exists to foster close relationships among the earth science learned societies and professional associations in Canada and to encourage the development of the geosciences in the best interests of both individual geoscientists and the nation. The Council is comprised of representatives of eleven societies whose total membership in 1975 was 12 118 (Barnes **et al.**, 1976, Table V). This figure compares with 9300 in 1974 (Neale **et al.**, 1975) and attests to the growth of interest in the geosciences.

The first Annual Report of the Canadian Geoscience Council (CGC) assessed the status of Canadian geoscience (Neale **et al.**, 1975). Reports were solicited for about fifty disciplines and subdisciplines which, after editing, were published together with an analysis and a series of recommendations. The Council considers it worthwhile to produce similar reviews periodically.

With improved communication and organization within the CGC,the Editorial Committee placed the prime responsibility for producing reports on the societies with CGC. The societies were provided with guidelines for the reports in January 1976 and given five months to solicit authors and prepare and approve the submissions. The societies selected the disciplines on which they wished to report, but in no case were more than two societies allowed to cover an individual discipline.

Thus, discipline reports included in Part II of this volume are reproduced with minimal editing by the Editorial Committee and their authors and sponsoring societies are identified. For each report, the Committee requested information on the current level of activity, major advances, and future needs and directions. As might be expected, despite the guidelines, the responses of the authors and societies were highly variable. This attempt by the Editorial Committee to secure more objective and comparable reports has not been entirely successful and the reports still have a wide range of quality. It is hoped that disciplines with weak reports will receive improved coverage in future status reports and that the societies will accept greater editorial responsibility.

The Editorial Committee

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ANALYSIS AND RECOMMENDATIONS

National Effort

Several articles (Neale and Wynne-Edwards, 1975; Strangway, 1976; Wynne-Edwards and Neale, 1976) and some of the discipline reports in Part II have claimed the need and value in recognizing and developing excellence in Canadian geoscience. This quality is in part a function of individual or groups of researchers. However, the national environment may help foster excellence in certain areas. Because of the very nature of the physiographic, climatic and geologic setting of Canada, certain disciplines are perhaps most logical for study: muskeg, permafrost, snow and ice, Quaternary geology, engineering geology, geochemical and geophysical surveys, northern drilling and pipeline development, etc. In many of these fields, Canadian geoscience has an enviable reputation both in research and development.

In a global sense, we have an obligation to develop or pioneer such disciplines that may be applied to less well-endowed regions. In a more pragmatic sense, the nation would be unwise not to further encourage the development of new technologies associated with these disciplines. Such new developments can be used both to improve exports and as an increased component in foreign aid (e.g. through the Canadian International Development Agency). Further, as a developed nation, Canada should do more to participate in certain international geoscience programs. In particular, lack of Canadian participation in the Deep Sea Drilling Project must be re-examined. With major concerns for adjacent oceans, it makes no sense at all to avoid involvement in the principal oceanic exploration program.

We recommend that funding agencies ensure that viable research programs are maintained in those disciplines particularly favoured by the Canadian geologic and geographic framework. In particular, those areas where new technologies are being developed and which represent significant potential exports must be nutured.

We recommend that the Department of Energy, Mines and Resources in consultation with Treasury Board give full consideration to Canadian participation in the Deep Sea Drilling Project.

We recommend that the Federal Government, through its agencies such as CIDA, make greater use of Canadian geoscience expertise in foreign aid projects.

Development of New Technology and Equipment

Over the past decade a major trend in the geosciences has been toward greater instrumentation. This has ranged from analysis of miniscule material (scanning electron microscope, electron microprobe, stable and radioactive isotopes), to the use of manned

TABLE I

CONFIRMED SIGNIFICANT METALLIC MINERAL DISCOVERIES
1974-1976

Among its accomplishments in the 1974-76 period, Canada's mining exploration community lists the following significant mineral discoveries:

Name and Year of Discovery	Responsible Companies	Location	Type of Deposit	Grade and Reserves*
Corbet (1974)	Falconbridge	Noranda, Quebec	Massive Sulphides	(Not available)
Grum (1974)	Kerr-Addison & Canadian Natural Res.	Vangorda Creek, Y.T.	Massive Sulphides	28.6 million tons @ 10.9% combined Pb & Zn & 1.88 oz/ton Ag
Detour Lake Gold (1975)	Amoco	125 mi. NE of Timmins, Ontario	Gold in Archean volcanic rocks	(Not available)
Izok Lake (1975)	Texasgulf	225 mi. N. of Yellowknife	Massive Sulphides	12.1 million tons @ 13.70% Zn, 2.83% Cu, 1.43% Pb, 2.07% oz/ton Ag
Goldstream (1975)	Noranda	Revelstoke, B.C.	Massive Sulphides	3 million tons @ 4.49% Cu, 3.0% Zn
Detour (1975)	Selco and Pickands-Mather	70 mi. W. of Matagami Lake, Québec	Massive Sulphides	A 1 Zone: 35.4 million tons @ 0.39% Cu, 2.30% Zn, 1.04 oz/ton Ag, & 0.009 oz/ton Au B Zone: 3.375 million tons @ 4.49% Cu, 0.80% Zn 1.15 oz/ton Ag; 0.036 oz/ton Au
Gartner Orebody (1975)	Inexco Oil & Gas; Uranerz; Sask. Govt.	Key Lake, Sask.	Uranium adjacent to Athabasca Sandstone	500,000 tons @ 3.9% U_3O_8 (Deposit also contains substantial amounts of nickel)
X-25 Orebody (1976)	Western Mines and Dupont of Canada	Pine Point, N.W.T.	Pb-Zn Sulphides in Devonian carbonate rocks	2.8 million tons @ 4.1% Pb, 11.9% Zn
Deilman Orebody (1976)	Inexco Oil & Gas; Uranerz; Sask. Govt.	Key Lake, Sask.	Uranium adjacent to Athabasca Sandstone	(Not available)
Kutcho Creek (1974)	Imperial Oil; Sumitomo	Pitman River Area, B.C.	Massive Sulphides	(Not available)

*Best available published reserves. Mostly "drill-indicated", undiluted, but may include other categories. Best taken as order-of-magnitude estimates.

submersibles in mapping the floor of the Great Lakes and offshore areas, to the use of satellites to secure remote sensing data. Not only has this required a new level of funding but has provided incentive for the development of Canadian equipment for this new technology

A highlight of Part II of this volume is the documentation in several reports of major new advances in geoscience technology. The hydrocarbon exploration in northern and eastern offshore areas has spawned a wide variety of new equipment. The marine geosciences report notes the development of two separate deep-towed seismic systems; of two unmanned submersibles, both self powered and surface powered, capable of operating to depths of 400 m and equipped with a television camera and manipulator arm; and of specialized drill systems for use in submarine foundation engineering. The engineering geology review notes the development of a mast equipped, light weight drill adapted to an all terrain vehicle for use in northern regions as well as a new borehole permeameter. In the snow and ice report, a variety of new techniques are described that permit improved and safer conditions for offshore drilling in Arctic regions.

New techniques used in engineering problems in urban regions are noted in the rock mechanics reports. In particular, the improved stress measurements in vertical bore-holes which allow greater assessment of the unusually high horizontal stresses in southern Ontario that can produce major problems in tunnel construction

For many years, Canada has been a world leader in the development and export of geophysical and geochemical equipment, especially that related to exploration surveys. The reports in Part II dealing with geophysical

TABLE II

CONFIRMED SIGNIFICANT HYDROCARBON DISCOVERIES – 1974-76

Region/Area	Well Name	Formation/Type	Operator/Participants
Williston Basin	Tableland 11-14	Winnipegosis/oil	Dome **et al.**
Alberta Basin	Rosevear 11-36	Beaverhill Lake/gas	Shell Canada
Alberta Basin	Fox Creek 10-13	Beaverhill Lake/gas	Chevron/Gulf
S. Foothills	Limestone AZ-13	Mississippian/gas	Shell Canada
S. Foothills	Mtn. Park 7-21	Mississippian/gas	Gulf/Mobil/Sun Oil
S. Foothills	Findley 5-26	Miss./Trias./Jur./gas	Pancanadian **et al.**
N. Foothills	Bullmoose d-77-E	Triassic/gas	British Petroleum **et al.**
East Coast	Bjarni H-81	not released/gas, cond.	Eastcan **et al.**
East Coast	Gudrid H-55	not released/gas, cond.	Eastcan **et al.**
S. Foothills	Willson 4-11	Mississippian/gas	Shell Canada **et al.**
Mackenzie Delta	Kamik D-48	Cretaceous/oil	Gulf/Mobil
S. Foothills	N. Burnt Timber 5-19	Devonian/gas	Shell Canada
Mackenzie Delta	Garry P-04	not released/oil, gas	Sun/SOBC/Bow Valley
Williston Basin	Minton 11-2	Winnipegosis/Ordovician/oil	Dome **et al.**
Alberta Basin	Pass Creek 7-13	Beaverhill Lake/gas	Chevron/Gulf

and geochemical exploration note new developments and evaluate the scale of operations. For example, over 1 million geochemical samples were taken by industry and government researchers in Canada in 1975 representing an expenditure of about $25 million. Foreign and domestic sales of the Canadian geophysical industry in that year totalled about $26 million, a growth of nearly 20 per cent over the previous year. The wide spectrum of new instrumentation developed recently for geophysical exploration suggests that future sales will continue to rise.

> *We recommend to the Federal Government that greater emphasis be placed in promoting exports of Canadian geoscience technology and equipment. We recommend to the Department of Energy, Mines and Resources, the Department of the Environment, the Department of Indian and Northern Affairs, and the Department of Industry, Trade and Commerce that greater support be provided in contracts and agreements to encourage the development of Canadian geoscience technology and equipment in those areas of high potential (e.g. muskeg, northern exploration and development, geochemical and geophysical prospecting, marine geoscience).*

Exploration

The state of the nation's economy dominates any discussion of applied geoscience and exploration. Although the Federal-Provincial struggle over taxation rights has largely been settled, the result has been sharply increased royalties or taxes for the industry section. Thus, uneven recovery in applied geoscience activity has taken place in the past two years.

In Alberta and British Columbia, exploration for oil and gas has increased significantly because of more stability in the political scene, and improved prices combined with specific incentives. In the Federal jurisdiction, interest has remained stable to moderately depressed because of the continuing lack of land regulations, concern over sharing of future discoveries, and extreme costs

Inflation has resulted in escalating and in some cases, prohibitive costs of exploration in frontier regions Progress in the Athabasca Tar Sands development is slow because of the inflationary impact on what was already massive capital costs. Uncertainty over future oil pricing in Canada is also affecting development. Depressed base metal prices on the world market have resulted in some cut-backs in mineral exploration programs. Exploration for uranium has increased significantly reflecting increased prices and prospects for future strong demand. Coal exploration is proceeding unevenly. In Alberta, new regulations and policies have caused a market slow-down in activity. A cautious approach in this area is predicted. In British Columbia, coal exploration and development has been moderately strong under that Province's announced policy of coal development.

In spite of these generally negative features, industry is responding somewhat optimistically. As noted above, this response reflects a return to a more stable political environment, incentives and in the case of oil, gas, coal and uranium higher prices or prospects of improved prices.

Resource Assessment

The emphasis placed on natural resource development and assessment in the 1974 report of the Canadian Geoscience Council (Neale **et al.**, 1975) was appropriate. The recent downward revision of Canada's potential hydrocarbon reserves is due, in part, to disappointing results of exploration in some of Canada's frontier areas, and in part to use of more improved and more realistic methods of resource assessment. Exploration for two other commodities, uranium and coal, is now at a high

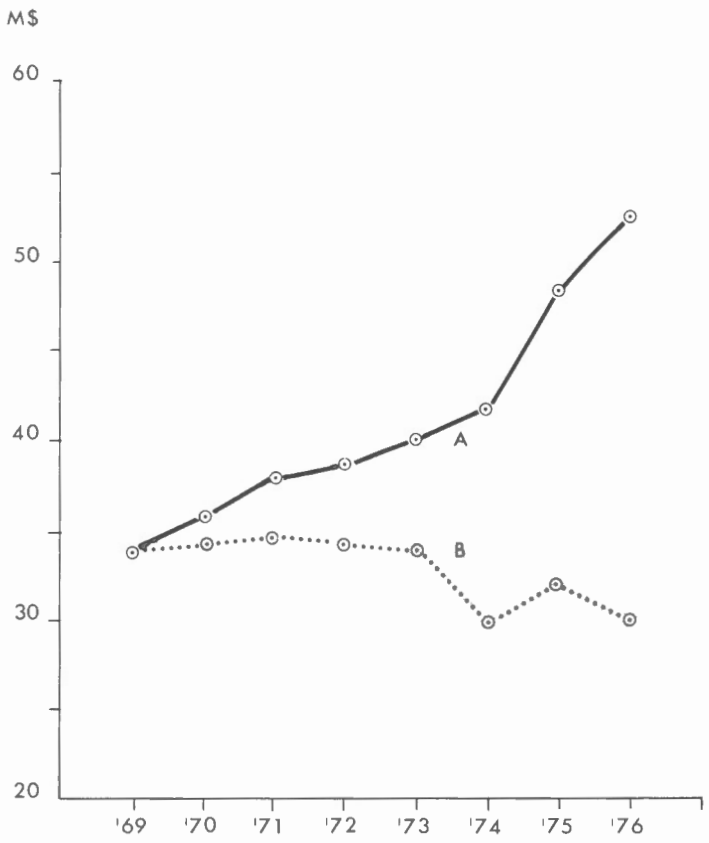

Figure 1. Amounts of research grants awarded by the National Research Council of Canada in real (A) and constant (B) dollars, 1969-76.

level. The reserves and resources of both these energy sources are still not accurately known. With the growing realization that Canada's natural resources are finite, and, in some cases, in short supply, improved assessment programs must be a priority objective of government and industry.

> *We recommend that the Federal Government improve its capability in mineral and energy resource assessment and that the data be available to the public and for additional research by other agencies and individuals, having due regard for confidentiality of some of the data used*

A better understanding of the rate at which mankind is consuming non-renewable resources, and what future alternatives are available is necessary. The concept of the time lag of about ten years between discovery and production of new mineral and hydrocarbon deposits in frontier areas must receive greater appreciation. A measure of current exploration progress is the record of new major mineral discoveries and those for the past two to three years are listed in Tables I and II.

A similar assessment should be made in the field of renewable resources and the rates at which the renewable resources can withstand exploitation must also be clearly understood.

Funding

The most critical factor in geoscience research and development at present is funding. At a time when it is evident (Department of Energy, Mines and Resources, 1975, 1976) that the nation requires a marked increase in geoscience research and development activity, the total funds to ensure this have been reduced. Inflation has seriously affected research grants and the support given the industry sector through IRDA grants has been removed. This decline in support has been especially critical in the research funded by the National Research Council of Canada (NRC). These research expenditures have effectively declined in terms of constant dollars since 1969 (Fig. 1). In the last year, NRC was forced to eliminate or suspend several programs including the vital Negotiated Development Grants.

Many systems can withstand periodic cutbacks in funding, but the funding levels in geoscience have been progressively devalued for a critically long time (e.g. Fig. 1) not only affecting on-going programs, but stifling urgently needed new programs and those involving international co-operation (Strangway, 1976). Neale and Wynne-Edwards (1975) have argued that the geosciences need to be provided with an increased proportion of total science funding; for NRC operating grants the geoscience allocation stands at only eight percent of the funds awarded.

Many discipline reports (Part II) urge increased funding and identify a number of particular areas critically affected by the present constraints. Three of these can be emphasized:

a) Canada has a small and poorly equipped oceanographic fleet despite having one of the longest shorelines in the world, exploration interests especially in the eastern and northern offshore regions, and a recently claimed 200 mile territorial limit. A considerable increase in funding is essential to provide data for future exploration and to tackle the special conditions of Arctic waters.

b) Much current geoscience research involves sophisticated and expensive analytical equipment. Considering capital installation and depreciation costs, such equipment must be used efficiently. Trained technicians are essential to operate and service such equipment and to provide 24 hour-a-day utilization of the equipment. However, the level of the average NRC Operating Grant in earth sciences last year ($9900) was less than the annual salary of a technician. Lack of adequate funding frequently results in this equipment being under-used and perhaps misused.

c) In a large and relatively unexplored area like Canada, geoscience field work in remote areas deserves a high priority if we seek to assess resource potential. Increased fuel prices have resulted in drastically increased transportation and shipping costs. For efficiency and safety, large field parties in remote regions must have aircraft support. The Geological Survey of Canada (GSC) has been forced to suspend or reduce many field parties this year. Smaller parties from universities now find it almost impossible to operate efficiently, if at all, in remote areas. Increased funding and greater co-operation and collaboration will be necessary in the future.

Field	1969	1970	1971	1972	1973	1974[2]	1975	1976	1977[3]	1978[3]
					BACHELOR DEGREES					
Geology[1]	234	287	384	510	540	671	624	647	669	726
Geophysics	27	34	38	55	45	50	29	19	24	28
Metallurgy	85	82	98	135	127	114	116	87	63	24
Mining	49	57	76	100	129	132	128	93	88	71
Petroleum Eng.	22	41	61	43	65	47	6	3	4	11
Sub-total	417	501	657	843	906	1014	903	849	848	860
					MASTER'S DEGREES					
Geology[1]	93	89	117	107	111	138	121	188	201	184
Geophysics	29	14	24	19	33	17	31	18	22	25
Metallurgy	46	44	61	51	47	38	67	49	14	4
Mining	26	24	30	27	23	24	23	24	17	15
Petroleum Eng	4	3	1	—	12	6	4	22	x	x
Sub-total	198	174	233	204	226	223	246	301	254	228
					DOCTORAL DEGREES					
Geology[1]	33	32	34	41	49	51	39	98	87	75
Geophysics	17	10	8	9	15	9	7	12	7	9
Metallurgy	19	17	40	28	27	20	28	21	19	6
Mining	5	5	3	7	4	5	4	5	4	5
Petroleum Eng.	—	—	—	2	7	2	1	3	x	x
Sub-total	74	64	85	87	102	87	79	139	117	95
TOTAL	689	739	975	1134	1234	1324	1228	1289	1219	1183

[1] *Including geochemistry.*

[2] *University estimates corrected by -5.6% for B.Sc., -28.8% for M.Sc. and -42.5% for Ph.D., based on 1968-73 statistics of estimates vs. actual figures.*

[3] *Figures may be as much as 10% low, due to incomplete returns.*

[x] *No forecast available.*

Figure 2. Number of Canadian University Graduates in Mineral Industry Fields, 1967-78. Compiled From: CIM Directory June, 1974, p. 68, plus March 1976, pp. 177-180

Since mineral and agricultural products form a large segment of the export trade, economic stimulation in the present period of recession can be assisted by greater emphasis on certain aspects of geoscience research and development. With hydrocarbon exploration in Alaska, Mackenzie Delta, Beaufort Sea, and the Arctic Islands continuing vigorously, and with the prospect of major pipeline construction becoming a reality, additional funding in all sectors is vital for work in muskeg, snow and ice, Arctic drilling techniques, and environmental geology related to permafrost. In many respects Canada has already become a world leader in these disciplines and has developed many specialized techniques and equipment. Together with many facets of geophysical and geochemical exploration, where Canada also leads the western world, it is important to emphasize that additional financial input to promote new developments will ensure major exports of such new equipment. The export of satellite packages using the LANDSAT system is an excellent example of the role Canada can play in exporting geoscience technology. The decrease in research funding of agricultural science can only be viewed with dismay. With urban sprawl rapidly consuming large tracts of available agricultural land, with major famines predicted for many developing nations in the next decade, and with the possible onset of more variable climatic conditions, it is evident that additional research must be undertaken to ensure increased productivity and optimum use of available lands. Likewise, the rapid move to nuclear power as a Canadian energy source necessitates a major increase in research on radioactive waste disposal. The Federal Government is to be congratulated for responding promptly to the energy crisis by at least instituting a crash program of uranium exploration and resource evaluation and preliminary steps to develop geothermal research. Response at this level is urgently required in many of the other areas noted above.

The 1975 Canadian Geoscience Council Report (Barnes **et al.**, 1976) included a revealing analysis of the substantial research undertaken mainly by industry, in

Petroleum Exploration Geology. It is reasonable to expect that industrial research capability and activity in other disciplines has also been under-rated. Accelerating these existing programs through fiscal action is a potentially powerful method of achieving immediate objectives. However, the industry research grants provided through the IRDA program have been eliminated.

We recommend that geoscience research and development receive substantially increased funding commensurate with the projected requirements in the immediate future. The Federal Government should provide increased revenues to the National Research Council, the Department of Agriculture, the Department of Energy, Mines and Resources, the Department of Industry, Trade and Commerce, the Department of Supply and Services and the Department of the Environment for this purpose. Specifically increased funding should be:

a) for the National Research Council of Canada to increase the amounts awarded to earth sciences and to reinstate the Negotiated Development Grant program to permit the support of large-scale research programs.

b) for the Department of Energy, Mines and Resources and the Department of the Environment to pursue more actively field work in northern and other remote areas of Canada; for these departments in turn to provide additional funds in the form of contract research and research agreements in the private sector, universities, and research institutions; for expansion and modernization of Canada's oceanographic research capability; for development of new geoscientific technology and equipment.

c) for the Provincial Departments of Mines to expand their programs in critical resource areas and, where possible, to interact more closely with universities. The new grant program for provincial universities proposed by the Ontario Division of Mines to promote mineral exploration should be considered by other provincial departments.

We recommend that the Federal Government through realignment of fiscal policies, stimulate industrial research outside of the aegis of the Department of Energy, Mines and Resources.

Employment

Patterns for present and future hirings of geoscience graduates are not clear due to the uncertain economic situation. Provincial, federal and university institutions have few openings at present, while industry seems to be expanding gradually; some areas such as environmental and engineering geology show a considerable demand for new staff. Geoscience enrollment at Canadian universities remains at a relatively high level (Fig. 2) and appears more than satisfactory to meet the current demands. Restrictions in funding do not permit expansion of programs in several sectors. However, it is worthwhile to identify those disciplines which reported (Part II) manpower deficiencies, yet it must be cautioned that this does not necessarily mean current vacancies: environmental geoscience, geochemical exploration, geochronology, marine geoscience, muskeg research, palynology, remote sensing, and soil science.

Scientific Communication

As emphasized by Neale **et al.** (1975, p. 2), an integral part and a measure of a healthy and vigorous scientific community is its ability to communicate. This interaction occurs in societies, meetings, publications and research co-operation. In all these, the spectre of fiscal restraint has had serious effects in terms of increased membership dues, reduced travel and conference funds, and drastically increased publication costs.

Communication at the national level has been improved by the Canadian Geoscience Council adopting a co-ordinating role and assuming responsibility for the administration of certain programs (e.g. Canadian part of the International Geological Correlation Project). Through the work of its Editorial Committee, it has begun to examine research in various sectors of the geoscience community, starting with Canadian exploration petroleum geology (Barnes **et al.**, 1976); examination of university geoscience research is in a formative stage as is a study of research in soil science. The same publication documents major developments and awards of the geoscience societies. The recommendation by Neale **et al.** (1975, p. 2) that societies continue to foster and promote specialist groups appears to have been partly satisfied with the formation of Paleontology and Precambrian Stratigraphy divisions of the Geological Association of Canada and a Coal Section of the Canadian Society of Petroleum Geologists. We endorse this earlier recommendation and hope that other groups and societies will be organized where better communication at the level of the individual geoscientist is needed. Increased international communication is achieved when societies host joint meetings with those from other countries. The Geological Association of Canada has invited a variety of non-Canadian societies to meet with it during its 1975, 1977 and 1978 annual meetings. These efforts should be both applauded and encouraged if new developments are to be fully disseminated.

Individual scientific papers and symposia publications have maintained high standards over the past two years. Both the Canadian Society of Petroleum Geologists and the Geological Association of Canada have markedly increased their publication of Memoirs and Special Papers respectively (**see** Table III). The Canadian Mineralogist is now published quarterly and devotes several issues per year to special collections of papers. The slimmer issues of the Canadian Journal of Earth Sciences attest to higher editorial standards but also to the financial constraint imposed on the National Research Council. One perennial problem that is becoming more acute with fiscal restraint is the publication of Canadian paleontological monographs. Paleontologists in the Geological Survey of Canada and provincial agencies (surveys, research councils, museums) are normally able to secure publication through their own institution. However, paleontologists in universities have no Canadian medium of publication. Such monographs are part of the documentation of Canadian natural science and the only agency that can finance publication of these data is the Geological Survey of Canada.

Neale **et al.** (1975, p. 4) proposed that the Canada Institute for Scientific and Technological Information immediately establish bibliographic and synoptic data on university theses, especially those relating to metallic mineral and hydrocarbon deposits. They noted that these were the single most important public source of geological data of Canadian metallic mineral deposits. Little action

seems to have been taken by CISTI to implement this proposal and we endorse the original recommendation. The revised form of Current Research in the Geological Sciences volume will eventually enable the retrieval, identification, and listing of masters and doctoral theses and will partly satisfy the original recommendation. Further, the abstracts of many theses are published annually in the Bulletin of the Canadian Institute of Mining and Metallurgy.

Some recent developments to improve communication in Canadian geoscience, through publications, are worthy of note. A new journal, the Journal of Great Lakes Research was launched in 1976 and Geoscience Canada, started in 1974 by the Geological Association of Canada, has ably filled a vacant publication niche. The Report of Activities published three times annually in a revised format since 1975 by the Geological Survey of Canada is a most valued series. Publication of the annual review of Canadian geophysics in the Canadian Geophysical Bulletin has been transferred from the National Research Council to the Earth Physics Branch of EMR and the 1976 issue was produced with minimal delay. The Canadian Geoscience Council has been involved in producing the volume on Current Research in the Geological Sciences published by the Geological Survey of Canada (GSC Paper 76-5, 1976). Attempts to provide greater coverage, data retrieval, and faster publication have received only partial success and further modifications will be introduced next year.

> *We recommend that the Canadian Geoscience Council continues to assume a co-ordinating role in Canadian geoscience and accepts the transfer of certain obligations previously undertaken by the Geological Survey of Canada. The Federal Government should continue to provide grants towards the publication of major Canadian paleontological monographs.*

Several discipline reports in Part II emphasize the need for improved organization in research programs and especially for greater liaisons between soil scientists and hydrogeologists, between Quaternary geologists, geomorphologists and civil engineers, and between structural geologists and specialists in rock mechanics and geophysics. While many areas are becoming increasingly interdisciplinary (e.g. marine geoscience), it is considered that major breakthroughs in certain disciplines (e.g. invertebrate paleontology, petrology, structural geology-tectonics) will be achieved only with more organized group research. In this regard, it is encouraging to note that the National Research Council has instituted a new type of group research grant in its 1977 awards.

A problem with certain disciplines is that the number of specialists in Canada is so small that there is little opportunity to form viable national groups or programs. Such areas include geothermal research, glaciology, paleobotany (excluding palynology), and vertebrate paleontology.

Finally, in relation to improved organization, several discipline reports in Part II stress the need for improved interaction between the main sectors of the geoscience community. Part of this interaction is purely concerned with research co-operation (e.g. Geological Survey of Canada to provide greater field assistance to university researchers in remote areas). Another theme, however, emphasizes financial power, with the federal government and large corporations having the potential to provide greater assistance to the less well-funded universities, provincial agencies, and consulting companies. For new private consulting companies or those developing new equipment (e.g. in environmental geoscience, geochemical and geophysical prospecting), initial support in the form of industrial or government contracts is critical. There are clearly concerns that the Department of Energy, Mines and Resources and the Department of the Environment have not significantly increased the proportion of their budgets allocated for contracts and agreements to the private and university sectors. This was a specific recommendation of Neale **et al.** (1975, p. 4). One step toward this direction has been the establishment by the Geological Survey of Canada of an external advisory committee to review its main operations and budgetary plans. However, for the operation and continued maintenance of a fully viable geoscience community in Canada more consideration must be given to adequate funding of all sectors (government, industry, university) to promote efficient interaction. So important is this matter that we must repeat the recommendation of Neale **et al.** (1975, p. 4).

> *We recommend that the Department of Energy, Mines and Resources achieve a higher proportion of its research and development objectives through contracts and agreements for geoscientific research by industry and university personnel in order to help raise Canadian research capability to the level of excellence, and to contribute to university and post-university training of Canadian geoscientists.*
>
> *We further recommend that the Department of the Environment also achieve a higher proportion of its research and development objectives through contract and agreement for geoscientific research by industry and university personnel.*

Geoscience and the Public

Several geoscience societies and organizations have recently placed greater concern in transmitting their specialized knowledge to a broader public forum. Both federal and provincial surveys seem to have more elaborate plans to produce guidebooks to parks, recreational areas, classical geological regions as well as highway maps and guides. The Canadian Society of Petroleum Geologists and the Geological Association of Canada have both been particularly active in this matter.

Many geologists are anxious to see the preservation of key sections or areas. The recently established Quebec Provincial Park at Miguasha is an excellent example of a park that will preserve important geologic data. Algonquin Park, Ontario, was slightly enlarged in 1975 to fully incorporate and preserve the Brent crater. Geoscientists, however, are also concerned that some park regulations may be so restrictive that scientific research will be prohibited.

> *We recommend that societies, federal and provincial agencies continue an active program at all levels of public geoscience education. We recommend that federal and provincial parks departments co-operate with geoscience specialists in establishing the regulations governing parks or in the creation of new parks. Resource assessment studies prior to the establishment of new parks and the consideration of a multiple-use policy for both new and existing parks is recommended. We suggest that they communicate with the Geological Survey of Canada or the Canadian Geoscience Council to identify appropriate specialists to provide assistance.*

It is evident from some discipline reports in Part II that there is, and will be, an increasing need for geoscientific input into legislation governing urban growth. Matters such as environmental protection, waste disposal, water supply, and construction projects all involve a major geoscientific contribution. With a continued move of Canada's population to the main urban centres, and with the increasing scale of construction projects and environmental problems, the future role of the geologist in this aspect of the public forum must be stressed.

Summary of Recommendations

The following recommendations arise from this report:

To the Federal Government:

We recommend that geoscience research and development receive substantially increased funding in the immediate future. The Federal Government should provide increased revenues to the National Research Council, the Department of Agriculture, the Department of Energy, Mines and Resources, and the Department of the Environment for this purpose. Specifically increased funding should be:

a) for the National Research Council of Canada to increase the amounts awarded to earth sciences and to reinstate the Negotiated Development Grant program to permit the support of large-scale research programs;

b) for the Department of Energy, Mines and Resources and the Department of the Environment to more actively pursue field work in northern and other remote areas of Canada; for these depart ments in turn to provide additional funds in the form of contract research and research agreements to the private sector, universities, and research institutions, for expansion and modernization of Canada's oceanographic research capability; for development of new geoscientific technology and equipment.

We recommend to the Federal Government that greater emphasis be placed in promoting exports of Canadian geoscience technology and equipment.

We recommend that the Federal Government, through realignment of fiscal policies, stimulate industrial research outside of the aegis of the Department of Energy, Mines and Resources.

We recommend that the Federal Government, through its agencies such as CIDA, make greater use of Canadian geoscience expertise in foreign aid projects.

We recommend that the Federal Government improve its capability in mineral and energy resource assessment and that the data be available to the public and for additional research by other agencies and individuals.

To Federal Departments:

We recommend to the Department of Energy, Mines and Resources, the Department of the Environment, the Department of Indian and Northern Affairs and the Department of Supply and Services that greater support be provided in contracts and agreements to encourage the development of Canadian geoscience technology and equipment in those areas of high potential (e.g. muskeg, northern exploration and development, geochemical and geophysical prospecting, marine geoscience).

We recommend that the Department of Energy, Mines and Resources in consultation with the Treasury Board give full consideration to Canadian participation in the Deep Sea Drilling Project.

We recommend that federal government departments should continue to provide grants towards the publication of important geoscience symposia by societies. The Geological Survey of Canada should provide greater support toward the publication of major Canadian paleontological monographs.

We recommend that federal agencies continue an active program at all levels of public geoscience education.

We recommend that federal parks departments co-operate with geoscience specialists in establishing the regulations governing parks or in the creation of new parks. Resource assessment studies prior to the establishment of new parks and the consideration of a multiple-use policy for both new and existing parks is recommended. We suggest that they communi-cate with the Canadian Geoscience Council to identify appropriate specialists to provide assistance.

To Provincial Departments:

We recommend that the Provincial Departments of Mines expand their programs in critical resource areas and, where possible interact more closely with universities. The new grant program for provincial universities proposed by the Ontario Division of Mines to promote mineral exploration should be considered by other provincial departments.

We recommend that provincial agencies continue an active program at all levels of public geoscience education.

We recommend that provincial parks departments co-operate with geoscience specialists in establish-ing the regulations governing parks or in the creation of new parks. Resource assessment studies prior to the establishment of new parks and the consideration of a multiple-use policy for both new and existing parks is recommended. We suggest that they communicate with the Canadian Geoscience Council to identify appropriate specialists to provide assistance.

To Research Funding Agencies:

We recommend that funding agencies ensure that viable research programs are maintained in those disciplines particularly favoured by the Canadian geologic and geographic framework. In particular, those areas where new technologies are being developed and which represent significant potential exports must be nutured.

To Geoscience Societies:

We recommend that societies continue an active program at all levels of public geoscience education.

To the Canadian Geoscience Council:

We recommend that the Canadian Geoscience Council continues to assume a co-ordinating role in Canadian geoscience and accepts the transfer of certain obligations previously undertaken by the Geological Survey of Canada.

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PART II

REPORTS ON THE DISCIPLINES OF THE GEOSCIENCES

AREAL MAPPING

L. D. Ayers, E. A. Babcock, E. H. Chown, J. E. Reesor, D. Tempelman-Kluit, and H. Williams for the Geological Association of Canada

Areal mapping, whether published or unpublished, is the basis for most mineral and petroleum exploration and for research in many other earth science disciplines. Published maps are used to select target areas for exploration and research projects, and follow-up mapping, largely unpublished, establishes the necessary basis for detailed exploration or laboratory work. Furthermore, up-to-date geological maps at various scales are a prerequisite for regional stratigraphic, tectonic, and metallogenic studies. Consequently areal mapping is far more important to the earth sciences than the routine publication of maps would indicate.

Areal mapping in Canada is done mainly by the Geological Survey of Canada, provincial geological surveys and research councils and is the main function of many of these organizations. Lesser amounts are done by the Department of Indian and Northern Affairs and other agencies of the Federal and Provincial governments. Mapping scales range from 1: 1200 to 1: 250 000.

Maps are now available for most of Canada at scales of up to 1: 250 000, but only a small portion of the country has been mapped at 1: 50 000 or larger scales. The present working scale for the Geological Survey of Canada is 1: 250 000 and most of its work is in British Columbia and the Territories. In addition, their 1: 1 000 000 compilation series is slowly being published although no maps were released in 1975-76. Provincial surveys work mainly at 1: 50 000 and larger scales, but they also provide smaller scale reconnaissance and compilation maps. The level of activity of the provincial surveys is variable but most bedrock mapping is concentrated in areas of potential economic interest. In Newfoundland and New Brunswick, areal mapping activity has increased dramatically in the past five years through financial support from the Federal Department of Regional Economic Expansion.

Some areal mapping and compilation is done by universities as background data for other research projects. This work, which ranges in scale from 1: 1200 to 1: 50 000 or less, is commonly buried in unpublished theses and research files, but seems to be increasing in scope and volume. Except where the mapping is done under contract for a government agency, there is presently no channel for publication or compilation of this basic geological data in map form. The large size of many maps, the complex cartography, and the need for colour printing of some maps precludes journal publication of the detailed maps, and most journal papers are accompanied by only simplified geological maps. There should be some central clearing house for collection and compilation of unpublished areal maps, not only because of their potential use, but to realize a larger return for the large amount of funds expended on the mapping (funds provided largely by the National Research Council).

For university research projects, mapping, particularly in remote areas (which includes most of Canada), is costly in terms of time expended, capital cost of equipment, and logistic support. The National Research Council does not appear to be fully cognizant of the need for field-based research or the costs of such research. University-based mapping, if properly funded and readily available, could be a major contribution to production of geological maps in Canada.

The present emphasis in areal mapping is twofold: to complete and update 1: 250 000 geological map coverage of Canada, and to provide larger scale maps of selected areas of higher economic potential or geological interest. The eventual completion of 1: 250 000 map coverage will not mean the end of such mapping and a shift of all effort to more detailed, larger scale mapping. On the contrary, many 1: 250 000 maps are now obsolete, and continual revision of these maps will be necessary.

Geological maps do not provide changeless factual data. Most maps are a subjective blending of more or less objective observations and interpretations based on these observations. The data and interpretations presented are influenced by hypotheses prevalent at the time the map was made, the prejudices of the mapper, the amount of knowledge available from adjacent areas, and changing perception of needs in mineral exploration or resource assessment. The first map in a new area may contain errors and misconceptions that can only be corrected as contiguous map sheets provide additional data. Consequently areal mapping is a continuing process that mirrors evolving geological concepts.

Many maps published in the last few decades are already outdated, and the rate of map obsolescence appears to be increasing because of the rapid evolution of geological knowledge. In many regions, the rate at which geological maps are being produced is not adequate to keep pace with obsolescence. For example, in the western Cordillera, from central Yukon to southern British Columbia, there are about ninety-five 1: 250 000 quadrangles measuring two degrees of longitude by one degree of latitude. Almost all of these have been mapped, mostly since 1945, but about 25 of these maps, mostly in southern British Columbia, now require major revision. In this area large scale detailed mapping is currently being done, but no small scale mapping has been done for a decade or more. With about a dozen geologists working on 1: 250 000 maps

in the western Cordillera, the maximum rate of map revision is four sheets per year. At the current level of activity the rate of obsolescence just exceeds the ability of the group to keep the mapping up-to-date.

Similar statistics regarding 1: 250 000 map coverage apply to many other regions of Canada and in some areas the available manpower is insufficient to provide both revisions and new maps. The amount of time required for revision will obviously vary from sheet to sheet and will not always involve complete remapping. It will depend on the amount of new mapping required, the regional extent of new interpretations, the amount of detailed mapping available from other sources, the extent of new subsurface, geophysical and geochemical work, and ease of access. For larger scale maps the rate of obsolescence is comparable, although the conflict between revision and mapping is possibly less acute because many large scale maps are more recent than many reconnaissance maps and in several regions large scale maps are not planned to be universal in coverage.

A major drawback of many recent maps is that they are accompanied only by marginal notes or descriptive reports. The concentration of effort on accumulation of up-to-date maps with limited staff working at full capacity has delayed or prevented broad syntheses, regional correlation, and generalization by the very geologists most familiar with large regions. Considering the large amount of money expended on preparation of the map, more emphasis should be placed on discussion and synthesis of the data, on preparation of more comprehensive reports, and on discussion of areas and problems that warrant further exploration or research that is beyond the limits of the scope of the mapping organization. This will undoubtedly require added time for completion of projects, but it must de done. Future needs dictate both faster accumulation of up-to-date basic data beyond merely keeping up with obsolescence, and additional emphasis on on-going syntheses.

In most regions of Canada large scale mapping is quadrangle-bounded and is mainly in areas of economic interest. Consequently we are acquiring a large amount of basic map data for some rock units while other rock units, for example the large granitic batholiths in the Precambrian Shield, are virtually neglected in large scale mapping programs. If we are to solve some of the basic tectonic, stratigraphic, and plutonic problems in Canada, large scale mapping by provincial and federal agencies should be more problem-oriented, more uniform in its coverage and should be integrated with isotopic, geochemical, petrologic, stratigraphic, sedimentologic, and paleontologic programs. From such studies may come ideas that can be applied to resource exploration elsewhere.

In summary we find that small scale areal mapping in Canada is progressing somewhat slower than required, particularly when obsolescence of maps is considered. If the rate of production is to be significantly higher than the rate of obsolescence, more manpower is required. Large scale mapping is highly variable in scope and intensity from province to province, and is concentrated mainly in areas of economic interest. At the present state of knowledge, more large scale mapping should be problem-oriented rather than quadrangle-oriented, and should be more uniformly spread over all rock units. More use should be made of mapping generated by university research projects, and by industry resource exploration. University mapping is relatively inexpensive, and small grants from Federal and Provincial surveys to support the mapping, although not necessarily the laboratory research, could provide a large amount of relatively inexpensive areal mapping. The National Research Council should also be more aware of the need for, and the costs of, field mapping related to research projects.

Adequate, up-to-date geological maps are essential for resource exploration, for more detailed research in many fields of earth science, and for regional syntheses, but their potential is not fully recognized in some circles. Synthesis of the map data by the field geologist should be encouraged.

Surveys should also be encouraged to prepare a wider variety of geological maps. For example, resource evaluation and land-use maps have only recently appeared, and there are many other types of maps that could make the basic geological data more useable.

ENVIRONMENTAL GEOSCIENCE

J-Y Chagnon, R.N. Farvolden, E.A. Babcock, J. Jones, D. Jeffs, and
J.C. van Loon for the Geological Association of Canada

For a comprehensive definition of this discipline the reader is referred to the 1974 Status Report (Neale *et al.*, Geol. Surv. Can., Paper 75-6, 1975). The activities of Environmental Geoscience are similar and in many instances closely related to those of other fields (Hydrogeology, Quaternary Geology, Geotechnique). However, they are primarily concerned with the interface between man's activities and their environmental effects and conversely with environmental effects on man's activities, always in a time reference significant to human society.

Current Level of Activity

The level of activity is now on an upward trend with no signs of abatement in the near future. This situation results from the increased concern of all for the preservation of the environment from man's activities. Most provincial governments in Canada have enacted legislation with the purpose of protecting the environment. Many municipalities now have stringent regulations concerning land development. Large corporations (mining companies, power utilities) have had to contend

with the questioning of their traditional practices. This increased concern has given rise to the formation of departments or divisions dedicated to the environment in most provinces, in many municipalities and in numerous private companies. In most areas of Canada consulting engineering and geology firms providing services in environmental geology are now active. Many universities now offer graduate and postgraduate training and are involved in pure and applied research on the environmental earth sciences. A major aspect of this increased level of activity is the recognition of the value of integrated or multidisciplinary studies.

Current research activities are best summarized under the following:

Pollution studies: Government regulations in most provinces require sound management of solid and liquid waste disposal systems and work is being carried out on specific problems such as:

- Amounts of pollutants reaching the Great Lakes from waste disposal practices (Ontario).
- Studies of pollutant travel in groundwater, and attenuation of leachate from sanitary landfills and industrial wastes (Ontario and Quebec).
- Evaluation of the suitability of proposed landfill sites and development of design criteria to protect surface and groundwater quality (most provinces).
- Study of toxic metal transport in the waters of Prairie rivers.

Urban development: Typical applied research topics are:

- Environmental impact studies on the possible effects of new subdivisions (British Columbia).
- Hazard evaluation; slope stability assessment (most provinces).
- Engineering geology of subway systems (Alberta and Quebec).

Heavy construction works: Most large construction projects (power plants — pipelines — highways) now require environmental impact studies prior to approval. Geoscientific research is currently underway in British Columbia and Quebec on the assessment of the effects of dams and transmission lines on the environment. The assessment of terrain conditions (slope stability problems — permafrost conditions) for highway and pipeline construction is now current practice.

Mining activities: The environmental impact of mining is the object of much research centered on:

- Toxicity of effluent from mining operations (Alberta).
- Assessment of impact of coal mines (British Columbia).
- Assessment of slope stability in open pit mines in urban areas (Quebec).

This short summary of the activities is far from exhaustive but is included to illustrate the diversity and multidisciplinary aspect of the work being carried out.

Symposia

The Environmental Earth Sciences Division of the Geological Association of Canada arranged symposia for the 1975 annual meeting of the parent society at Waterloo, Ontario, covering contaminants in subsurface flow systems, environmental isotopes, interactions between terrestrial and aqueous systems in the Great Lakes basin, and environmental aspects of marine geology.

The International Conference on Heavy Metals in the Environment held in Toronto covered health and environmental evidence and implications of metals in many disciplines.

Opportunities for reviews of field results were given by the GAC's Environmental Geology Field trips in southwestern Ontario, the 18th Conference on Great Lakes Research at Albany, New York, and the informal, one-day Environmental Earth Sciences and Engineering Conference in Toronto.

Major Advances

The most important development in Environmental Geology is the direct involvement of public authorities at all levels (municipal, provincial and federal) which is manifested by adoption of official policies and enactment of specific legislation. For instance, the Ontario government passed the Environmental Assessment Act, 1975, which, upon proclamation, will require the submission and approval of environmental assessments before major works are undertaken. It will apply initially to provincial and municipal works and later to commercial and business enterprises. The Federal government requires review of the environmental aspects of proposed federal and federally supported works as a matter of policy.

Cherry *et al.* (1975) accomplished the valuable service of integrating theoretical and practical information on contaminant movement through geologic deposits. One of the major needs in the environmental geosciences, for improved field information to enhance predictions and monitoring programs, is evidenced in their conclusion dealing with subsurface contaminants:

> "The differential equation that described the migration of dissolved contaminants in groundwater flow systems has been established for more than a decade. For the movement of conservative constituents it includes two main physical parameters (1) groundwater velocity and (2) dispersivity. The problem facing hydrogeologists in the following decade is to determine the most reliable and efficient methods of determining these parameters under field conditions and to develop a more quantitative understanding of the uncertainties associated with the field determinations.

The uncertainties include heterogeneities of grain size, cementation, and fracture pattern and size, in both unconsolidated sediments and rocks. For reversible reactions between pollutants and earth materials, the effects of other variables, such as contaminant concentrations and mineralogical and chemical properties of geologic materials are added."

A related need is to increase the availability of significant, site-specific, environmental data which frequently reach project files, rather than publications.

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GEOCHRONOLOGY — ISOTOPE GEOLOGY

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for the Geological Association of Canada

Canada's activity in the related fields of geochronology and isotope geology involves an annual expenditure of about one million dollars, an amount divided between salaries paid to university academics (and their government equivalents) and the operating costs of laboratories. The latter represented about ten per cent of NRC-sponsored operating grants earth science in 1975. The efforts of about 100 people are involved; one-quarter of these are academic-professionals and the remainder are students and research-technical support staff. Included in the latter group are about 20 Ph.D and 35 M.Sc. candidates who are variably involved in geochron-isotope research projects. Also, some two dozen undergraduates are involved in a minor way each year. Postdoctoral fellows (who are in a position to be maximally productive) are few, indeed, only about five in Canada. In reality, about 40 'effective' people are probably doing most of the geochron-isotope research in Canada, so that each is responsible on the average, for 100 000 square miles. It is no wonder that the demand for isotope work is insatiable! The Geological Survey of Canada with 11 full-time individuals probably produces over 30 per cent of the geochronological data published each year by Canadian labs. Consequently, the single most important publication in the whole geochron-isotope field is the Geological Survey's annual report of age determinations (Wanless *et al.*, 1974), a very efficient means of getting new data into circulation.

The number of active groups is relatively few (eighteen) and although these are scattered from coast to coast the distribution in somewhat uneven. The most active centres form a short list: the universities of Alberta and British Columbia in the west, the Geological Survey of Canada, McMaster, Waterloo, and Toronto universities in Ontario, and the Bedford Institute of Oceanography in the east. New or developing laboratories are at the University of Calgary and the Royal Ontario Museum. Essentially one-man operations exist at Manitoba, Western Ontario, Carleton, Queen's, Laval, Montreal, McGill, St. Francis Xavier and Dalhousie Universities. Private industry has established no earth-science isotope laboratories in Canada, though there are a number in the United States.

Most of the research in Canada is routine isotopic age determination work — providing ages for ongoing geologic research projects, mapping, and resource exploration programs. This is information that geologists need and appreciate, and is the prime justification for most funding in geochronology. This need is particularly evident in the field of Precambrian studies, where geochronology furnishes essential data. A notable accomplishment of recent years was the dating of 3.6 b.y. old gneisses in Labrador (Barton, 1975) and Greenland (Baadsgaard *et al.*, 1976).

In addition to routine data collection, Canadian laboratories are engaged at research frontiers in K-Ar dating ($^{40}Ar/^{39}Ar$ technique, Ar isochrons), Rb-Sr and Sr isotope studies (half life of Rb, Sr isotope regional mapping, mantle isochrons), U-Pb dating (zircon dating systematics and applications), Pb isotope studies (evolutionary models relation to ore deposits), and stable isotopes (S isotopes in lunar rocks, O, H, and C isotope hydrology and climatology, sea floor alteration processes, Archean chemical sediments).

While Canadian laboratories have not become involved in lunar-meteorite studies in any major way, Canadian geochronologists and isotope geologists have made important contributions in the international arena. Most noteworthy here are (i) the K-Ar dating and Sr-Pb isotope studies carried out by Queen's and McMaster universities respectively in South America, (ii) the participation of a number of Canadian laboratories in the study of rocks returned by Leg 37 of the Deep Sea Drilling Project, material from a number of deep drill holes into the crust of the Atlantic Ocean and (iii) the direct determination of the decay constant of ^{87}Rb at the University of Alberta.

Canada has proven to be such a fertile ground for geochron-isotope studies that Canadian laboratories have been unable to keep up with the demand. Consequently, American involvement has been substantial. For example, researchers at universities such as Georgia, Ohio State, Santa Barbara and Yale have had projects in the Cordillera, Appalachians, and the Canadian Shield.

There have been no dramatic changes in the scope, orientation or scientific stature of geochron-isotope research in Canada during the past two years. For msot laboratories funding has remained almost constant, very few have declined, and several report significant increases. The total number of individuals involved is increasing gradually. New zircon dating facilities are becoming active and existing zircon dating laboratories have significantly increased their capabilities. Rb-Sr and stable isotope research is expanding, K-Ar dating is holding approximately constant. Most laboratories, and especially the smaller ones, are in a perpetual struggle to stay abreast of the inflation of technical salaries and prices of scientifie supplies, and concern has been expressed about the need for replacement of obsolete equipment.

Apart from the reservations expressed above, the Canadian "physical plant" is reasonably adequately equipped but badly "undermanned", especially with regard to technical help. The most pressing need for the immediate future is some substantial increase in annual operating funds. This would increase the efficiency of existing laboratory operations, and in particular would provide for more continuity in the university environment. The output of existing facilities might easily be increased by at least fifty per cent, if more technical help were available.

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GEOMATHEMATICS

ANALYTICAL STUDIES

E. Nyland for the Canadian Geophysical Union

The Division of Mathematical Geophysics of the Canadian Geophysical Union (C. G. U.) has begun the process of bringing workers in the application of mathematical geophysics into closer contact in Canada. The subject is such that distinctions from other geophysical disciplines are somewhat arbitrary but the probability that the same mathematical methods may be of value in several disciplines suggests that mathematical geophysics should be independent of the more traditional geophysical disciplines. At the 1975 congress of the Canadian Association of Physicists there was a two day symposium on mathematical geophysics which was both well attended and showed the breadth and vitality of the activity in Canada. The 1976 meeting of C. G. U. at Laval included a session on geomathematics.

At the University of Alberta mathematical geophysics involves model studies of geodynamics, seismic risk under artificial lakes, lateral heterogeneity and the construction of synthetic seismograms. Takashima and Aldridge have studied the stability of a horizontal layer of dielectric fluid under the simultaneous action of a vertical D C electric field and a vertical temperature gradient. They found that when the electrical conductivity is assumed to be a quadratic function of temperature the electric field can exhibit a strongly destabilizing effect on the fluid layer and the numerical results coincide with existing experimental results in order of magnitude. This problem is interesting from a geophysical standpoint because the electric field can provide the driving force in laboratory models of thermal convection in the earth's core. Further details can be found in the Geomagnetism section of this report.

At the Memorial University of Newfoundland, mathematical geophysics or core dynamics is studied extensively. At the University of Toronto, work continues on the study of wave propagation in heterogeneous media.

At York University, Smylie and co-workers are active in the application of mathematical methods to geophysics. A variational approach is being used to estimate eigen-frequencies of oscillation of stably stratified core models. The method employs piecewise cubic Hermite splines as approximating functions resulting in a quadratic eigenvalue problem for banded matrices. Instrumental development for the observation of core modes by detection of variation of gravity has proceeded in parallel to the theoretical work. Observatory data at the 10^{-11}g value is now being collected at a site in Montreal.

Recalculation of the dissipation of tidal energy in the earth's mantle including the higher harmonics of the deformation field arising from the ocean response is being carried out. Early results indicate that mantle dissipation is a factor of 2 or 3 times larger than previously thought.

Application of the maximum entropy method to two dimensional problems is being investigated. Algorithms are being developed for high resolution filtering and spectral analysis of satellite data from the Canada Centre for Remote Sensing.

The geophysical research group at York has participated in experiments with Canadian radio astronomers acquiring trans-Atlantic baseline data at 2.8 cm wavelength since 1973. All the software development including a computer model of the interferometer and all known motions of the antenna relative to inertial space as well as aberration and proper motion of the source has now been completed. The inversion of the March, May and June 1973 data has yielded geodetic ties to England accurate to ±150 cm formal error for all three experiments.

The work on geodynamics carried out at the University of Alberta has immediate application to engineering problems in areas of seismic risk. The synthetic seismogram projects at Toronto and Alberta are of great interest to problems encountered in seismic exploration for oil and the work on global dynamics at York and Memorial is of great importance in the direct measurement of plate tectonic activity.

DATA STORAGE AND INTERPRETATION

J.E. Robinson for the Canadian Society of Petroleum Geologists

The practice of using geomathematical tools as a means to a geological conclusion and not as the end in itself is becoming more common and shows that geomathematics and computer applications have finally reached maturity. Interest in the art remains high with a continuing output of quality publications and good attendance at geomathematical meetings such as those held by the Geomathematics and Computer Applications division of the Canadian Society of Petroleum Geologists. This is in spite of a general paucity of new methods and developments so that progress has been confined to the improvement and enhancement of known and generally familiar procedures.

The large commercial geological data files are generally in a stable condition. New wells are digitized and added to the files but there are no plans for expansion. However, individual companies continue to expand and improve their operational files. The Data Base concept is proving to be very effective in both day to day play interactive evaluation and integrated regional studies that require multiple file interrogation and complex hard copy displays. Interactive graphic systems give the user the ability to create stratigraphic cross-sections and maps, then adding Scout ticket information so that the geologist can evaluate current data and easily correct spurious anomaly and data deficiences. Admittedly, graphic display CRT devices display only a limited data set at any one time, however, their speed and correcting abilities make them as invaluable addition to a geologic system that has Data Base flexibility.

While the major data files have stabilized, smaller, special purpose files continue to proliferate. The Western Canadian Coal Resource Data Base is an excellent example of where co-operation between the Federal Government, the Saskatchewan Provincial Government, and the University of Alberta has produced a series of files covering information obtained from the numerous coal boreholes of Western Canada.

Although not Canadian in origin, the first international geological data file became operational in 1976. The Petroleum Data System of North America, compiled by the University of Oklahoma and accessible through the General Electric computer network, contains field and production information for Alberta and Ontario as well as the majority of States having significant production. Canadian subscribers to the G.E. system can access any of the information.

The percentage of new wells in which the wire-line log information is digitally recorded, continues to show an annual 50 per cent increase. At present, approximately 18 per cent of all new well logs are digitally analyzed with the majority of the computations being carried out by the logging companies with only a few of the major oil companies doing their own detailed analysis. Newly available computed log presentations include a Production Management Log based on thermal delay time and a more sophisticated synthetic seismic log utilizing both sonic and density information.

Custom digitizing of logs appears to have declined in the past year. Although a computer accessible file of digitized well logs would provide a valuable new source of exploration information, digitizing and file construction is very expensive and in a sagging and uncertain economy, major new expenditures are difficult to justify.

The use of remote sensing, particularly LANDSAT imagery, is becoming more widespread in exploration. Digital techniques have been developed to minimize the effect of hazy Canadian skies, and to enhance the subtle multivariate contrasts that denote geology. The enhanced images are useful for mapping the structural and stratigraphic features that can lead to petroleum prospects and takes interpretation beyond the initial mapping of lineaments.

While the integrated Data Base type systems require large computers, another branch of geomathematics has trended towards the use of smaller, special purpose mini-computers. Where even very complex function calculations must be repeated many times, they can be hardwared so that sophisticated models and processes can be simulated quickly and cheaply on small fast computers. This trend to miniaturization is particularly important for plant or reservoir simulation and management and for standarized enhancement procuedures applied to remotely sensed data.

Canadian geomathematicians continue to be prolific publishers. They contribute approximately 20 per cent of all papers published in such international journals

as Mathematical Geology (Plenum) and Computers and Geosciences (Pergamon). Dr. J.E. Klovan of the University of Calgary co-authored volume one "Geological Factor Analysis", of the Elsevier series on methods in geomathematics. Canadians have also authored important segments of "Random Processes in Geology", D.F. Merriam, editor (Springer-Verlag); "Quantitative Studies in Geology", E.T. Whitten, editor, the Geological Society of America Krumbein Memorial Volume, Memoir 142; and "Concepts in Geostatistics", R.B. McCammon, editor (Springer-Verlag), 168 p.

Not Canadian, but still notable publications in geomathematics include: "Decision Analysis for Petroleum Exploration" by Paul D. Newendorph, Petroleum Publishing Company, Tulsa, 668 p.; the A.A.P.G. publication, "Methods of estimating Volume of Undiscovered Oil and Gas Resources", John D. Haun, editor, 206 p; "Pattern Recognition Principles" by J.T. Tou and R.C. Gonzaly (Addison Wesley), 376 p.; and the comprehensive volume on statistical methods in sedimentology, "Sedimentation Models and Quantitative Stratigraphy" by W. Schwarzacher (Elsevier), 382 p.

Metrication of oil and gas information systems will require major revisions in the present file formats, data, and presentation forms. This is a time for real co-operation between government agencies, commercial data gathers and operational companies, if the transition is to be reasonably smooth with a minimum of redundant effort and expense. Should a reasonable level of co-operation be attained, it could continue into the organization of existing files into a National Data Bank concept to achieve a new and more useful system of integrated, compatible files with a minimum of overlap and conflict. This is really a proposal for a return to the concepts of a decade ago that have been largely lost in the federal and corporate shuffle.

While new geomathematical techniques are always welcome, there are generally more tools available than there is good data to use them on. Therefore, an integrated centralized Data Base might so reduce the present maintenance effort that new data sources such as digital log files might become feasible.

GEOPHYSICS

GEODESY

P. Vanicek for the Canadian Geophysical Union

The situation in Canadian geodesy has somewhat improved in the past two years. The Geodetic Survey of Canada (Surveys and Mapping Branch) has taken the decision to redefine the first order Canadian horizontal geodetic network by 1977. Towards this goal, further progress has been made to complete the coverage of Canada by Doppler satellitepoints spaced 200-500 km apart, with positions accurate to about 1 metre. Also both the terrestrial horizontal and vertical networks have been further extended and densified.

NRC Time and Frequency Section continued both its national time service and international cooperation with BIH (Bureau International de l'Heure). Gravity and Geodynamics Division (Earth Physics Branch) have maintained their involvement with IMPS (International Polar Motion Service) and begun to supplement their PZT (Photo Zenith Tube) observations with Doppler satellite determinations of polar path.

An international Symposium on Redefinition of North America Geodetic Networks was held at the University of New Brunswick in Fredericton in May 1974. The Proceedings appeared in The Canadian Surveyor, v. 28, no. 5, 1975. A Symposium on Satellite Geodesy and Geodynamics took place within the second annual meeting of Canadian Geophysical Union in Waterloo. Proceedings are published in Contributions of Earth Physics Branch, v. 45, no. 3, 1976.

Two Canadian interdisciplinary teams participate in exploits of Geos-3 satellite focusing on direct measurements of earth tides and sea surface topography in Hudson Bay. Canadian expertise in Doppler satellite positioning was called on by various other nations. There has been some Canadian geodetic involement in studying tectonic movements in California and Peru.

While the existing academic programs in geodesy continued to grow, moves to create a new program in Alberta were made with the establishment of a new Geodetic Research Institute.

On the research side Bedford Institute of Oceanography has pursued their ongoing research and testing of different navigation systems. The researchers at Memorial University, among other achievements, succeeded in putting an upper limit on the controversial diurnal polar wobble. Other groups investigated problems related to the forthcoming redefinition of geodetic networks, crustal movements, sea level variations, geoid, etc. The specific achievements were reflected in numerous invitations for international co-operation.

The Geodetic Survey of Canada adapted and tested the recently acquired Inertial Surveying System. Accuracy better than 50 cm can now be achieved in position interpolation; deflections of the vertical and gravity values are obtained as by-products. Canadian Marconi satellite receivers are gaining acceptance all over the world.

The manpower shortage in geodesy reported in 1974 has declined slightly. Generally, a national geodetic policy should be designed soon to ensure that appropriate attention is paid to all branches of geodesy. Sustained funding from government sources of a few centres of excellence is badly needed to promote serious work on new generations of terrestrial and extraterrestrial positioning systems with decimetre and centimetre accuracy, and four-dimensional geodesy. There is a demonstrated national and international demand for a map of vertical crustal movements in Canada.

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GEOMAGNETISM

D.I. Gough for the Canadian Geophysical Union

Full reports on the very large volume of work in the disciplines grouped under geomagnetism can be found in the Canadian Geophysical Bulletin for 1975. Here only types of investigation and locations of studies can be indicated.

Geomagnetic surveys at sea have been continued in the Newfoundland Basin and Labrador Sea by the Bedford Institute of Oceanography. Results from the Labrador Sea are being interpreted in terms of seafloor spreading. Aeromagnetic survey data in Western Canada have been further interpreted in terms of large-scale tectonic processes by Earth Physics Branch, Energy, Mines and Resources Canada. Interpretative work on aeromagnetic anomalies in Quebec has continued at Université Laval.

New charts of the geomagnetic field elements for epoch 1975, covering Canada on a scale of 1:10 000 000 have been published by Earth Physics Branch.

Studies of rapid variations of the geomagnetic field such as micropulsations, geomagnetic bays, solar and lunar variations have continued at the Defence Research Establishment (Pacific), in Earth Physics Branch and in the University of British Columbia. Interpretation of geomagnetic substorm fields in terms of phenomena in the magnetosphere has continued at the University of Alberta.

A large variety of investigations of electrical conductivity structure in the Earth was set forward in 1975. Interpretation continued on data from large arrays of magnetometers which had recorded natural time-varying geomagnetic fields in Saskatchewan and northern United States (the University of Alberta and Earth Physics Branch), in the Saguenay-Laurentide area of Quebec (Earth Physics Branch) and in northern Alberta-southern Northwest Territories (the University of Alberta). The last-mentioned array was designed for study of the overhead substorm currents, the other two for study of structure in the solid Earth. Smaller magnetometer arrays were used in the Arctic Islands by Earth Physics Branch and by the University of Toronto across the Appalachians in the Eastern United States.

Magnetotelluric investigations were advanced by Earth Physics Branch in Quebec and in the north-central United States by the University of Alberta, mainly directed to study of crustal structures. Audio-frequency magnetotelluric work, adapted to upper crustal and shallow depths, has been used by the University of Toronto to study Shield rocks in northwestern Ontario; for investigations related to the proposed use of a middle-crust high-resistivity layer for transmission of very low frequency radio signals to submerged submarines; and to study permafrost thicknesses in arctic Canada.

Interpretation of electrical conductivity structure uses model studies of two kinds; numerical calculations in a computer or analogue models of structures in a water tank. Model studies of both types have been actively pursued in the Universities of Alberta and Victoria and at the Dominion Astrophysical Observatory, Victoria, British Columbia.

The use of man-made source fields for deep electromagnetic soundings is under study at the University of Toronto.

Quantitative interpretation methods for surface and airborne electromagnetic exploration data have been worked out at Université Laval, and have been applied in the Schefferville and Lac Minto regions of Quebec.

Several active groups continue with contributions to knowledge of paleomagnetism in Canada and of the physics of rock magnetism. Work on rocks from various parts of the Shield directed largely to improved knowledge of the polar wander path in Precambrian time, is in progress in Earth Physics Branch and Western Ontario. Paleozoic rocks from eastern Canada are under paleomagnetic study in Memorial University of Newfoundland, in Earth Physics Branch and in Université Laval. Basalts drilled from ocean floors are being studied, partly for geomagnetic reversals, at Memorial University and at the Universities of Alberta and Toronto. The secular variation of the geomagnetic field in the last few thousands of years is being investigated, through Quaternary sediments, at the University of Alberta.

In relation to interpretation of paleomagnetic results it is important to understand the physics of both the

remanent magnetism which has been stable through geological time, and the unstable components of rock magnetism. Work on such topics has made progress at the universities of Alberta and Toronto and at Memorial University of Newfoundland. Similar studies of lunar rocks are in hand at the University of Toronto.

Small changes in the magnetic field which may precede earthquakes have been studied at the University of Alberta. At the same university rock fabric is being studied through magnetic anisotorpy for some sedimentary rocks from the Shield.

Core dynamics and the main geomagnetic field have been studied through both theoretical and experimental work at the University of Alberta.

GEOMAGNETISM

F. S. Grant, A. Spector, and D. W. Strangway for the Canadian Exploration Geophysical Society

In the recent past there have been a number of important trends in the field of geomagnetism as viewed by the Mining Exploration community. Aeromagnetics are increasingly being used as a standard geological mapping tool. After eight years of experience with high sensitivity instruments it is becoming increasingly clear that there is a great deal more information available in the fine structure of the magnetic fields than is being used by interpreters. We should expect important developments in processing and displaying of this type of data in the future. Quantitative analyses have improved to the point of being routine. However, there is a general feeling that the ability to make depth determinations and to map magnetic mineral concentrations is limited only by factors relating to the data gathering process itself, such as unknown line spacing, width line spacing, variations in flying height, etc. The outstanding problem in the geological interpretation of magnetometer data still remains that of finding relationships between geological parameters (lithology, metamorphic facies, dominant mineral assemblages, etc.) and the concentration of magnetic minerals. Until some advances are made in this area, we are unlikely to witness a significant improvement in the general quality of interpretations, as applied to mapping.

Paleomagnetism has made great strides in the recent past. Perhaps most significant is the intense effort now under way to reconstruct the Precambrian apparent polar wandering paths for various continental blocks. This study is necessarily leading to the question of thermal overprinting and the clear isolation of various components of remanent magnetization. These efforts are slowly being correlated with the relatively more established methods of studying metamorphism, viz: petrology and isotopes. Some attempts to examine ore deposits and their time of formation are underway. This consists of comparing the paleomagnetic directions in the ore and the host rocks to see if there are discrepancies related to the time at which the magnetization was acquired.

It appears that the study of magnetic fields and magnetic properties can do a great deal more in the mapping of Canadian geology and, in a general way, in the characterization of favourable ore environments. The high information content of high sensitivity surveys has not been fully exploited. In fact until the complete system from grid control to survey line spacing, to elevation control to compilation can be properly put together, it is unlikely that the full potential of these methods will be exploited. It is necessary to develop the concept of a complete more definitive system.

The interrelationships of magnetic properties, magnetic mapping and the general geochemistry of iron is a subject that is still in its infancy, notwithstanding twenty-five years of commercial experience with aeromagnetic surveys. We would hope to see moves made by geologists, geochemists and geophysicists to address themselves to the problem of finding out more about the geological and geochemical behaviour of iron, particularly with relation to ore deposits and ore genesis. It would be interesting, for example, to understand the nature of the magnetic minerals associated with modern ore forming processes such as those in the Red Sea basins or those that seem to be operating along the mid-ocean ridges.

In general, we have to state that although there is a considerable need for extracting better information with existing tools, there is almost no effort being placed in developing the next generation of tools. It is already known that cryogenic magnetometers have several orders of magnitude more sensitivity than any current instruments. In Canada there is only one laboratory that is using such devices for sample studies and there is little effort being expended to develop them for survey work. While the commercial advantages of these instruments are not altogether clear at the present time, there seems to be little question that using such devices for vector gradient studies and for electromagnetic exploration could have important implications in mining within the next five years.

In terms of manpower, we seen the need for small numbers of people with advanced training in ore deposits geology, hard rock geochemistry, instrumentation, digital techniques, rock magnetism and paleomagnetism and time series analysis and inversion techniques to provide the thrust for these new approaches. There does not seem to be a need for more numbers at the undergraduate level, but for groups of well-trained people with strong backgrounds in geology, geophysics, mathematics and instrumentation. There is also a need for people with these skills at the masters level.

GEOTHERMAL STUDIES

A. E. Beck for the Canadian Geophysical Union

Basic measurements related to various aspects of terrestrial heat flow continue at a number of centres so that only one or two highlights from each will be picked out here.

Members of the University of Dalhousie have obtained the first heat flow measurements in boreholes drilled into the basaltic ocean crust on Leg 37 of the Deep Sea Drilling Project; three holes were used, one to a depth of 540 m. They have also obtained measurements in a number of British Columbia inlets which have a stable thermal regime close to the bottom. The Geothermal Studies group of the Department of Energy, Mines and Resources has completed the World Heat Flow Data compilation being made on behalf of the International Heat Flow Committee; much work is also being done in the permafrost with measurements of the thermal properties of rocks and soils, both frozen and unfrozen, being made on a continuing basis. At the University of Toronto measurements have been made in a number of lakes in the Superior province where it has been found that averaging results from five or six neighbouring thermally stable lakes gives a reliable value of heat flow. At the University of Western Ontario equipment has been built which, through the use of deconvolution techniques, allows a continuous logging of borehole temperature gradients to high accuracy.

The preceding paragraph simply picks out highlights from more extensive programs. What must be cause for simultaneous congratulation and concern is that the university activity, although not as great as it should be, is surprisingly high when the low level of support is taken into account. For instance, each university group is essentially based on a single faculty member making use of whatever interested students are available; however, the combined amount of NRC operating grants for 1974-75 awarded to the faculty members involved came to less than $50 000 of which certainly less than 75 per cent, and probably less than 50 per cent, was specifically earmarked for geothermal studies. In other words, although overall university activity may be low, individual productivity is quite high. This low level of financial support occurs at a time when an increasing number of young scientists require training to investigate the geothermal energy potential of Canada — which constitutes Program 4 of Task 5 (Renewable Resources) of the Federal Government Energy Research and Development program. This level of support may be compared with the more than $11 000 000 distributed in the United States by the National Science Foundation alone over the last four years to support research in the development and use of geothermal energy or, closer to home, with the number of individual scientists in other disciplines, e.g. Chemistry, who each receive annual operating grants in excess of $50 000 each year.

The lead agency for the Canadian geothermal program is the Department of Energy, Mines and Resources, the work being performed principally through the Geothermal Services group which at present consists of five professionals, one Post-doctoral Fellow and two support staff. Large though this group is compared with the total university group, it is still understaffed considering the magnitude of the task it faces — namely, to undertake basic background studies in terrestrial heat flow, to assess geothermal resource potential and development, and to investigate many aspects of permafrost problems (such as measuring the thermal properties of materials along potential pipe line routes). The situation at present might not be a cause for concern if work could be contracted out to commercial companies experienced in geothermal investigations; however, there is no such Canadian company although a number have indicated an interest in gaining the necessary experience.

Therefore, if the Department of Energy, Mines and Resources wishes to expand the level of Canadian activity in geothermal studies, it has the choice of a) hiring personnel of its own who, because of the relatively low university production of trained people, may well be trained in another area and must therefore be retrained, b) letting contracts to industry which is then faced with the same problem of acquiring trained people, c) letting contracts to universities which are in a good position to train people but do not really have either the desire or ability to handle large contracts.

The type of resources that need to be investigated are: 1. High temperature ($T > 200°C$) reservoirs (both steam and water), 2. Low temperature waters ($100° < T < 200°C$), 3. Dry hot rock, 4. "Normal" heat. Appropriate technology already exists for utilization of 1 and 2 but a knowledge of suitable reservoir characteristics (e.g. permeability) as well as temperature are required. For 3, suitable temperatures ($T > 300°C$) are required and appropriate permeabilities in normally competent rock are created artificially; technology for this is being developed in the US but is unlikely to become economically viable for a decade. Since resource types 1-3 rely on local concentrations of geothermal energy there are obvious geographical limitations in their use. Use of "normal" heat may be the ultimate long range objective since the reserves are vast and not subject to geographical limitations; unfortunately an appropriate technology has yet to be devised and may not be available, if at all, until the end of the century.

Although there is so little data on which to base a reliable judgment the following statements may not be too unreasonable. It is unlikely that steam reservoirs exist to any significant extent in Canada. It is possible that high temperature water reservoirs and hot dry rock "deposits" do exist and the Department of Energy, Mines and Resources has made some preliminary attempt to separate areas of least probability of success from the rest. The rest of the geothermal resource picture is virtually blank. Clearly a six-man government group plus a three or four man university is not going to make rapid progress.

GLACIOLOGY

G. K. C. Clarke for the Canadian Geophysical Union

The stimulus of the International Hydrological Decade, which ended in 1974, tended to obscure two discouraging trends in Canadian glacier research: a decline in the amount of field research, and a reduction in the number of active workers. The first is an immediate consequence of a long period of financial retrenchment, and the second is due to the reduced number of active universities and federal agencies. Neither trend promises a bright future for glacier research in Canada.

For a country in which snow and ice have enormous impact on both the economy and national imagination, the present low level of university interest is remarkable. McGill University and the University of British Columbia are the only Canadian universities which have a recent record of continuous activity in glacier science. The decrease in Canadian university activity has been partially countered by increased field research in the high arctic by foreign institutions such as the University of Colorado, University of Minnesota and the E. T. H. (Zurich). Increased activity may also result from the creation of a new graduate program in "Snow, Wind and Ice" offered at the University of Guelph and the new Centre for Cold Ocean Research at Memorial University of Newfoundland which may develop along glaciological lines.

The dominant role of federal agencies was one of the themes of the 1974 CGC report. Little has changed since that time but the present weakness of the university sector is greatly exacerbated by a steady erosion of National Research Council support. This effectively strengthens federal control of university research through government contracts and subventions programs. One early casualty of such an unbalanced system is informed and objective comment on federal research, policies and planning. For an environmental science with concerns which impinge on northern development policies, this is an unfortunate loss.

Because the Glaciology Division of the Department of the Environment is the nation's largest glacier science group and funds much of the glacier science conducted by Canadian universities, its present status deserves special comment. To an outsider it would appear that this group has been fettered by unfavourable terms of reference. Glaciology has been perceived as a branch of freshwater hydrology, and from this narrow interpretation a number of unfortunate consequences have followed. Glacier scientists have been isolated from their natural community of ice and polar scientists (e. g., sea ice studies were deemed to be related to marine rather than freshwater hydrology), and the geophysical side of glacier science has been downplayed. To their credit, scientists within this group have managed to carry out research on a broad range of topics under what must be trying constraints. It now appears likely that the Glaciology Division is to be relocated in Saskatoon as part of a larger hydrological sciences centre to be established there. Whatever the hydrological merits of this new centre might be, there is no logic to moving the Glaciology Division to a site which is both far from glaicers and far from existing concentrations of glaciological expertise. A realignment of federal glaciological activity around its present Ottawa base would be a far more reasonable step.

Although there is some disagreement about how improvements in Canadian glacier science might best be effected, scientists in both the federal and academic sectors strongly believe that snow and ice research is not receiving financial support in proportion to its national importance. In comparing Canadian glaciological research with that carried out by other leading countries, one is struck by the absence of any research group of the size or status of the Scott Polar Research Institute (U. K.) or the Cold Regions Research and Engineering Laboratory (U. S. A.). From time to time it has been suggested that a similar centre of excellence be established in Canada. Were such a centre set up outside the federal government, though with core support from it, the present imbalance between the federal and non-federal sectors might to a large extent be corrected.

Despite this background of pessimism, a number of noteworthy events have occurred since the 1974 report. The National Research Council's Subcommittee on Glaciers sponsored a highly successful international symposium on "The Thermal Regime of Glaciers and Ice Sheets" at Simon Fraser University, April 8-11, 1975. Canadian contributions on glacier surging, the thermal regimes of White Glacier (Axel Heiberg Island) and Steele Glacier (Yukon Territory), paleoclimatic studies in Castleguard Cave, corehole measurements in Devon Island Ice Cap, and creep instability in ice sheets were read and proceedings have been published in a special volume (Glen *et al.*, 1976). The Canadian glaicer inventory and mapping program is being continued (Ommanney, 1974). Further studies related to surging of the Barnes Ice Cap (Baffin Island) and glaciers in the Steele Glacier region have been carried out. An airborne UHF glacier sounder has been successfully tested, and the electromagnetic scattering properties of glacier ice in the 1-32 KHz range measured *in situ* with an interferometer. Interest in climatic change continues to grow. Paleoglaciation levels on Baffin Island have been determined from satellite imagery; a computer modelling study of the growth of the Barnes Ice Cap during the Wisconsin glaciation has been completed; and the oxygen isotope record of past temperatures is being studied from deep cores in the Devon Island Ice Cap (Paterson, 1976). Variations in the oxygen isotope ratios with depth in ice sheets give a continuous record of climate fluctuations over the past 20 000 years. These data provide important constraints on theories of climatic change and form a basis for predicting the future climate. Coreholes are now being planned for Mount Logan, Penny Ice Cap, Barnes Ice Cap, and central Ellesmere Island. Related research has already received wide attention and

extensive funding in the United States; indeed, two of the four planned drilling programs will originate from that country.

In preparing this assessment the recent annual reports published in the Canadian Geophysical Bulletin (Patterson, 1974; Ommanney, 1976b) and an excellent overview of glacier studies in Canada by Ommanney (1976a) were heavily relied upon. I thank G. Holdsworth, S.J. Jones, O.H. LØken, W.H. Mathews, C.S.L. Ommanney, W.S.B. Paterson, and J. Rossiter for their suggestions.

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GRAVITY STUDIES

J.S. Tanner for the Canadian Geophysical Union

The agencies responsible for the bulk of the gravity measurements in Canada are the Earth Physics Branch and the Atlantic Geoscience Centre (Geological Survey of Canada) of the Department of Energy, Mines and Resources. At the Earth Physics Branch the bulk of the emphasis in terms of gravity mapping continues to be placed on offshore surveys. Approximately 31 000 line kilometres of shipborne surface meter gravity surveys were logged in coastal waters offshore of British Columbia and in Hudson Bay. Some 1000 new observations were observed on the ice in James Bay and the Beaufort Sea.

The Atlantic Geoscience Centre operated two Askania meters in a joint hydrographic/geophysical survey aboard the M/V MARTIN KARLSEN. The southern portion of the Labrador Sea was completed at 40 km intervals and a start made on interlining at 5 km intervals off Newfoundland and Southern Labrador. Other marine gravity measurements were carried out aboard the HUDSON east of Newfoundland.

A significant step forward was made in our understanding of anomalies over the boundaries between structural provinces of the Shield. Work at the Earth Physics Branch suggests that the anomlies are due to an edge effect between two crustal blocks of different composition and to a slight thickening of the crust at the boundary. In the offshore region, progress was made with the continuing study of gravity highs over the continental break in the Arctic Ocean. Although the cause of these anomalies is controversial, the discovery of earthquakes occurring within their boundaries places the interpretation that they are caused by uncompensated recent sedimentary loads in a more interesting light. In another interesting study a scientist at the Atlantic Geoscience Centre is attempting to place possible density limits on density distributions in models of continental margins.

Elsewhere gravity studies continued at a moderate level. The Geological Branch of the Ontario Ministry of Natural Resources continued its program of detailed gravity surveys over metavolcanic belts in several areas of the Canadian Shield in Ontario. It is hoped that this program will lead to a better understanding of the evolution of these structures and their often associated mineral deposits. Four universities throughout Canada have reported significant activity with respect to gravity studies, usually as part of a multidisciplinary study. A good example of this type of activity is the geotraverse being conducted by the University of Toronto in western Ontario; a project involving standard geophysical, geochemical and geological techniques in an effort to unravel the evolution of the structure of the region. No statistics are available from the petroleum and mineral exploration industry, but it is believed that generally the industry continued to be depressed last year.

The Earth Physics Branch tested their LaCoste and Romberg gravimeter aboard NRC's North Star Aircraft in March of 1975. Although designed to evaluate possible modes of airborne operation the tests indicated that without any major refinements in procedure a precision of 5-10 mgal appears possible under normal conditions. A number of possible avenues for improving the system exist, hence there is reason to hope that a precision of 2-3 mgal may eventually be possible.

One of the improvements could be in the gravimeter itself. Recent developments by a number of manufacturers have led to the appearance of the so-called linear gravimeter where the mass moves in a line rather than a plane. As this design eliminates the cross-coupling effect on the gravimeter a substantial improvement in the performance of the gravimeter can be expected.

REMOTE SENSING

L. W. Morley for the Canadian Geophysical Union

Function

The Canada Centre for Remote Sensing was established to innovate the new technology of remote sensing into the resource and environmental management fabric of Canadian society. It was done on the premise that the cost of this high technology was too large to be borne by agencies or organizations, and that one central agency could supply satellite and airborne services to the whole country. Since much of the technology is experimental, a viable market for remote sensing services does not yet exist. The modus operandi of the Centre is to develop the technology and then demonstrate its effectiveness in various applications. Whenever a particular application is developed to the stage that a user agency or private company is prepared to take over responsibility for its operation or to provide adequate service to users, it is the policy of the Centre to withdraw from that particular activity. The effectiveness of the Centre is judged by the number and value of experimental applications that have advanced to operational programs.

Forest Information and Management

In co-operation with the Forest Fire Research Institute and the Outaouais Forest Region Organization, Martin Taylor enhancements of satellite images have been made which provide the forest fire fighting personnel with information enabling them to predict the direction and intensity with which a forest fire will proceed. This helps them in the more efficient deployment of fire bombers.

It has now become routine to use satellite images for the assessment of forest fire damage. Satellite image enhancement techniques are used to assist and accelerate the rate of forest inventory mapping and in the control of the spruce bud worm disease.

Transportation

Gregory Geosciences of Ottawa, using LANDSAT and NOAA imagery are providing a regular service to companies and agencies operating in the North. Weekly maps show the state of snow and ice cover in all of northern Canada. This enables the more efficient deployment of field parties.

ISIS Limited of Prince Albert, offers a facsimile service of LANDSAT and NOAA images to shipping and exploration companies operating in ice-infested waters of the Arctic and East Coast.

Agriculture

In co-operation with the Canadian, Prince Edward Island and New Brunswick departments of Argiculture, LANDSAT images are being used to provide an inventory of the potato crop.

LANDSAT images are used in Alberta to assist in range land management.

Experiments are underway with the Canadian and U. S. Departments of Agriculture to use LANDSAT for estimating not only North American but the world wheat crop.

Land Use

In co-operation with the four Atlantic Provinces, a project is underway to carry out coastal zone land use mapping.

Hydrography

In co-operation with the Canadian Hydrographic Survey, two systems of aerial hydrography are being proven out. The first consists of conventional colour aerial photography taken over the inshore shoal areas to contour the bottom features which show up in the photography. The CCRS contribution has been the design of a gyro reference system which can give the tilt and tip of the photograph to within a half minute of arc.

The second method being further developed with OPTECH Limited is a blue-green Lidar appartus which penetrates the water further than colour photography. The depth is recorded along a profile under the aircraft track.

Offshore Radar Surveillance of Human Activities and Environmental Monitoring

Experiments with airborne synthetic aperture radar are underway to test various systems for ocean surveillance work. This includes ships, oil rigs, oil spills, ice, sea state and temperature — all through cloud and darkness. It is the long term plan to provide radar satellite coverage for these purposes.

Geological Applications of remote sensing are limited to satellite photo analysis of large scale structural features and to biogeologic mapping. Geophysical methods, although a form of remote sensing, are generally not included as part of remote sensing since a well-established infrastructure already exists in Canada.

SEISMOLOGY AND PHYSICS OF THE EARTH'S INTERIOR

E. R. Kanasewich for the Canadian Geophysical Union

Level of Activity

There are approximately 60 academics, government scientists and Post-doctoral Fellows with Ph. D.'s carrying out research in seismology, and various related aspects in the field of Geophysics. Approximately a third are in government agencies. In addition, there are an equal number of technicians with technical training in electronics or seismology and technologists and engineers with B. Sc or B. M. training. Approximately two-thirds of this latter group are in government service. There are about fifty graduate students in Canadian universities in these fields; about two-thirds are directly in seismology.

Seismic activity is monitored by 20 first order stations; 13 second order stations; six digital recording arrays operated by the Department of Energy, Mines and Resources and by four universities. If all instrumentation was deployed it would be possible to have about seventy stations recording earthquake activity in Canada. With budgetary restrictions the total is seldom over 45 except for brief experimental periods.

A Canadian seismological delegation consisting of K. Whitham, M. J. Berry and W. G. Milne from the Department of Energy, Mines and Resources, A. C. Heidebrecht from the Department of Civil Engineering and Engineering Mechanics, McMaster University and E. R. Kanasewich from the Department of Physics, University of Alberta, visited the People's Republic of China between October 17th and November 11th, 1975. Over 6000 miles of travel were made within China by plane, train and automobile. Included was a detailed four-day field visit to the site of the February 4th, 1975 magnitude 7. 2 earthquake at Haich'eng which had been predicted and in which the populace was evacuated prior to the earthquake.

Major Advances

A number of Canadian scientists are working on techniques for making earthquake prediction. The techniques are similar to those which are being employed in other countries with advanced programs in seismology (U. S. A., U. S. S. R., China, Japan). Although there are encouraging advances, both experimentally and theoretically, there has been no major breakthrough reported either here or abroad.

A large amount of research is being carried out to determine the degree of lateral inhomogeneity of the upper and lower mantle. The interpretation is ambigous at the present time because of limitations in data, instrumentation, or a lack of knowledge of crustal structure.

Major advances have been made in computer processing of seismic data. There are many inversion techniques that have been developed to a highly sophisticated level including generalized version techniques of linear systems, hedgehog techniques, and techniques for ray studies including the TAU method. Synthetic seismograms of considerable sophistication have been developed with the research being advanced at the Universities of Alberta, British Columbia, and Toronto and in the Earth Physics Branch of Energy, Mines and Resources. Both wave and geometrical ray theory has been applied to inhomogeneous media and also to anisotropic media.

Major progress has been made in seismological instrumentation. Advanced systems for digital recording, telemetry, remote operation, and on line computer control, are being developed in many laboratories. Seismic oceanographic equipment is also being rapidly developed at the Bedford Institute, Dalhousie University and at the Univerity of British Columbia.

Both theoretical and experimental programs are being carried out to determine the strain from induced stress due to large artificial lakes. The computer simulation techniques are becoming highly sophisticated and should help in interpreting field results. Canada's lead in this field was recognized when it hosted the first International Symposium on Induced Seismicity under the sponsorship of the Universities of Alberta and British Columbia with financial support from UNESCO, NRC, University of Alberta and British Columbia Hydro.

Core and mantle convection is receiving considerable attention with respect to the maintenance of the geodynamo and also in studies of plate tectonics. New techniques for measuring heat flow along continental margins have been developed at Dalhousie. The sophistication of high pressure laboratories is increasing and the physical properties of many rocks and minerals are being determined in several laboratories.

Future Needs and Directions

The level of earthquake prediction studies in China and their success in at least one prediction with the saving of many thousands of lives impressed the Canadian delegates who visited Chinese geophysical institutions. This is in marked contrast to the recent Guatemalan earthquake of the same magnitude as the Haich'eng earthquake in which over 20 000 lives were lost. This experience indicates the value of increased research in techniques for earthquake prediction. While Canada is subject to an order of magnitude less earthquake activity, there are populated areas in eastern and western Canada which may suffer in the future. As a contribution to science in general, advances in earthquake prediction may be a very beneficial contribution. This has much to recommend itself in the long-run over a program based only on offering disaster assistance after the event, valuable as this is. In any case Canada has the instrumentation and the scientific manpower to launch a very broad range of significant programs for determing techniques of earthquake prediction. What is needed is a commitment and the operating funds.

Because scientific laboratories have suffered severe cutbacks, mainly through inflation, in the level of funding over the last five years, much equipment and scientific personnel is not being used to maximum advantage. Experimental programs, particularly those involving the acquisition of basic field measurements, have been curtailed, probably by fifty to seventy per cent. Many academic scientists are now found to limit their research to the more theoretical or computer modelling aspects. This is useful in the short run but will soon lead to sterile arm-chair theorizing in the earth sciences unless actual field measurements are available to distinguish between competing hypotheses. It will also lead to the production of geology and geophysics students who have had no significant field experience. A study of seismology and the physical properties of the earth should aid in increasing Canada's fossil fuel and mineral resources. The Canadian Geoscience Council is urged to forward a case for an increased percentage of financial support from what is presently accorded the sciences.

GEOTECHNIQUE

ENGINEERING GEOLOGY

O. L. White for the Canadian Geotechnical Society

Current Activities

The Engineering Geology Division of the Canadian Geotechnical Society, now with 133 members, was recently admitted as the Canadian National Group of the International Association of Engineering Geology.

Engineering geology projects throughout the country are diverse but in the past year much activity has been evident, in addition to major developmental projects, in:

i) urban geology studies for a) solid waste disposal sites and b) the preparation of planning documents for municipalities,

ii) the development of mapping (Maranda, 1975) and data handling systems (Belanger, 1975) and

iii) slope stability studies a) in urban setting (Fransham *et al.*, 1976), Sauer (1976)), b) in regional studies as well as on c) specific project sites.

Other studies, initially somewhat localised, but recently extended to other areas include the investigation of biogeochemical heaving of shale under buildings (Grattan-Bellew and Eden, 1975) and the investigation of high horizontal residual stresses in rock at shallow depth (White *et al.*, 1974; Palmer and Lo, 1976). In all these studies activity is found at federal and and provincial level, at universities and within the private sector of the economy. In many cases, projects involve the co-operative activity from several sectors of the professional community.

The current interest and activity in urban geology mapping and data handling was reflected in the fact that these topics formed the major theme of a day-long discussion session at the 28th Canadian Geotechnical Conference at Montreal, October, 1975 — the first time in Canada that a whole day of the Geotechnical Conference had been devoted to engineering geology. The engineering geology character of the meeting was maintained the following day when several field trips were organised to permit visits to the various Montreal construction sites. Another conference item of note was the organization in February 1975 of an inter-disciplinary conference on Glacial Till under the auspices of the Royal Society of Canada. Papers presented on the geological, pedological and geo-technical aspects of till, provided an excellent review of the state of knowledge of till from the various viewpoints.

New equipment

New equipment developed in the past year includes a mast equipped, light weight drill adapted to an all terrain vehicle for use in Arctic regions (Veillette and Nixon, 1975). The drill is designed for transport by Twin Otter aircraft with minimum dissembly and set up time and has been successfully operated in the Arctic for the augering and drilling of holes to a depth of three m. The development of a new borehole permeameter with pneumatic packers and pressure take-up inside the injection chamber, involving industry and university personnel, is well under way with the recent completion of successful field tests (D. Marcil: pers. comm.).

Future needs and directions

Although an economic slowdown is evident (in some areas more than in others), there are indications of an upsurge in activity with more demands for engineering geology input into the preparation of inventories of construction material as well as a whole range of urban problems and the preparation of planning documents for municipalities. Such an increase in activity in urban areas might well assist in absorbing some of the "surplus" new graduates in the Spring of 1976. The situation for new graduates is particularly difficult in the Province of Quebec where by far the greatest per-centage of graduates with degrees in engineering geology are graduated each year. Although new graduates in engineering geology are experiencing difficulty securing employment, the graduate with 10-15 years experience is well sought after and numerous positions are available. Likewise several academic positions in engineering geology remain unfilled at the present time.

The relationship of engineering geology to urban and housing problems led the Annual Meeting of the Division in October to instruct the members of the Division executive to make representations to the Federal Government on this matter. This was done in due course over the name of the President of the Canadian Geotechnical Society.

As part of an international study of courses and curricula in engineering geology initiated by the International Association of Engineering Geology a compilation of course offerings in engineering geology (and geological engineering) is presently underway in Canada. Later a questionnaire will be distributed to industry, government agencies and universities to assess the needs and available resources regarding all aspects of the training of engineering geologists.

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MUSKEG

C.O. Brawner for the Canadian Geotechnical Society

Muskeg covers an extensive area in Canada. As a result, the development of transportation and industry, particularly in the north, has created a great need for practical research in the development of specialized vehicles for access, and specialized road, pipeline and building construction techniques. Canada has become one of the leaders internationally in this field.

Airphoto identification techniques, a peat classification system and laboratory and field testing procedures have been developed to assist in identifying and quantifying Muskeg problems in Canada. The National Research Council through the guidance of the Muskeg Subcommittee has been the co-ordinator of these programs. The application of these techniques has led to the development of successful design and construction techniques in Muskeg.

Recently attention has been directed to standardization of laboratory test procedures for peat and a Test Manual is in the process of preparation. Major consideration is being given to the environmental impact of development in Muskeg areas. A text entitled "Muskeg Northern Development in Canada" will be published this summer.

The last Muskeg conference, held in Montreal, emphasized the interrelationship of intergrating development in Muskeg into man's environment. Major contributions included construction in Muskeg on the Alaska pipeline, research by CAREL in the U.S.A., land reclaimation in Muskeg for residential and industrial purposes in British Columbia, testing to determine the shear strength of peat and Muskeg as an ecosystem.

PERMAFROST

W. O. Kupsch for the Canadian Geotechnical Society

The engineering and scientific aspects of permafrost are receiving increasing attention from Canadian researchers in government and in the universities. This upsurge in activity is mainly due to proposals for large scale engineering projects, particularly the laying of pipelines, in permafrost-affected terrain. Hearings are currently in progress on pipeline construction in the Mackenzie District, Northwest Territories. At these hearings advice on the effects of construction on the ground temperature regime is sought. At some future time other hearings dealing with a gas pipeline from the Arctic Islands to eastern Canadian markets can be expected. Again, those knowledgeable about the geotechnical problems attendant with construction in areas of permafrost can be expected to be required to give testimony. It is therefore of importance to Canada to maintain, and if possible to increase the current activity in permafrost studies.

The Permafrost Subcommittee of the Associate Committee on Geotechnical Research is a major force in stimulating permafrost research. It is significant to note, however, that it is no longer the exclusive body dealing with this aspect of geotechnique. At several meetings of engineering societies across the country permafrost-related construction problems have of late been the topic of discussion. Also, geophysicists appear to direct their attention more to the occurrence and distribution of ground ice than in the past. Attempts at the use of esoteric prospecting methods applicable to permafrost, such as the use of infrared photography or even satellite imagery, are currently in progress. No avenue appears to be closed to those willing to tackle the multitude of problems connected with permafrost in Canada's northern terrains.

Attempts are being made to find common ground for all permafrost workers who come into the field from many and diverse disciplines. The Permafrost Terminology (NRC Publication 14274) has now been issued in English and a French version is currently being prepared. In future it is hoped to expand this to include Russian language terms as well. Progress is being made on the Permafrost Engineering Manual. Perhaps the most significant move toward co-operation has been the creation of the Organizing Committee of the Third International Conference on Permafrost. This conference, scheduled to be held in Edmonton, July 10-13, 1978, will make it possible for Canadian permafrost workers to show their activities and results to others while at the same time permitting them to learn about achievements elsewhere.

ROCK MECHANICS

B. Ladanyi for the Canadian Geotechnical Society

In addition to the rock mechanics research activities related to mining, a great majority of which were connected with various projects of the CANMET, including the five-year project on problems of design of open pit mine slopes, research in rock mechanics has been conducted in a number of university departments, government agencies and major civil engineering companies.

While some fundamental research on the mechanical behavior of rocks and rock masses continued at certain university departments (University of Alberta, University of Toronto, Ecole Polytechnique de Montréal, Université du Québec à Chicoutimi, University of New Brunswick), the most important research contributions were made in the field of applied rock mechanics, and in particular in the fields of tunnelling, ground stress measurement and rock foundations.

Continuous rapid urban growth in the two largest Canadian cities, Toronto and Montreal, and their vicinities, has increased the demand for water supply, liquid waste control, transportation and power developments. These developments invariably involve construction of tunnels, underground cavities or deep excavations in bedrock, the costs of which often run into millions of dollars. The research in this field, conducted by the University of Western Ontario in the Toronto area, and by Ecole Polytechnique in the Montreal area, was mainly oriented towards improving the tunnel design methods, and increasing the efficiency of tunnel driving machines.

In connection with some tunnel stability problems in the Toronto-Hamilton-Niagara region that were suspected to be due to the presence of high horizontal stresses acting at shallow depth, a comprehensive program of *in situ* stress measurements was undertaken in the vicinity of Thorold, Ontario. For that purpose a new technique of stress measurement in vertical down-holes through overburden was developed at the University of Western Ontario. The technique uses the ordinary USBM stress meter, but is applicable at much greater depths, to over 120 feet (40 m), with a very accurate over-coring control. The results of this investigation have confirmed some earlier qualitative conclusions concerning the existence of high horizontal stresses in southern Ontario.

The maximum horizontal stresses found at relatively shallow depths of 40 to 80 feet (12 to 24 m) varied from at least 1200 psi (8.3 MPa) up to 2100 psi (14.5 MPa), and their main direction in the horizontal plane was about N 60°E. The existence of high horizontal stresses in the Canadian Shield was known from extensive ground stress measurements carried out earlier by CANMET in several underground mines in northern

Ontario. The presence of such high horizontal stresses in horizontally bedded rock in southern Ontario leads to high compressive stress concentrations at the crown and invert, even for shallow tunnels, that have to be taken into account in the design of temporary supports and permanent linings of all tunnels in this area. In addition, some published observations of horizontal displacements due to these high horizontal stresses made in the Thorold Tunnel and in a deep pit at the Niagara Falls show that the displacements not only increase continuously with time, but that they also manifest regular seasonal variations in rate.

Rock mechanics tunnelling research in the Montreal area was mainly oriented towards improving the methods for the prediction of the efficiency of full-face boring machines. For that purpose a comprehensive program of rock mechanics laboratory and field tests was undertaken at three sites in Montreal where such boring machines were active. In addition, a new borehole lateral punching apparatus was developed at Ecole Polytechnique, enabling the drillability of rock to be assessed ahead of the tunnel.

In the field of rock foundations, due to the increasing number of high rise buildings being constructed in the cities, a continuous need is felt for a better predictability of rock mass deformations under the buildings and better understanding of the rock-structure interaction in direct foundations and in drilled-in caissons. While the research on the prediction of settlements of buildings directly founded on rock continued mainly at the University of Alberta, some valuable efforts towards better understanding of the behavior of large diameter caissons drilled in rock were undertaken both in Toronto and in Montreal, where such caissons were instrumented at several sites for a long-term observation.

In the Ottawa area, the Division of Building Research of the National Research Council of Canada continued its study of heaving of shale due to weathering aided by the presence of sulphur bacteria. The expansion of shales leads to extensive heaving of basement floors and the sulphate solution formed by the oxydation of pyrite in the shale attacks the concrete floors.

The 10th Canadian Rock Mechanics Symposium which was held in September 1975 at Queen's University, Kingston, was oriented mainly towards mining aspects of rock mechanics, including the themes such as: underground safety and design, mining-induced subsidence, pit slope stability and open pit blasting studies. Several of the subjects treated at the Symposium were, however, of a great interest also for potential civil engineering applications.

In addition to this Symposium, the 28th Canadian Geotechnical Conference, held in Montreal in October 1975, devoted one session to the urban geology and mapping and another to tunnelling and rock mechanics. The latter involved two papers on tunnelling and two on rock foundation problems of high rise buildings and of several structures at the Olympic Site in Montreal.

As far as future needs and directions are concerned, there are two main areas of research in rock mechanics that will need continuous attention in the future years, e.g.: (1) research connected with rapid excavation and tunnelling in rock related with underground works in the cities and in connection with some large hydro-electric projects; and (2) research oriented towards a better understanding of rock-structure interaction under static and seismic conditions. Both of these fields of research require an appropriate funding, preferably by the federal or provincial governments, to cover the cost of often expensive instrumentation and of manpower for many years of continuous observation of performance.

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ROCK MECHANICS

D. F. Coates and D. G. F. Hedley for the Canadian Institute of Mining and Metallurgy

The major organizations involved in rock mechanics research in Canada include: the Mining Research Laboratories, CANMET, the mining, mineral, civil and geological engineering department of universities, mining and civil engineering companies, electric power utilities, and consultants.

A major five-year project on the stability and design of open pit slopes is in the final year. This project is being undertaken by CANMET with many research studies being done under contract to universities, mining companies and consultants. A comprehensive engineering manual is being written defining the most up-to-date technology for planning and designing open pit mines in Canada, including chapters on groundwater, blasting, structural geology, materials testing, monitoring, support systems, environmental planning and design procedures. This manual will be the theme of the Eleventh Canadian Rock Mechanics Symposium to be held in Vancouver, October 1976.

Another CANMET project, carried out in co-operation with mining companies over a period of years, involves measuring stresses in the rock to define the variation of field stresses with depth. Measurements have been taken in a number of mines in Northern Ontario to a maximum depth of 7000 feet. At many measurement sites the horizontal stresses are found to be greater than the vertical stress.

Current rock mechanics research activities of companies, universities, and consultants include: remote monitoring of pit slope deformation and failure; investigations on the ground control and design aspects of post-pillar, cut-and-fill and sub-level stoping mining methods; testing of cable bolt reinforcement systems; measurements of surface subsidence over underground mining operations; laboratory investigations on the strength and failure mechanisms of rock; and stability studies in civil engineering tunnels.

The tenth Canadian Rock Mechanics Symposium was held at Queen's University, Kingston, September 1975. Twenty-three papers were presented and published in two volumes. The theme of the symposium was the environmental aspects of rock mechanics and the papers covered subsidence, underground safety and design, and slope stability.

A comprehensive list of Canadian contributions in the field of rock mechanics is published each year in the Bulletin of the Canadian Institute of Mining and Metallurgy (latest list in June 1976 issue). In 1975 there were 54 papers published in journals and symposia and five university theses.

Canada has a very large mining industry compared with most other countries and it is unrealistic to expect to import the required technology to mine our mineral resources. Rather, most of the research and development should be done within Canada and be applicable to Canadian conditions. A similar argument could probably also be made regarding the large civil engineering projects taking place or planned.

SNOW AND ICE

B. Michel for the Canadian Geotechnical Society

Sea ice research

Extensive work has been done during the past year in applied sea ice research by firms active in exploration for oil and gas in the Arctic and on the East Coast. Of particular geotechnical interest is the work done by Imperial Oil Ltd. and Arctec Canada Ltd. to determine the forces exerted by a moving ice field on an offshore structure. Tests are done on models using natural or synthetic ice, reproducing either a continuous ice sheet or a pressure ridge. They are also doing some basic work on the strength of sea ice under various modes of loading. Panarctic Oils Ltd. and Fenco have developed interesting new ice technology where sea ice is thickened by surface flooding and freezing to be used as a drilling platform. This has been used successfully in the sea close to Melville Island. The Arctic Petroleum Operator's Association (APOA) tested a model of an ice cutter last winter, using a rotating cylinder containing teeth to continuously grind the ice. They are also studying scour made on the sea bed either by ice islands or icebergs. Many operators in this group, the Department of Environment of Canada (DOE), and the Defence Research Establishment are studying ice conditions and movement in the Beaufort Sea, Baffin Bay, the Sverdrup Basin and the East Coast.

The properties of sea ice, its thermal regime and the wind and water stresses on the cover are studied by McGill University, the Bedford Institute and the Glaciology Division of DOE. An iceberg study program is active at Memorial University in Newfoundland.

A new area of research which has developed recently is the effect of oil spills on ice covered water. The Canada Centre for Inland Waters, the Glaciology Division and the Frozen Sea Research Group of DOE, as well as some operators of APOA, have projects dealing with this problem. A large number of recent Canadian research projects on ice are discussed in the proceedings of the "Third International Symposium on Ice Problems" USA CARREL, Hanover, 1975.

Lake and river ice

The formation and breakup of lake and river ice are being studied at the Canada Centre for Inland Waters (DOE), Laval University, the University of New Brunswick, the Alberta Research Council and are the object of continuing studies by most of the hydro-electric firms in Canada as they affect their power production. Special techniques have been developed to model the river ice phenomena mainly at break up, and are used by Acres Ltd., Lasalle Hydraulic Laboratory and Arctec Canada Ltd. The proceedings of the most recent seminar on the "Thermal regime of river ice" were printed as "Technical Memorandum No. 114", 1975 NRC 14407.

The Ministry of Transport has commissioned many studies this year relating to the design of new icebreakers and to study ice impact loads. A unique feature of one design which was field tested is the embodiment of an air cushion vehicle in front of the hull. This work is being done by Arctic Systems Ltd. with Arctec Canada Ltd.; this latter firm doing most of the model testing for the new Canadian icebreakers.

Studies on the mechanical properties of ice have been again emphasized. Two approachs are taken which complement each other. Laboratory cold room work is being done at National Research Council of Canada (NRC), the Glaciology Division of DOE, Imperial Oil Ltd., Laval University and the University

of Alberta. *In situ* field work is carried on by the Alberta Research Council and many consultants and private firms.

One problem of high geotechnical interest is the bearing capacity of an ice cover. Many groups are interested in this question of increasing importance, as the north country is being developed. Leading research is being done by the Geotechnical Section of NRC. Of special interest this year was the publication by the Ministry of Transport of a revised edition number AK-68-14-001 of a document on "Recommended minimum ice thickness for limited operations of aircraft".

Snow and avalanches

There has been an increase of activity in the field of snow research during the past year. A graduate program on "Snow, Ice and Wind" was set up at the University of Guelph. They have a special flume to study snow drift. The Working Group on Snow Engineering of the ACGR has grouped most of the snow researchers in the country on a task of preparing a general text on snow. The construction of snow roads is being studied at the University of Manitoba.

Activities have been accelerated in the study of avalanches on the western side of the country. The Glaciology Division of DOE has joined with NRC in avalanche research. Some basic work on snow creep is being done at the University of British Columbia.

SOIL MECHANICS

J.D. Brown for the Canadian Geotechnical Society

Soil mechanics is a term which is undergoing a metamorphosis of meaning. In the past, "soil mechanics" was the conventional jargon to cover all the activities in the civil engineering field having to do with the use of soils as construction materials and foundations. "Soil mechanics" was the English synonym for the "geotechnique" of many European languages. With the increasing popularity of the term "geotechnical engineering", there has been a clarification of the term "soil mechanics" and it is now more properly confined to the solid and fluid mechanics of particulate materials.

In a parallel manner, fewer researchers and practising engineers can be described as working in the area of soil mechanics as would have been the case only a few years ago. Also, recent trends have shown research workers moving out of soil mechanics into allied areas such as rock mechanics, permafrost and engineering geology, where principles developed in soil mechanics are being applied.

Within the field of soil mechanics and its traditionally closely-linked partner, foundation engineering, activity has continued along well established lines. Published contributions have been made in about equal proportions by universities, government agencies and industry, mainly in the areas of soil properties and piled foundations.

The annual NRC-sponsored research seminar in 1975 dealt with failure criteria and other aspects of soil behaviour, and revealed that there is considerable scope for improvement of existing physical and analytical models. Other recognized areas requiring concentration of effort, and in which some gains may be made, include sampling and testing of properties of Canadian soils at both ends of the spectrum — very stiff and very soft or loose. In addition, problems in earth pressures, consolidation of clays, tie-back walls, tunnels, and piled foundations continue to confront engineers and the solutions being adopted are often not the most cost-effective.

SOIL SCIENCE

R. Hedlin for the Canadian Society of Soil Science

Canada has a land area of over 900 million hectares. This might lead one to believe that our potential for the production of forest and agricultural products is almost unlimited. Nothing could be further from the truth. It is true that over a third of our land area is in forests but on much of this land the climate does not favor rapid growth. It is in the agricultural sector, however, that our land resource base is small compared to what might be expected from our total land area. In 1971 we had 63.2 million hectares of land in farms of which only 43.2 million hectares was improved (cultivated). Thus cultivated land is less than 5 per cent of our total land area. It has been estimated that nearly 30 million hectares of land could eventually be improved for agriculture bringing the total to 72 million hectares. Most of this land is in more northerly fringe areas of settlement and will be difficult to develop and because of climatic and other limitations less productive than most of the land already cultivated. There will also be a greater limitation as to the number of crops which can be successfully grown. In addition some of this land is in Forest Reserves and hence is not presently available for agricultural development.

There are a number of concerns regarding the use of this agricultural land. One of these is the loss of good agricultural land to urban uses. Since cities are frequently located in good agricultural areas it is the best land that is lost. This problem can best be illustrated by reference to the densely populated area of southern Ontario and Quebec. Between 1951 and 1971

an estimated 2.8 million hectares was lost to urbanization between Windsor and Quebec City. Half of this was improved land. Loss of land is not restricted to that resulting from the urban sprawl. Construction of divided highways which, together with access roads, are up to one-tenth of a mile in width is becoming all too common. Such roads require about 65 acres of land per mile and much of this is good agricultural land.

The situation outlined above points to the need for careful planning in the use of our land resources so that we are not left with insufficient land for food production. It also emphasizes the importance of research designed to increase crop yields while maintaining soil quality. A brief discussion of some of the kinds of research in progress indicates the importance and complexity of the task with which soil scientists are faced.

Increasing crop production involves the use of adequate levels of nutrients in the form of commercial fertilizers. These must be applied in a way which minimizes fixation of elements such as phosphorus by soil minerals. Nitrogen applied as a fertilizer may be lost by denitrification or by leaching. Not only are soil scientists concerned with the effect of fertilizers upon crop yield but also with their effect on crop quality. Encouraging results have been obtained in increasing the protein content of cereal grains by nitrogen fertilization.

As agriculture becomes intensified there is a danger that it will contribute to the deterioration of the environment. Examples of problems with which soil scientists are concerned include the loss of nutrients such as nitrogen to the groundwater. This problem is most acute around farmsteads and feedlots. The use of sewage sludge as fertilizer may pose a problem where these material contain toxic heavy elements. Another area concerns the fate of various chemicals such as herbicides and insecticides. Many of these are biodegradable and hence are unlikely to create a problem but others are persistent and tend to accumulate.

The energy crisis has brought a new challenge to agriculature, namely, that of maximizing production while reducing the energy inputs, particularly from fossil fuels. This has sparked an interest in zero tillage, that is, use of chemicals for weed control so that crops can be planted without tillage.

The challenge facing soil scientists in crop production will require increased research relating to soil productivity. Unfortunately the Government of Canada is reducing its expenditures for research in agriculture. It is unfortunate, but perhaps not too surprising, that studies relating to soil productivity will probably suffer more than projects which are less useful in increasing crop production but which have a greater popular appeal.

HYDROLOGY

SOIL SCIENCE IN HYDROLOGY

G. C. Topp and R. W. Gillham for the Canadian Society of Soil Science

Historically, soil scientists, and soil physicists in particular, have concerned themselves with transport processes primarily in the unsaturated zone. Elrick and Groenevelt (1975) have itemized the recent advances and achievements in such areas as: theory of unsaturated flow, infiltration, coupled transport, miscible displacement and instrumentation. Hydrogeologists on the other hand have concentrated on saturated zone processes. This division of interest has, in the past, been a natural consequence of the problems to be addressed by the respective disciplines which in turn reflects the interests of their primary funding agencies. Nevertheless, the division of interest is quite artificial since the physics of flow and transport are continuous across the interface between the saturated and unsaturated zones.

Recent trends show quite clearly the need to discard this division of responsibility and for both disciplines to co-operate in treating subsurface transport as a continuous and unified system. This is exemplified by a survey conducted by Lennox and Parsons (1975) in which four major subsurface hydrology research areas were identified as having been neglected in Canada. These included 1) interface processes, 2) modelling as a stochastic process, 3) the soil-water-ice complex and 4) mass transport processes. A complete understanding of each of these areas will require the application of both saturated and unsaturated zone principles. Logically, these problems should be approached through a co-operative effort by soil scientists and hydrogeologists. The fact that they remain as problems may reflect the current structure of research funding.

Over the past ten years, considerable effort and money have been devoted to the development of physically-based mathematical models for the prediction of water, solute and heat transport in both the saturated and unsaturated zones. The result of this effort is a wide variety of models which, for the most part, are untested. A recurring theme at the 1975 Canadian Hydrology Symposium, sponsored by the National Research Council of Canada, was the need for field measurement and testing of mathematical models. Until the applicability (or lack of applicability) of the existing models is demonstrated, the investment of the past ten years will bear minimal returns. Field testing will involve a major research effort requiring a substantial increase in funding. The testing of many of the potentially useful models should be approached through a co-operative effort by soil scientists and hydrogeologists and their funding agencies.

In summary, the past division of interest between the soil physicist and the hydrogeologist has been primarily on factors other than the physical processes. The solution to many problems of current concern to both the soil scientist and the hydrologist will require a closer co-operative effort on the part of both disciplines. This co-operation should be encouraged through increased interdisciplinary funding.

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HYDROGEOLOGY

R.A. Freeze, J. Toth, W. Meneley, and J.C. Roegiers for the Geological Association of Canada

In August, 1975, a National Hydrology Symposium was convened in Winnipeg, with the stated objectives of reviewing Canadian scientific achievements during the International Hydrologic Decade (1965-1974), and assessing Canada's current and future research requirements in hydrology. In the lead paper of the groundwater session, Lennox and Parsons (1975), identified the most significant areas of Canadian research endeavor during the I.H.D. as regional groundwater flow, groundwater recharge-discharge phenomena, moisture transfer in frozen soils, hydrogeologic modeling of aquifer systems, hydrochemical phenomena, saltwater intrusion, and the application of geophysical techniques in hydrogeology. Research areas that they feel deserve more emphasis in the coming decade include the analysis of chemical, physical and biological transfer and retardation processes; the application of geostatistical concepts in hydrogeology; and the investigation of unsaturated mechanisms of water movement, especially those involving soil-water-ice systems.

Research activities in hydrogeology in the federal government are centred in the Hydrology Research Division of Environment Canada. Their research program (Environment Canada, 1975) outlines four main spheres of activity. These involve research into saltwater intrusion and flow through fractured media; subsurface contamination research; research into the hydrogeology of groundwater-permafrost systems; and the development of a computerized storage-retrieval system for groundwater data.

The nature of research activities in provincial government agencies and in universities can be gleaned from Bolton (1975). The three largest provincial efforts are those of the Alberta Research Council, the Saskatchewan Research Council and the Ontario Ministry of the Environment. However, significant groundwater activities, particularly of an applied nature, are also conducted by the British Columbia Department of Lands and Forests and the Nova Scotia Department of Environment. The primary areas of emphasis in these agencies are the preparation of hydrogeological maps, the development of observation-well networks, continuing commitments to watershed studies begun during the International Hydrologic Decade, and intensive local investigations of groundwater conditions for water supply, geotechnical and environmental purposes. Fundamental research contributions often grow out of the programs designed for these more practical objectives. In Saskatchewan, studies are in progress to develop computer-based hydrogeologic models of aquifer systems. The objective is to develop creditable prediction models that will estimate the consequences of a proposed allocation of groundwater prior to actual development of the resource. In Saskatchewan, several years of records from the provincial observation-well network have not revealed significant local or regional aquifer depletion. It is now accepted there that groundwater should be managed as a renewable resource. This decision, based on a long-term program of field instrumentation and research, represents a complete policy reversal from a decade ago.

The largest university research program in hydrogeology in Canada is that of the Department of Earth Sciences at the University of Waterloo. Recent emphasis there has been on the application of natural isotopes in hydrogeochemical studies, and on the development of finite-element simulation techniques for aquifer evaluation. Graduate programs in hydrogeology are well developed in the geology departments at Alberta and U.B.C. At U.B.C. research emphasis is on the geostatistical aspects of hydrogeological modeling. There are also components of groundwater research and training in various other departments across Canada; for example, in geography at McGill and Carleton, and in argicultural engineering at Guelph and Saskatchewan. Several civil engineering schools, notably the University of Toronto and Alberta, offer courses concerned with geotechnical and environmental aspects of groundwater. At Toronto, research with a groundwater thrust is being carried out on geothermal energy extraction and on flow through fractured media in relation to underground storage of petroleum products.

A quick statistical analysis of the projects listed under 'Hydrogeology' in Bolton (1975) reveals that about half of Canada's research effort still goes into hydrogeological mapping and improving techniques of groundwater resource development. The other half reflects the increased attention being paid to hydrogeochemical and pollution aspects, and to geotechnical aspects of groundwater research. There is little question that current trends in hydrogeology are leading from purely geological and hydrological concerns to those with geotechnical and environmental overtones.

This trend is also reflected in the publishing habits of Canadian researchers. In previous years hydrogeology articles often appeared in the Canadian Journal

of Earth Sciences, but in 1975 there were none. The Canadian Geotechnical Journal, on the other hand, showed an increase in groundwater articles from 2 to 7 between 1974 and 1975. At the international level, an analysis of Water Resources Research, which is probably the leading journal for the publication of theoretical results in groundwater hydrology, showed that Canada is maintaining its hard-won international eminence in groundwater hydrology. Roughly half the groundwater articles in 1975 were written by American authors but the rest were split almost evenly between Britain, Israel and Canada.

Internationally, in recent years, federal and provincial agencies as well as universities and private consulting firms have been providing counselling services or executing exploration and development programs in Asia, Africa and Latin American, mostly under the aegis of the Canadian International Development Agency. Also, several CIDA sponsored foreign students have been receiving classroom and practical field training with various Canadian universities and provincial agencies.

On the consulting front, Lennox and Parsons (1975) reported an almost four-fold expansion over the 10-year I.H.D. period, both in terms of the number of firms providing consulting service and in terms of the number of hydrogeologists employed. In the public sector they reported a steady linear growth trend in manpower. However this growth has been accompanied by an accelerated growth in costs, and the diversion of a larger percentage of financial resources into salaries. There is concern both in the public sector and in the academic community that these trends, coupled with antipathetic governmental policies toward research support, will lead to a less-than-healthy research environment at a time when hydrological research, with all its environmental and geotechnical implications, is badly needed. In particular, it is felt by many that too much funding emphasis is being placed on short-run management objectives at the expense of long-term research requirements.

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INORGANIC GEOCHEMISTRY

R.W. Boyle for the Association of Exploration Geochemists

A knowledge of the chemical reactions in the earth yields information on migration, concentrations, or dispersion of the elements in various spheres of the earth which are of vital importance in the practical use of geochemistry in agriculture, forestry, fisheries, pollution control, and geochemical prospecting. Fundamental data on abundance and chemistry of the elements in the earth are the foundation on which all practical work in geochemistry is based.

In Canada research in inorganic geochemistry is pursued, with varying degrees of intensity, at most universities, at the Geological Survey of Canada, CANMET, Canada Centre for Inland Waters and other agencies of Environment Canada, the Soil Research Institute of Agriculture Canada, the Bedford Institute of Oceanography, and most provincial government geological surveys and research councils. This diversity of research in inorganic geochemistry makes it impractical to estimate the number of persons engaged in providing fundamental geochemical data or to determine the money spent on the acquisition of data. While research in inorganic geochemistry at Canadian universities and government institutions has increased yearly since 1950 to a relatively high level, the level of activity is still relatively low on a per capita basis compared with the U.S.S.R. and the U.S.A.

The state of research is discussed below.

(1) Geochemical research on igneous rocks and processes and on metamorphic rocks and processes seems adequate and is expanding slowly each year.

(2) Geochemical research on sedimentary rocks and processes is low and not expanding rapidly enough given their importance in petroleum and ore geology.

(3) Geochemical research on surficial materials (soils, till, glacial clay, stream and lake sediments) seems adequate for agriculture and forestry needs. It is inadequate for pollution research, and is certainly inadequate for geology, especially for geochemical prospecting. Few geochemists have been addressing themselves to surficial materials research in Canada. Research in surficial chemical processes at universities and government institutions is woefully inadequate — a state that urgently requires correction, since the surface geology of Canada is largely concerned with Pleistocene deposits and the soils developed on them.

(4) Geochemical research on natural waters (oceans, lakes, rivers, streams, and groundwaters) falls into two categories: that concerned with major constituents, and that concerned with trace constituents. Production of data on major constituents by government

institutions and agencies has been extensive and will probably continue to expand. Production of data on trace constituents of natural waters leaves much to be desired — these data are particularly valuable in pollution control, fisheries research, and geochemical prospecting. There is also a dearth of research concerned with the solution, migration, and precipitation of elements is natural waters. There is little attempt to train students intensively in the complex chemistry of natural waters; research on hot and cold springs has been low.

(5) Production of fundamental data on the atmosphere seems adequate for pollution control research.

(6) Research on the geochemistry of ore formation continues at a relatively high level and shows signs of increasing. More emphasis on the trace element constitution of orebodies of all types and on their primary halos is warranted, especially on the so-called "volcanogenic" deposits; there are theories but few facts to support the theories.

(7) More research should be directed to elucidating the source of elements comprising mineral deposits; trace element analyses and stable isotopic analyses should be used more. Research on the chemical and mechanical processes that disperse elements from deposits during weathering and glaciation — a subject of great importance in geochemical prospecting — requires much greater emphasis.

With a population of some 22 million, it is probably beyond Canada's means to support adequately all aspects of inorganic geochemical research, yet it should be borne in mind that a large part of the nation's wealth depends on the products of the earth which can only be won by an increasing knowledge of the chemistry of the rocks, soils, waters, and air. It is possible to import certain chemical knowledge with respect to industrial processes; this is not the case with chemistry in the earth sciences. The Canadian natural environment is unique, and the chemistry of this environment can only be elucidated by sustained research *in situ*.

MARINE GEOSCIENCE

M. J. Keen, P. G. Sly and R. L. Chase for the Geological Association of Canada

Current level of activity

The number of groups working in some way in the marine geosciences is rather large, as is shown in Table III. This table obscures however the level of involvement — very high in the case of the Atlantic Geoscience Centre (for example), and very low in the case of others.

Pacific Region

Coastal zone studies have continued on the sedimentological and geochemical dynamics of the Fraser Delta and the Prince Rupert-Skeena Estuary, and limited studies have been undertaken on the distribution of gravels and suspended sediments off the southwest shore of Vancouver Island. A systematic survey of geophysical and geological characteristics of the shelf and continental margin has also concentrated in the southwest Vancouver Island/Juan de Fuca Strait area. In Vancouver, McElhanney Offshore have continued with their development of unmanned submersibles (*see* later comments) and the August Picard (Horton Marine) is nearing completion of refit as an advanced manned submersible system for geological and geophysical exploration and research.

Arctic

Work has continued in the Mackenzie Delta and Beaufort Sea where shallow seismic studies have been used to define the origin and distribution of subsurface permafrost and to compare with shallow core and drill data, in an attempt to correlate with soil mechanics. Interpretations of ice-scour, based upon scuba and submersible observations and sonar records, show that scour depths average 1.0-1.5 m with maxima to 6 m in water depths of 50 m or less. Ice-scour is strongly affected by bathymetry and shoreline configuration and shows seasonal variation. Sediment thickness and structural components in the Arctic Ocean north of Ellesmere Island have been computed based upon aeromagnetic data obtained by the Geological Survey of Canada and National Aeronautical Establishment in 1975, as part of ongoing studies.

Great Lakes

Regional geochemical and sedimentological surveys of each lake have been completed. Major contributions, additionally, are reported in the 1976 J. Fish Res. Board Canada Special Issue (v. 33, no. 3) on Lake Erie in the early 70's. In this issue, core and surface sediment data have been used to establish the effects of "cultural loadings" and to quantify loading rates in verification of estimates based upon demographic evidence. Further, the mineral component of phosphorus release has been developed which couples sediment response to wave energy (characterized by orbital velocities). In May 1975 a major report by the International Working Group on the abatement and control of pollution from dredging activities in the Great Lakes was submitted to the governments of Canada and the United States. During 1975, T.R.O.V. (Tethered Remotely Operated Vehicle) was used for the first time in support of sediment/water interface studies in the Great Lakes. T.R.O.V. was designed and built by McElhanney Offshore (Vancouver) and is the first Canadian unmanned submersible fully self-contained, operational to depths of 400 m and equipped with T.V., camera, and manipulator arm.

TABLE III

Some Organizations and Some Activities

Groups	Selected Activities
Arctic	
E. M. R.: G. S. C. (all offices) Earth Physics C. C. R. S. N. A. E. Environment Canada Geocon ?Universities	MacKenzie Delta, Beaufort Sea: permafrost, ice scour Arctic north of Ellesmere: sediment and structure
Pacific	
E. M. R.: G. S. C. (Vancouver) Earth Physics Environment Canada HYCO, Lockheed, McElhanney, Horton Marine U. B. C.	Pacific crustal structure Interaction of N. American and Pacific plates Fraser Delta dynamics Shelf and margin studies Submersibles
Atlantic	
E. M. R.: G. S. C. - Atlantic Geoscience Centre; Environment Canada N. S. Research Foundation Geomarine Associates Universities: Dalhousie, Memorial, Queen's, McMaster	Geology of shelf and slope Labrador Sea, Baffin Bay Deep tow systems
Great Lakes and St. Lawrence	
Environment Canada Universities: Waterloo, Queen's, Laval, I. N. R. S., Quebec (Chicoutimi) Golder Associates Huntec Ltd.	Geochemistry and sedimentology of the Lakes Cultural loading of lakes Pollution and dredging Unmanned submersibles Marine incursions
World's Oceans	
GSC: Atlantic Geoscience Centre Dalhousie University	Aid to Senegal Deep Sea Drilling Project Site surveys for D. S. D. P.
Industrial development: activites	
Drill systems for use in submarine foundation engineering Hydrostatically supported sand structures Deep tow seismic systems Unmanned submersibles	

St. Lawrence

Studies have led to a more detailed examination of the fresh/salt water interface and the differential effects of marine incursion and fresh discharge are being studied in terms of both bottom sediments and suspended load.

Atlantic

Contributions to marine geology have been particularly well documented by the landmark publication of Volumes 1 and 2 of Geological Survey of Canada Paper 74-30 on the Offshore Geology of Eastern Canada (1974 and 1975). In addition the special publications on the geology of the Scotian Shelf, which appear in Marine Science Paper Series of Department of the Environment further extend the availability of detailed regional mapping. These publications document studies in the coastal zone of the Lower St. Lawrence, the Labrador Shelf, Canso Strait, Chedabucto Bay, Bay of Fundy and Scotian Shelf (work in the coastal zone, around Prince Edward Island has also continued). In addition the structural and lithostratigraphic components of the Appalachian and Atlantic province regions, and the bedrock structure and overlying sedimentary units of the continental margin from Baffin Bay to Georges Bank are discussed. Excellent coastal studies have been made by Greenwood and others (University of Toronto), Owens and others (Atlantic Geoscience Centre), and McCann, Middleton and others (McMaster University).

More recently a study of the Paleozoic geology of the northeast Gulf of St. Lawrence has been aided by the Huntec ('70) Ltd. deep tow seismic system in conjunction with the Bedford Institute electric rock-core drill, and a study of the shelf northeast of Newfoundland has been completed using bathymetric, gravity, magnetic, and seismic data, and selected shallow drill cores. Additional studies on the Newfoundland coastal zone and of the Quaternary depositional history of the Grand Banks are also currently in progress.

World's Oceans

Work on rocks collected on Leg 37 of the Deep Sea Drilling Project continued, and was reported at the Edmonton meeting of the Geological Association of Canada. Participation on an ad hoc basis in the International Programme is planned. Scientists have worked on the Mid-Atlantic Ridge on cruises from the United States and the United Kingdom. Geophysical programmes on the Explorer Ridge have been initiated by the Earth Physics Branch. The Atlantic Geoscience Centre supported a marine aid program to Senegal.

Industrial Research and Development

Canadian industrial participation has been closely linked with the exploration and development of oil and gas resources. Advances have included: the development and application of specialized drill systems (and techniques for sub-sampling disturbed and undisturbed materials) for use in submarine foundation engineering in both Arctic and Atlantic regions; the development of a concept for hydrostatically supported sand structures as a means of cheap construction for steep sided offshore structures (North Sea); the further development and application of two separate deep-towed seismic systems (Huntec (70') Ltd., and Nova Scotia Research Foundation); and the design and deployment of two unmanned submersibles, T.R.O.V. I (self-powered) and T.R.O.V. II (surface-powered).

Major commercial activities have focused in the Mackenzie/Beaufort Sea area (much in support of DOME drilling planned for '76), and off the Labrador Shelf, Grand Banks and Scotian Shelf, in the east. Canadian industry also, has been active in support of oil and gas development in the North Sea.

Major Advances

We can only risk offending, and select a few.

(1) The understanding of the dynamics of the Fraser Delta (unfortunately, the scientist responsible is returning to the U.S.A.).

(2) The advance in understanding the Kodiak-Bowie hot spot system.

(3) The completion of the geochemical and sedimentological surveys of the Great Lakes.

(4) The volumes of Atlantic Geoscience Centre on "Offshore Geology" and by C.S.P.G./G.A.C. on "Canada's Continental Margins".

(5) The excitment of results from the study of Leg 37 of D.S.D.P.; the discovery in the funding of this programme that only modest carrots are needed to get many laboratories across the country working together.

Major Weaknesses: a selection

(1) We have a huge coastline: but few studies are being undertaken of our numerous coastal inlets and fjords on any of our coasts, except those close to major research centres.

(2) We have no formal involvement in the International Programme of Deep Sea Drilling; 0.5 per cent of the Orion aircraft budget would have ensured full participation in the whole program. We participate at all only by courtesy of the United States.

(3) Ten years ago we had well equipped ships for marine work. We now have barely adequate ships. Only one ship is planned to our knowledge. Without a crash program now we will have totally inadequate facilities in a few years time.

(4) The west coast university involvement in the marine geosciences is at a level which can be described as only barely viable.

Some Questions

(1) The universities produce five marine biologists for every marine geoscientist. Is this proper?

(2) The Department of Energy, Mines and Resources has no public plans for integrating its west coast programs with the opening of the Patricia Bay Institute. Does it have such plans, and what expansion will there be?

(3) Does the Government of Canada have plans to do anything more than formally takeover our offshore regions?.

(4) Should we not establish a Canadian equivalent of Wood's Hole Oceanographic Institution? The government laboratories have to be too concerned with brush fires (well, their marine equivalents), and the universities have too much undergraduate teaching for either groups to do the excellent long-range research which needs to be done.

MINERAL AND ENERGY GEOSCIENCE

COAL GEOLOGY

A. Kahil for the Canadian Society of Petroleum Geologists

Although interest in all phases of coal-related technology has greatly increased in the last few years, the achievements have been dampened by government regulations and/or uncertainties produced by lack of coal policies. The formation of a Coal Division of the Canadian Society of Petroleum Geologists attests to the greater involvement of a variety of companies in coal but particularly of oil companies. Several conferences and symposia have been held internationally which included a variety of papers related to the coal industry.

The sudden world-wide interest in coal has caught the Canadian industry, almost unaware and ill-equipped to produce the coal needed, principally because of its archaic methods of exploration. It is now going through a crash program of modernization. Major changes have taken place in the following areas:

1. Recognition that geologists can make a contribution.
2. Use of downhole logging tools.
3. Use of seismic techniques.
4. Use of structural interpretation techniques.
5. Paleoenvironmental recognition and utilization as an exploration tool.
6. Improvement of core recovery.
7. Use of computers in exploration, mine planning, and production.
8. Improvements in coal petrography.

Great advances have been made in each of the above areas in the last few years, but these have resulted from simple adaptations of techniques used in other fields. Although this will continue, the more difficult process of developing new techniques for coal exploitation and the perfecting of borrowed approaches for use in coal technology is still far down the road. Geologists have made a definite contribution in exploration, mine planning and mining. Nevertheless, the full capability of the geologist has not yet been realized, principally because of inadequate training in coal-oriented geology or insufficient experience in Canadian conditions.

The development of downhole logging tools is possibly the area where most work has been done and the greatest achievements have been realized. There is, however, a great lag between the development of the tools and the extraction of information from them. The interpretation of logs is presently in its infancy when compared to that of the oil industry. Techniques need to be developed for accurately measuring the ash, sulphur and sodium content of the coal as well as for its type, rank, porosity and permeability.

Attempts have been made in England and Germany to adapt conventional seismic techniques so that they could be used to detect faults with 5 foot throw or less from near surface to a depth of 2000 feet. Currently, the limits of detection are faults with about 25 foot throw. A technique has also been developed in which energy is introduced into a seam at one point, usually in a borehole, and is recorded at another point. This is used to determine continuity of the seam and for correlation. To date, the maximum distance over which the signal can be received is about two miles.

The determination of structure is vital to efficient mine planning, and the participation of geologists in all phases of the coal industry has introduced modern techniques in structural interpretation. However, these have been of a general nature, and techniques directly related to coal mining have yet to be developed. For example, the industry needs to be able to predict or relate cleating to larger structure, and to determine the mechanism and conditions for the flow of coal in structurally contorted strata.

The generation of models for the environment of deposition of coal-bearing sediments is an approach to the exploration for coal that has had very little use in Canada in the past, but is gaining momentum. Until recently, almost all of the exploration involved tracing a known seam through drill holes until it became too thin to be of interest. Through paleoenvironmental reconstruction it should be possible, when models are sufficiently sophisticated, to forecast areas favorable

to peat accumulation. Much work needs to be done to improve models by studying peat-forming processes in modern environments, especially those in deltas, and also by studying well-documented coal basins.

Drilling has been the main exploration technique in the past and has, therefore, not required much modification. However, coring techniques have to be improved to achieve the 100 per cent recovery required in coal exploration. In the past few years great strides have been made and it is anticipated that 100 per cent recovery will be achieved consistently in the near future. The application of an inhole sampling tool, developed to sample uranium sands of the western United States, has been partially successful. This tool cuts a vertical channel on the side of the borehole. With some improvement in its reliability it should prove an excellent exploration tool.

Computers, which are well suited to solving engineering problems, have made fast inroads into the coal industry. They have been used for calculating reserves given various constraints, doing economic analyses of properties, handling data for the design of preparation plants, and as data banks.

Studies in coal petrography have led to a better understanding of various aspects of coal, specifically that of the contribution of each component of the coal to coke making. This had led to a more effective use of coal. Coal petrography has also been shown to be a useful tool in exploration.

Several facets involved with coal exploration require attention. The following are considered the most important:

1. Seismic or other geophysical techniques that would indicate structure and discontinuities in coal seams.

2. Improved downhole tools and better interpretation techniques in order to determine accurately such factors as ash, sulphur, sodium porosity, and coal types.

3. A greater insight into the make-up of coal, probably through coal petrography, for a more efficient utilization of the coal.

4. A better understanding of the environments that generate coal deposits for more efficient exploration.

5. Much greater effort in training coal geologists.

Except for the area of coal petrography, in which the Geologic Survey of Canada has concentrated a reasonable amount of effort, there has been a pitifully small amount of work done on any of the above aspects of the coal industry in Canada. Expecially delinquent have been the universities which, to a great extent, appear to be oblivious to the renewed interest in coal. The amount of research undertaken by private companies is difficult to assess because these programs are generally kept confidential.

The following is a selected list of significant publications on the coal industry or science:

Bielenstein, Hans U.
1975: Thrust Faults a Problem in Western Canadian Coal Mining; Paper presented at CIM Annual Western Meeting, Edmonton.

Diamond, W.P., McCulloch, C.M., and Bench, B.M.
1975: Estimation of Coal-Cleat Orientation Using Surface Joint and Photolinear Analysis; U.S. Bureau of Mines, Pittsburg, Penn., p. 687-690.

Hacquebard, P.A.
1975: Correlation Between Coal Rank, Paleotemperature and Petroleum Occurrences in Alberta; *in* Report of Activities, Part B, Geol. Surv. Can., Paper 75-1B, p. 5-9.

Shibooka, M. and Smith, M.
1975: Coal Petrology and the Formation of Coal Seams in Some Australian Sedimentary Basins; Economic Geology, v. 70, p. 1463-1473.

Stach, E.
1975: Textbook of Coal Petrology; Berlin-Stuttgart, Gebrueder Borntraeger, p. 428.

Strauss, P. *et al.*
1976: Coal Petrography as an Exploration Aid in the West Circum-Pacific; *in* International Coal Expl., Symposium, London, (in press).

GEOCHEMICAL EXPLORATION

E.M. Cameron and C.F. Gleeson for the Association of Exploration Geochemists

Despite the vastly greater effort within the U.S.S.R., Canada is widely regarded as leading the world in the field of geochemical exploration. This success can best be ascribed to the development of geochemical exploration within four different sectors, each, to a greater or lesser extent, stimulating the other. Each sector is considered here separately.

Mining Industry

One of the superior attributes of Canadian economic geologists is their willingness to try new ideas. Few "research" geochemists complain that their work is ignored; practical approaches are rapidly filtered from the more abundant chaff. However, a deterrent to even more efficient use of these methods has been the paucity

of formal training in applied geochemistry. The current trend towards increasing numbers of applied geochemists on university staffs should be encouraged, as should the welcome introduction of multidisciplinary postgraduate courses in mineral exploration.

Consultant Companies

These vary from one-man operations to large, integrated earth science organizations operating on an international level. Few mining companies employ specialist geochemists; the necessary expertise comes from consultants who play a vital role in disseminating knowledge. The larger consultant firms, many of which are prominent in exploration geophysics, have been developing sophisticated new technologies for the *in situ* measurement of geochemical parameters, for example, instrumentation for use in low-flying aircraft, and portable instruments that may be operated at the edge of a lake or stream. While the high costs of this technological development strain relatively small industrial enterprises, and there is an ever-present danger of a premature introduction of such new methods on a routine basis, there is excellent potential for the growth of this export-orientated industry if adequate support is given.

Government

Until recently the principal activity of government was research on geochemical exploration methods along fairly conventional lines, with federal activities greatly dominating; exchange of information with the mining industry is generally excellent. The recently introduced federal-provincial Uranium Reconnaissance Program gives government a new role. By carrying out reconnaissance-level surveys for uranium and other commodities, geochemistry in government is filling the role adopted by geology in the nineteenth century and by geophysics two decades ago. Since these surveys are being carried out largely by contract, the program should assist in the development of the consulting sector. The involvement of government geochemists in reconnaissance and follow-up surveys will stimulate their research on applied geochemistry. The program will also encourage the transfer of expertise from the federal to the provincial level.

Universities

The rather high proportion of foreign-trained applied geochemists in Canada testifies to past weaknesses in this sector. While this has improved recently, with a moderate number of Canadian graduates in this speciality, there is presently a requirement for greatly increased effort on the more basic aspects of geochemical research to support the applied research efforts of industry and government. Much of this effort is wasted because of the lack of essential basic information of geochemical processes, particularly those occurring in the near-surface environment. Some schools, under the guise of research programs, are putting too much emphasis on carrying out routine geochemical surveys, a role which should be left to industry and government. Fortunately at the same time much fine work is being carried out within the universities which should form the base for expansion. Funding for basic research on geochemical processes should be increased to a more realistic level relative to total expenditures on geochemical exploration.

A survey of Canadian geochemical laboratories was carried out to provide data for this report. Approximately 1.1 million geochemical samples were taken by industry and governments throughout Canada in 1975. This probably represents a total expenditure of some $22 to 28 million and indicates about a 30 per cent increase over the average for the previous five years. A breakdown on types of samples taken shows that about 60 per cent were soils, 15 per cent were rocks, 13 per cent were stream sediments, 7 per cent were lake sediments, 4 per cent were waters, and one per cent were vegetation. The most common elements analyzed in soils were Cu, Pb, Zn, Ag, Mo, Mn, and Fe; in rocks they were Cu, Pb, Zn, U, and Ag; in lake sediments they were Cu, Pb, Zn, Ni, U, Co, Ag, Fe, Mn, As, Mo, and Hg; in stream sediments they were Cu, Pb, Zn, Mo, Mn, Fe, As, Ag, and U; in waters they were Cu, Pb, Zn, U, and Ni; and in vegetation they were Cu, Pb, Zn, and As. Atomic absorption spectroscopy is by far the most frequently used analytical technique and dominant digestions are those using hot solutions of HNO_3-HCl or HNO_3-$HClO_4$. There is a critical need for standard samples for use in this field.

GEOCHEMICAL EXPLORATION: PETROLEUM

S. W. Burnie for the Canadian Society of Petroleum Geologists and
B. Hitcheon for the Association of Exploration Geochemists

During the 1975 to 1976 review year, a variety of subjects in petroleum geochemistry received research attention as reported in the literature. Of particular interest are six papers on the characteristics of oil and gas in Canada's frontier areas. Two articles, 1) "Regional Organic Metamorphism in the Mesozoic Strata of the Sverdrup Basin" (Snowdon and Roy, 1975), and 2) "Hydrocarbon Source Potential of Sediments in the Sverdrup Basin" (Baker *et al.*, 1975), discuss maturation and petroleum source rock potential in the Sverdrup Basin. The following four papers review organic geochemical data from the Mackenzie Delta: 3) "Properties of Beaufort Basin Liquid Hydrocarbons" (Burns *et al.*, 1975), 4) "Geochemistry of Oils and Condensates from the Mackenzie Delta Basin, N.W.T." (Powell and Snowdon, 1975), 5) "Organic Matter,

Compaction History and Hydrocarbon Occurrence Mackenzie Delta, Canada" (Evans *et al.*, 1976), and 6) "Structural Features and Hydrocarbon Deposits in the Mackenzie Delta" (Bruce and Parker, 1976). Papers three and four relate general oil properties to biodegradation or the lack thereof. The fifth paper is an overall view on organic matter and hydrocarbons in the Delta and possible migration processes. Barefoot and Van Elsberg (1975) discuss the relationship between a phase of clay diagenesis and the occurrence of oil. The authors suggest that this phase of diagenesis can be recognized in the subsurface on sonic logs and can therefore be mapped using seismic velocity data.

The petrography of dispersed organic matter and its use to petroleum exploration, is covered in two publication, "Petrographie de la Matière Organique des Sediments, Rélations avec la Paleotemperature et le Potential Pétrolier" (Alpern, 1975), and "Etude Microscopique de la Matière Organique — ses Applications à l'Exploration Petrolière (Correia and Peniquel, 1975).

Several articles were published on the use of stable isotopes in organic geochemistry and their application in petroleum exploration. In the paper by Burns *et al.* (1975), δC^{13} values were used in the characterization of their group I and group II oils. A paper by Stahl and Carey (1975) discusses the use of δC^{13} analyses of methane gas from source rocks to define a maturity index and outline migration paths. Hitchon *et al.* (1975) illustrate the use of stable isotopes to classify oil and gas in Western Canada.

Papers on petroleum migration were published by Price (1975), Evans *et al.* (1976), Tissot *et al.* (1976), and Webb (1976). Price's paper reviews migration mechanisms and advocates aqueous solubility of hydrocarbons. The author's experimental work emphasizes the importance of temperature to the hydrocarbon-carrying capacity of formation fluids. Tissot *et al.* (1976), and Webb (1976) give evidence for late migration.

The origin of petroleum is discussed in the following three papers: "On the Origin of Petroleum" (Lijmbach, 1976); "The Deep Subsurface Temperature Controlled Origin of the Gaseous and Gasoline-range Hydrocarbons of Petroleum" (Phillipi, 1975); and "Etude Physiochemique des Residus de Pyrolyse de la Sporopollénine (Libert, *et al.*, 1976). In the third article, a model for the origin of petroleum is suggested using the natural polymer which forms the resistant walls of spores and pollen, sporopollenin.

Correlation of petroleum to source rocks and the geological control of crude oil composition are dealt with in papers by Welte *et al.* (1976), Powell and McKirdy (1975), and Sikander (1975).

Biodegradation of crude oil is discussed to some degree in many papers. Articles by Burns *et al.* (1975), Powell and Snowdon (1975), and Gilbert *et al.* (1975) discuss the effect of bacteria on crude oil composition. Of interest is a Ph.D. thesis by Jobson (1976), in which the author concludes that sulphate-reducing bacteria are incapable of utilizing petroleum as a nutrient.

The relation between ore deposits and the organic milieu is an area of research receiving increasing attention. A paper by Hitchon (1975) gives a synthesis of the relation between ore deposits, sediments, and hydrocarbon occurrences. The effect of organic acids on formation-water properties such as pH and alkalinity is discussed in a paper by Wiley *et al.* (1976).

There is an increasing need for continued research on the broad topic of fluid-rock interaction. The relation between hydrocarbon migration, diagenetic plugging of porosity, hydrocarbon accumulation, and the formation of ore deposits in sedimentary rocks could be highlighted. A study of the whole field of oil and ore in sedimentary rocks could prove to be a beneficial link between the petroleum and mining industry.

The origin of hydrogen sulphide in the petroleum system is still quite controversial. Opinions are divided as to whether the occurrence of hydrogen sulphide with hydrocarbons is 1) biologic in origin, related to source rock characterisitics, 2) generated by thermal effects within the reservoir from secondary anhydrite or organic sulphur compounds, or 3) formed by some combination of these processes. It is now necessary to model the reservoir sulphur system in the laboratory. The elucidation of the hydrogen sulphide-generating mechanism would help greatly in the *a priori* defintion of sulphur-prone reservoirs.

Another topic requiring research is that of the typing of biodegraded oils and correlation to source rocks.

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GEOCHEMICAL EXPLORATION: COMPUTER APPLICATIONS

R. G. Garrett for the Association of Exploration Geochemists

The equipment used in many analytical laboratories is becoming more sophisticated and expensive, and labour costs are increasing; in contrast, computer hardware is decreasing in price. Therefore many laboratories (e.g., the Geological Survey of Canada, Barringer Research Ltd.) are using or investigating the use of minicomputers for process control and data reduction tasks. Automation of laboratory procedures is also leading to ever larger volumes of data; orderly storage and access to this data is a matter of prime concern. Simple and sophisticated data file and data base management systems for editing and selective retrieval are being developed (e.g., a simple file management system developed at Queen's University with Department of Energy, Mines and Resources funding; and packages to carry out standard calculations and displays). At the same time, the pocket calculator, pencil, and graph-paper have brough mathematical and statistical techniques within reach of individuals at every level; at the University of British Columbia a comprehensive guide to the construction and use of cumulative frequency distributions is being prepared.

Data handling in large government regional surveys (undertaken under contract) is highly computer-dependent, especially analytical quality control and data presentation; National Geochemical Reconnaissance maps published by the Geological Survey are produced using a photohead to plot symbols directly onto film at the rate of one a second. The greatest expansion in the future will be in the areas of automated data aquisition and the application of more sophisticated data management techniques since many organizations insist that data are retrievable and have a longer potential life than the project yielding the data. The innovative use of techniques now available to prepare hard-copy maps will expand; however, interactive data display methods will probably be restricted to major data-gathering and using organizations.

GEOPHYSICAL EXPLORATION: MINING

L. E. Reed for the Canadian Exploration Geophysical Society

The trend toward lower geophysical activity has been modified somewhat with the resurgence in interest in uranium exploration, while the use of geophysics in exploration for other minerals has not grown signifcantly.

Among a selection of 257 professionals representing a large majority of the mining oriented geophysicists in Canada, the following employment distribution was found:

Instrument Manufacturers — Contractors	: 28%
Mining Companies	23%
Academic	18%
Consultants	16%
Government	15%

(1976 — Spring KEGS Membership;
1976 SEG Yearbook;
1975-76 GSC Report of Activity)

The foreign and domestic sales of the Canadian geophysical industry in 1975 were $25.9 million, a growth of 18 per cent over 1974. Much of this increase was attributed to foreign sales of airborne surveys (up 62 per cent to $10.5 million). Domestic airborne surveys decreased slightly to $6.0 million. Domestic ground surveys were $1.4 million and instrument sales and rentals were $2.7 million (both increases over 1974). Foreign ground survey were $0.7 million and instrument sales and rentals were $4.6 million (Hood, P., 1976 — April, Canadian Geophysical Industry Continues Growth Trend, Canadian Mining Journal).

Instrument research and development over the past several years has produced a proliferation of new and improved instruments for mining exploration geophysics in the last year. Seven airborne electromagnetic systems join or replace several existing systems. Three ground EM systems employing large transmitter loops became available. Two of these have borehole measuring capability. Both ground and airborne systems reflect the move to a broader spectrum of information (in both time and frequency domain methods).

One new resistivity instrument, one new induced polarization instrument and advances in three I.P. instruments were announced in the last year. Further advances were noted in the technique of neutron activation in boreholes. Five new or improved magnetometers for base station or mobile use were announced. A new Alpha-meter for radon detection became available.

Two new airborne gamma-ray spectrometers and seven new or improved ground instruments were produced. Two of the ground instruments have an airborne capability. One may be used with a borehole probe.

Greater use of digital recording with associated computer processing has been noted with the development of these new instruments (airborne particularly). A number of companies have developed programs for the processing of the data, including gridding, processing and analyses (Hood, P., 1976 — February, Mineral Exploration Trends and Developments in 1975, Canadian Mining Journal).

The expansion of the data base for mineral exploration by Canadian Government agencies is exemplified by publication of 191 aeromagnetic maps, several airborne electromagnetic maps, regional gamma-ray surveys in a number of provinces and the Northwest Territories and the detailed gravity surveys on volcanic belts in Ontario.

The slow growth in exploration suggests a limited increase in manpower requirements in the short term. Conversely the increasing difficulty in finding ore deposits, indicates a long term need for growth in professional manpower applied to both exploration and research.

Continued research and development of new instruments and methods by industry, universities and governments is necessary, although the sudden outpouring of new instrumentation this year indicates there will be a period of evaluation and improvement of instruments now available.

More studies involving the intergration of geophysical measurements with geological observations are needed. Some evidence of research in this area was noted in 1975.

Mining exploration geophysicists look forward to Exploration '77, an international symposium on geophysics and geochemistry applied to the search for metallic ores to be held in Ottawa, October 16th to 20th, 1977.

GEOPHYSICAL EXPLORATION: PETROLEUM

G. A. Pinsky for the Canadian Society of Exploration Geophysicists

The gradual decline in the level of geophysical crew activity in Canada continued in 1975. Estimates suggest actual activity in 1975 to be down 23 per cent from 1974 and 33 per cent from 1973. This decline is indicated in all parts of Canada with the exception of Alberta where seismic activity in 1975 remained at 1974 levels. There are many divergent opinions as to what part the Alberta Geophysical Incentives Program has played in maintaining this level of activity.

The exodus of seismic crews Canada experienced in 1973, 1974 and the early part of 1975 appears to have abated. By the end of 1975, crew availability was stable at 58, and 2 crews had been returned from foreign assignments. This is probably a reflection of the downturn in exploration activity in the United States. The present supply of crews is down 25 per cent from the same period in 1973 (1974 data are unreliable) and 52 per cent from the number available during the late 1960's. It is also interesting to note that present level of crew availability is considerably above present requirements.

Although for the past several years group participation surveys have been common in the high cost frontier areas, this has not been so in Western Canada. During the past year or so, however, a number of these surveys have been conducted in Western Canada with indications of many more to come. This is one area that has undoubtedly been stimulated by the Alberta Geophysical Incentives Program.

Significant advances have taken place in the general area of seismic interpretation during the last year or so. For the most part these advances have been possible because of the increased capability of the data gathering system and the data processing system.

In some marine 'hard bottom' areas or on ice, water bottom reverberations have often been so severe that recorded data has been virtually unuseable. However, recently, several data processors have developed improved dereverberation procedures that have substantially attenuated the reverberations allowing the interpreter to see the true geologic reflections.

As a result of the need for more detailed structural control, data gathering and processing improvements aimed at increased structural definition are being developed. In structurally complex areas, such as in the thrust belt of Western Canada and in the Frontier areas, which have substantial undiscovered potential for natural gas, proper migration of seismic data can be invaluable in making the correct interpretation. This has led to improvements in migration techniques based on solutions of the equation describing the wave propagation on the earth's surface. Three-dimensional shooting and processing, combined with improved quality three-dimensional migration of seismic data, is now available. This overall system provides increased data density and flexibility.

The relationship between seismic response changes and the occurrence of hydrocarbon-bearing reservoirs is receiving renewed attention. Primarily this is a result of the improved overall data quality of the digitally-processed multifold data and the preservation of relative amplitudes. A large percentage of the remaining undiscovered potential of oil and natural gas in Canada lies in stratigraphic traps which will defy delineation by conventional interpretive techniques. However, the prediction of lithology from multifold data, and the recognition that seismic response changes in certain unique circumstances can be direct hydrocarbon indicators, has provieded an area of fruitful advance in interpretive technology.

GEOTECHNICAL RESEARCH (INDUSTRIAL MINERALS)

No report submitted

METALLIC MINERAL RESEARCH

L. S. Collett for the Canadian Exploration Geophysical Society

Geophysical exploration for metallic sulphides employs in general two methods, namely, induced polarization (IP) and induction electromagnetic (EM) sounding techniques. The instrumentation in both these methods have advanced in the past three years in improvements in signal-to-noise, in the use of multifrequencies, and the measurement of the complex impedances and fields generated. Lately microprocessor technology is being introduced into the systems whereby real time processing will be able to be done in the field. With this increase in sophistication of measurement, it may be possible to understand and interpret the anomalies generated in terms of "geologic noise" and the separation of sulphides from other types of conductors due to graphites and serpentinites. To improve our understanding of these anomalies and to be able to sort them out, laboratory investigations on the electrical characteristics of soils, rocks and conductors will afford some guidelines.

In Canada, the Geological Survey of Canada has just completed the construction of a minicomputer controlled laboratory to measure the complex electrical impedances of soil, rock and mineral samples. The techniques on handling samples and the methods of displaying the complex electrical characteristics from < 1 Hz to > 10 MHz have been worked out. It is the aim of this laboratory to test the possibility of differentiating copper-rich sulphides from iron-rich sulphides. Standardization of laboratory procedures on a set of synthetic samples containing pyrite of varying grain size and amount has been carried out between the GSC laboratory and three laboratories in the United States (Kennecott Exploration Services, University of Utah and Zonge Engineering and Research).

In the field of induction research on geological samples, Ecole Polytechnique has constructed laboratory equipment for measurement of electromagnetic properties. Results are described by R. Bazinet (M.Sc. Thesis) which show that electrical conductivity of massive sulphides is a complex function of sample mineralogy, in particular that magnetic relaxation loss in some minerals can make a significant contribution to the EM response. This phenomena appears as a reduction of the apparent conductivity of the sample with increase in frequency of the measurement. Laboratory results confirm a number of field observations made by other investigators.

Non-linearity behaviour of rocks has been investigated at Ecole Polytechnique (M. St-Amant, Ph. D. Thesis). When polarizable rock mineral including sulphides is energized by a pure sinusoidal current source, St. Amant has demonstrated theoretically and experimentally that harmonics are generated. This phenomenon is independent of the excitation amplitude. The spectra show a maximum in the vicinity of 0. 1 Hz. The physical-chemical mechanism of induced polarization is thought to be controlled by diffusion. Experience seems to show that the composition of interstitial water in rocks influence these non-linear parameters more than the chemical composition of their polarizable minerals.

Prof. G. J. S. Govett, University of New Brunswick, has been doing research studies to determine the influence of electrogeochemical processes and the resultant electrical field (self potential) upon the movement and fixation of elements in the vicinity of sulphide deposits. This work has been carried out in the laboratory with sulphides in tank experiments. A field case study in co-operation with Barringer Research Limited has been done over the White Lake deposit about 7. 5 miles southeast of Flin Flon, Manitoba. The tank experiments have shown that Pb ions tend to be concentrated at the bottom of the sulphides in the tank and Zn at the top. Also the Cu ions tend to be absorbed by the sulphide, thereby decreasing the Cu content in the vicinity of the sulphide cell. One interesting fact that has been brought out in the laboratory is the electrode potentials that are exhibited by each type of sulphide. Pyrite exhibits the highest electrode potential and these potentials decrease in order from pyrite-chalcopyrite-galena-sphalerite. This phenomena may be the key to the understanding of why some sulphides oxidize more than others which could depend on the micro-galvanic effect between sulphide grains of differing electrode potentials. In field work, the research has shown the importance of measuring the pH (H^+ ion concentration) and the conductance of soil samples which can give a good indication of how deeply the conductor is buried. This information is complementary to trace element distribution. Hopefully, this research will create a closer co-operation and understanding between exploration geochemical and geophysical technology.

METALLIC MINERAL RESEARCH AND EXPLORATION

G. W. Mannard for the Canadian Institute of Mining and Metallurgy

This review summarizes the current situation in those aspects of geology which are applied to the study of, and search for, metallic mineral deposits. The current level of activity is somewhat higher in his field than it was when a predecessor to this report was compiled (Neale *et al.*, Geol. Surv. Can., Paper 75-6, 1975). This increased activity is in the industrial sector, and can be attributed to the improving economic situation. Work in the universities and government agencies has not kept pace due to constraints imposed upon research funding.

Most of the trends noted by Neale *et al.* (1975) have continued, but there have been some shifts in emphasis.

A major area of study is that which includes the concordant massive sulphide deposits within volcanic rocks. Spatial and genetic relationships of these deposits to the enclosing rocks are of great importance in mineral exploration. During the review period, investigations continued on the stratigraphy of Archean and younger greenstone belts, the distribution of massive sulphide deposits within these belts, the morphology of the deposits, and the chemistry and mineralogy of associated alteration zones.

Attention has been directed towards the establishment of geological criteria for the recognition of volcanic vents which may have been foci of mineralization. A recent trend has seen increased emphasis placed on the description and analysis of the volcanogenic massive sulphide environment as it exists in highly metamorphosed terranes. Geologists involved in such studies find themselves increasingly collaborating with their geophysical and geochemical colleagues.

The Canadian Precambrian Shield and Appalachian regions, traditionally the hunting grounds for massive sulphide deposits, now face competition from the Cordillera of British Columbia, where significant massive sulphide deposits have been found in Mesozoic, late Paleozoic, and, possibly, Proterozoic rocks. Within the Shield, the areas of most intense activity are the Slave Province, N.W.T. and the eastern half of the Abitibi greenstone belt, Quebec. In the Appalachian Region, the Bathurst-Newcastle district has seen increased exploration, resulting in the discovery of significant prospects. Geological reassessment of this important producing district is in progress.

Exploration for gold, and the study of gold deposits have lost impetus during the 1974-76 period, for economic reasons. The reverse is true of uranium. Deposits of several geological types have contributed to uranium production in Canada in the past, and all of these are under investigation at present. The most important types are: (1) the deposits within Proterozoic quartz pebble conglomerates, and (2) those which are spatially associated with the Athabasca sandstone, as exemplified by the Rabbit Lake deposit, Saskatchewan. Geologic theory on deposits of the first type is relatively stable at present, but with respect to the second, a conceptual revolution has been in progress for the past few years, which should contribute to an improved understanding of the genesis of these deposits and enhance our ability to explore effectively for them. Expressed briefly, the current thinking is that deposits of the Rabbit Lake type have been formed relatively near surface, by downward percolation of meteoric waters. The spatial relationship of these deposits to the nearby Athabasca sandstone is obviously significant, but is incompletely understood. The unsolved problems of the genesis of these economically important deposits present a challenging field of endeavor to Canadian earth scientists.

The porphyry copper deposits which form the basis of British Columbia's copper mining industry have been, and continue to be the subject of a considerable research effort.

An important product of this effort is the general recognition that many Canadian porphyry copper deposits do not fit the widely used conceptual model developed for the Arizona deposits (Lowell-Guilbert model). This recognition has stimulated further study of the tectonic and petrologic environment, mineralogy, and alteration patterns of the Canadian porphyry coppers. Some of the results of this work are embodied in a special volume to be published by the Canadian Institute of Mining and Metallurgy during 1976.

At the time of writing of the predecessor to this report (Neale *et al.*, 1975) exploration for, and the study of, lead-zinc deposits of the Mississippi Valley type had become important subject to Canadian economic geologists. This situation has continued, although the emphasis has shifted somewhat towards base metal deposits within marine basinal shales rather than those within carbonate strata. It is anticipated that this trend will continue and intensify.

Long-term, basic research into the geology of metallic mineral deposits in Canada is carried out mainly in the universities, although all levels of governmental and quasi-governmental organizations are becoming increasingly involved. The private sector, with the exception of a few major mining companies, confines itself mainly to short-term research projects such as the geological mapping of mineral deposits or districts. Both industry and government geologists participate in the vital task of converting new concepts into practicable exploration techniques.

Scientific meetings, symposia, and field trips organized by the Canadian Institute of Mining and Metallurgy, the Geological Association of Canada, the Prospectors and Developers Association and local geological discussion groups provide arenas for the exchange of new geological data and ideas. At these meetings, geologists working in widely separated research centres have the opportunity to participate in formal discussions with each other. Information can be exchanged on the spot, thus eliminating the lengthly delay (commonly six months to two years) between the development of new data and its formal publication.

The importance of the scientific meeting as a clearing-house for geological ideas cannot be overemphasized.

PETROLEUM GEOLOGY

N. C. Wardlaw for the Canadian Society of Petroleum Geologists

Significant advances in petroleum geology are being made in the areas of fluid flow, shale compaction, the solubility of hydrocarbons in aqueous solutions and modes of hydrocarbon migration. These studies are being integrated with currently well-advanced geochemical principles and structural and stratigraphic geology to provide a better understanding of oil occurrence. Advances continue to be made in organic petrography and the relations of time and temperature to petroleum potential (Alpern, 1975).

Important CSPG publications in petroleum geology include Canada's Continental Margins, Memoir 4 (Edited by Yorath, C.J., Parker, E.R. and Glass, D.J.) and Devonian Reef Complexes of Canada, volumes 1 and 2 (Edited by Davies, G.R.); for an overview of exploration and drilling in Canada the reader is referred to Ower (1975) and Bryant *et al.* (1975).

The 9th World Petroleum Congress, Tokyo, has provided a set of 8 volumes with numbers 2, 3 and 4 dealing with geology, exploration and production. Volume 2 contains sections on global tectonics and petroleum prospecting, analysis of large sedimentary basins, time and temperature effects on petroleum origin, petroleum in delatic deposits and prospects in the deep oceans. Volume 3 contains two papers on innovations in petroleum exploration in the high Arctic. Other important conferences include the Gordon research conference on fuels science, New Hampton (June 75); probability methods in oil exploration, an AAPG research conference at Stanford University (August 75); offshore Europe, hydrocarbon basins, tectonics and reserves, Aberdeen, Scotland (September 75); well log analysts symposium, New Orleans (June 75); and , for reservoir production studies, the American Chemical Society symposium on advances in petroleum recovery, New York (April 76) and the Society of Petroleum Engineers annual meeting, Dallas (September 75). Important Canadian conferences were the CSPG-CSEG joint convention on advances in exploration technology, Calgary (May 75); exploration update 75, sponsored by the GSPG, Calgary (May 75); sequence concepts, seismic facies and the relationships of petroleum occurrences to major unconformities and stratigraphic sequences, national conference on earth science, Banff (April 76). The importance of Canadian petroleum geologists on the world petroleum scene is manifest by their substantial contributions to the cited international conferences and the drawing power that Canadian sponsored conferences have to attract attendees of international reputation.

The Canadian Government has published "An Energy Strategy for Canada" (Energy, Mines and Resources, 1976) which provides information on Canada's energy situation based on technically advanced methods of analysis. Methods of estimating the volume of undiscovered oil and gas resources is also the subject of a recent volume published by the American Association of Petroleum Geologists (Haun, 1975). Although rigorous statistical approaches are used, resource estimates are inherently speculative.

At present rates of consumption, Canada's known recoverable oil reserves ($\sim 9 \times 10^9$ bbls), exclusive of oil sands, represent a 15 year supply. Recent Federal Government estimates show a 50 per cent probability of the existence of a further 21×10^9 bbls of recoverable oil, a figure which has been reduced by 60 per cent from 1973 estimates. The potential for adding conventional oil from previously sub-economic plays should not be overlooked but will be dependent on control of inflationary trends and further rises in Canadian energy prices.

The Athabasca oil sands contain 38×10^9 bbls recoverable by mining methods but production is likely to remain a small fraction of consumption in the next decades because mining methods are capital-and labor-intensive. If geological and engineering research on the enhanced recovery of heavy oil is successful, *in situ* production from the Cold Lake and similar accumulations may become significant ahead of *in situ* production from the Athabasca oil sands. Conversion to other energy forms is inevitable in the foreseeable future and will cause far reaching disruptions to society. Our present and future prosperity depends directly on the supply of mineral and energy resources and the vital role of the geosciences should be recognized in research and development funding. For several years, grants in science and engineering have failed to keep up with inflation. Within the earth sciences, Bolton's current survey of research (Geol. Surv. Can., Paper 75-5) reveals that of 1190 projects only 8 are listed as dealing with petroleum geology in Canada.

New priorities of Federal spending on energy research and development are designed to involve the private sector and encourage contract work outside of government but provide an increase in funds of less than 10 per cent. There is an immediate need to build up research capabilities in the earth sciences and, especially in the area of petroleum geology, to encourage innovative research.

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MINERALOGY AND CRYSTALLOGRAPHY

CRYSTALLOGRAPHY

R.B. Ferguson, G. Donnay, F.C. Hawthorne, E.P. Meagher, and L.T. Trembath for the Mineralogical Association of Canada

Crystallography is an integral part of mineralogy, and during the period covered by this Report, vigorous programs of crystallographic research have been carried out in a number of laboratories on both the structural and the crystal-chemical characteristics of rock-forming, ore, and other minerals in order to increase our understanding of the origins and phase relationships of these minerals. Much of this work has been published in the MAC's journal, The Canadian Mineralogist, and the remainder in leading mineralogical and crystallographic journals outside Canada.

Among the ore minerals, some of the structural complexities of the chalcopyrite series including related haycockite, and of recently described costibite and paracostibite, have been unravelled (CANMET). Among the sulphosalt minerals, the structure of fülöppite has been solved (University of Toronto), and the geometrical complexities resolved for benjaminite (University of Toronto) and cylindrite (McGill University). The cation site occupancies in a titanomagnetite have been derived structurally (University of Calgary).

The greatest amount of crystallographic research in mineralogy has been on the rock-forming silicates. Detailed cation distributions in some olivines and garnets at elevated temperatures have been derived structurally (University of British Columbia), and the growth habits of olivines and pyroxenes have been interpreted in terms of their crystal structures (University of Western Ontario). The detailed structures, cation site occupancies and crystal chemistry have been described for three Canadian vesuvianites (University of Toronto, NRC), schorl (tourmaline) (McGill University), omphacite (amphibole) (Universities of Toronto and Manitoba), serpentines (Royal Ontario Museum, Oxford University), scapolite (McMaster University), and pellyite (University of British Columbia). The twin laws of low quartz in relation to electrical/optical properties have been clarified (Université de Montréal, McGill University), and molecular orbital interpretations of some silica polymorph and zeolite structures carried out (University of British Columbia, Virginia Polytechnic Institute).

The crystal structures and crystal chemistry of a number of non-ore and non-silicate minerals have also been described: the halides paratacamite (University of Western Ontario) and cryolite (University of Manitoba), the sulphates anhydrite, celestite, thenardite and kröhnkite (University of Manitoba), and among the phosphates, an unusual apatite and the apatite-like mineral whitlockite (McMaster University), and weloganite from Montreal Island (Carleton University, Ecole Polytechnique).

In the area of X-ray powder diffraction techniques, two Canadian mineralogists play important roles in the publication of the invaluable Powder Diffraction File, L.G. Berry (Queen's University) as Editor, and he and P. Bayliss (University of Calgary) as members of the Minerals Subcommittee. A standarized procedure for presenting X-ray powder data was presented by the latter, and descriptions have been published of a file of powder diffractograms of the commoner minerals (Manitoba University), and of a centring device for the Gandolfi camera (University of Toronto).

Several mineralogists attended an ad hoc meeting of Canadian crystallographers at McMaster University in the spring of 1976. Papers that were relevant to mineral structures dealt with large-cation co-ordinations and bond strengths in inorganic and mineral structures, the latter an area in which Canadian mineralogists are active (Universities of McGill, McMaster, Manitoba). At the crystallographic meeting, plans were laid to seek financing for modernizing all of the dozen or so Picker diffractometers in Canada, a move that would assure a continuing high standard of mineralogical and other crystal structural research in this country.

Crystallography through X-ray and to a lesser extent electron and neutron diffraction is still, despite recent instrumental advances, essential to the unequivocal identification and characterization of the minerals that make up ores and rocks, but with the detailed crystal structures of the most important ore and rock-forming minerals now established, future crystallographic studies should be correlated with electron microprobe and scanning and transmission electron microscope investigations of important natural and synthetic minerals. By such means, crystallography and the related procedures should increase our understanding of the nature of minerals, and therby clarify still outstanding problems in petrology and economic geology.

MINERALOGY

J.I. Jambor and J.M. Mandarino for the Mineralogical Association of Canada

Minerals are the fundamental units of rocks and, therefore, the study of minerals inevitably overlaps many other geoscience disciplines. In Canada, most of the basic research in pure mineralogy is being carried out in universities and museums. Federal and provincial government participation in pure mineralogy continues to maintain a low profile. For example only about a dozen research scientists are employed as mineralogists by the federal government throughout Canada. The number of professionals providing back-up mineralogical work is larger and most of these are involved in providing data such as X-ray identifications and microprobe analyses to their geologist colleagues.

The bulk of mineralogical work in the federal government is applied rather than basic research; the largest single mineralogical group in the government is at the Canada Centre for Mineral and Energy Technology (CANMET) within the Department of Energy, Mines and Resources. The main thrust of this group is directed toward improving metal recoveries from New Brunswick massive sulphide ores, toward evaluation of the Peace River sedimentary iron deposits, and toward mineralogical studies of platinum-group and related elements in ultramafic rocks. Recognition of the contribution that mineralogists can make to broader geoscience studies is manifested in the appointment of mineralogists to the groups involved in two new programs introduced in 1975 by the Geological Survey of Canada: the Uranium Reconnaissance Program (URP), and the Non-Renewable Resource Evaluation Program (NREP). URP is a systematic reconnaissance of uranium in Canada which is to serve as a guide and incentive in exploration for new deposits and to provide a basis for uranium resource appraisal. NREP is a four-year Canada-Manitoba shared-cost inventory and appraisal of mineral resources, largely base metals, in the Precambrian Shield of Manitoba.

Outside the government programs, most pure mineralogical research carried out in universities and museums is funded poorly, by such agencies as the National Research Council. Research projects dealing with the pegmatites of Manitoba (University of Manitoba), the Yukon phosphate minerals (Royal Ontario Museum), the minerals of St. Hilaire, Quebec (Carleton University, Ecole Polytechnique, and Royal Ontario Museum) are among several on-going pure mineralogical studies.

A small but highly competent group of Canadian mineralogists from government, universities, and museums continues to describe a significant number of new mineral species.

Mineralogical activity in Canada is largely reflected in publications which appear in the quarterly journal, The Canadian Mineralogist. The total number of exclusively mineralogical papers originating in Canada and published in Canadian and foreign journals during the past report year (May 1, 1975 to April 30, 1976) is estimated to be about 90, of which about one third deal with crystal-structure, Mössbauer, and optical-absorption studies. Authorship is almost exclusively of university, government (both federal and provincial), and museum origin, with input from industrial sources being negligible. Special issues of The Canadian Mineralogist included "Environmental Aspects of Mineralogy and Sedimentary Geochemistry" and "Water and Magma Genesis", both derived from symposia held at the M.A.C. Annual Meeting in Waterloo in May, 1975. In preparation are special issues dealing with "Physics and Chemistry of Silicate Melts and Magmas" and "Garnets"; both topics were included as special sessions at the Annual Meeting in Edmonton, May 1976.

The diversity of topics as outlined above points to the increased trend away from pure mineralogy towards a multi-discipline approach with mineralogy as an intergral part. This perhaps reflects a broader usage and knowledge of mineralogy in modern-day geology, which in turn may partly reflect the present widespread use of X-ray and microprobe techniques.

A particular highlight for Canadian mineralogy was the holding of an M.A.C.-sponsored Short Course in Microbeam Techniques. The course, held at Edmonton preceding the Annual Meeting in May, 1976, attracted more than 40 participants. An interesting aspect is that the lecturers were from government, university, and industry, and participants attracted to the course were from diverse fields in the geosciences and from several countries.

A second highlight was the presentation of the Hawley Award of the Mineralogical Associaiton of Canada to Professor Ralph Kretz for "Kinetics of the Crystallization of Garnet at Two Localities near Yellowknife", judged by an international panel to be the best paper published in The Canadian Mineralogist during the years 1973 and 1974.

PALEONTOLOGY

INVERTEBRATE PALEONTOLOGY

B. S. Norford for the Canadian Society of Petroleum Geologists

The Canadian oil industry applies foraminiferal studies to the construction and application of biostratigraphical and paleoecological models in order to solve stratigraphic and structural geological problems in subsurface Canada; primarily in the Mackenzie Delta, Sverdrup Basin and Atlantic and Pacific continental shelves. Studies of macrofossils and virtually all detailed taxonomic work on invertebrates are restricted to universities and government agencies and a very few geological consultants. Publication of precise taxonomy of Canadian fossils is vital to their use in schemes of biostratigraphic and paleoecological zonation and the latter's application to refinement of knowledge of the geological fabric of Canada and of the country's mineral resources.

Biostratigraphic studies dominate in all three sectors: industry, university and government. Significant refinements are being achieved of Devonian coral zonation (A.E.H. Pedder) and several major oil companies have combined to describe their schemes of zonation of the Cenozoic rocks of the Mackenzie Delta using both foraminiferal faunas and palynofloras (F.L. Staplin). Published paleoecological contributions virtually were restricted to studies of the role of stromatoporoids in Devonian reefs (D. Kobluk; C.W. Stearn); but some papers describing applications of Foraminifera to facies discrimination and depth zonation are in press. Taxonomic studies have included detailed descriptions of corals, graptolites, brachiopods, trilobites, pelecypods and ammonites but proceed at a pace far too slow for effective documentation and calibration of biostratigraphic and paleoecologic zonations.

A continual need in invertebrate paleontology is modern taxonomic description of Canadian faunas. Other than the micropaleontological fields, employment opportunities for invertebrate paleontologists can be expected to be restricted to universities, museums and government agencies and primarily for specialists at the doctorate level of education. Undergraduate and masters programs of study need to concentrate on paleontological principles illustrated by selected examples rather than to attempt comprehensive coverage of paleontology, bolstered by cabinets of index fossils. Most of the graduates of these programs can be expected to be employed in the fields of sedimentary, stratigraphic and petroleum geology, and paleoecology and to be applying and synthesizing the results of detailed paleontological studies rather than conducting them.

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INVERTEBRATE PALEONTOLOGY

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The primary thrust of Canadian paleontology has changed little over the past century. It is still largely directed towards discovery and inventory of Phanerozoic fossil faunas. Its utility is seen in the existence of a successful biostratigraphic framework that is used to correlate widely separated rock sequences. Biostratigraphy is, and must remain, an important aspect of Canadian paleontology. It is a valuable, although little used, tool in the exploration for stratabound mineral deposits. With few exceptions, present faunal correlations are gross approximations; and increased biostratigrahpic refinement can only be achieved by concerted and sustained efforts in such fields as taxonomy, phylogeny, paleoecology, and paleobiogeography. Canadian efforts in these latter fields have been disappointing. These studies must be based on careful field work in areas containing well exposed and continuous rock sequences and well preserved faunas. Such successions are commonly found in the more remote parts of Canada; and field work in these areas requires extensive support from granting agencies — support that is increasingly difficult to obtain.

Slightly more than 200 investigators carry on paleontologic work in Canada. They are employed in universities (41%), industry (30%), government (23%), and museums (6%). This number is insufficient to work on all required aspects of paleontology at one time. Whereas some fossil groups are well known, others have

been ignored. Little work has been carried out on Paleozoic microfossils (other than conodonts), bivalves, gastropods, bryozoans, echinoderms, plants, and trace fossils. The few paleoecologic works that have been published concentrate on a single group of organisms; and pay little attention to co-occurring taxa. Field parties consisting of several paleontologists interested in different groups of fossils, working on the same section at the same time, can best provide comprehensive data on the paleoecology and biostratigraphy of the strata examined.

In recent years, many important paleontological collections have left the country. Canadian funded (GSC or NRC) paleontologic collections should first be offered to Canadian workers; and only be exported (even 'temporarily') to workers outside the country in cases where there are no interested and competent Canadian paleontologists available and some immediate need for completion of the work can be demonstrated.

The natural history and general interest aspects of Canadian invertebrate paleontology have largely been ignored and our discipline suffers from lack of public awareness. The preparation of a series of regional and general guides to Canadian fossils would help to rectify this deficiency. Such a series (logically published by the GSC) could include pamphlets on exceptional faunas (Burgess Shale), paleoecologic case histories (Upper Devonian reefs, Banff and Jasper), and regional fossil field guides (Cambrian, Cape Breton Island to Crétaceous, Vancouver Island) written and illustrated with the interested layman in mind.

Publication of paleontologic works, especially monographs, remains a significant problem for those paleontologists not employed by the Geological Survey; and consideration should be given to the establishment of a national publications medium for works of this sort.

Co-operation and communication between Canadian paleontologists will be stimulated by the newly formed Paleontology Division of the Geological Association of Canada and by the continuation of successful symposia and seminars (Conodont Paleoecology in Waterloo; P.S. Warren Biostratigraphy in Edmonton; and the continuing Biostratigraphy Seminars held in central Canada).

PALEOBOTANY AND PALYNOLOGY

D. Jarzen, G. Norris, and G. Rouse for the Geological Association of Canada

Paleobotany

Plant macrofossils continue to be studied only sporadically in Canada in spite of their abundance in some horizons. This work is concentrated in universities in Alberta, and centres around only two principal investigators. No macroplant studies (with one exception) are being conducted at present by any government agencies. There are simply too few paleobotanists working in Canada on Canadian material. In contrast, paleobotanists in the U.S.A. are continuing to systematically collect and study Upper Paleozoic fossil plants from eastern Canada.

The following three main areas are urgently in need of study:

a) Devonian floras of Gaspé-Bay of Chaleur region, and Carboniferous floras of Nova Scotia and New Brunswick.

b) Leaves and reproductive structures from the Mesozoic-Cenozoic of British Columbia and from the lower Tertiary of the Mackenzie Valley.

c) Anatomical studies using modern techniques to reveal significant fine structures of use in identification, phylogenetic and paleobiogeographical studies.

Clearly, there is a real need for additional active paleobotanists in Canada. We recommend that the concerned federal government agencies be encouraged to recruit paleobotanists for the two major fields of investigation, i.e. (a) and (b) above. Possible affiliation would be with the Geological Survey of Canada or with the recently-created Paleobotany Laboratory of the National Museum of Natural Sciences, Ottawa. Furthermore, geology and botany departments in Canadian universities should be urged to consider hiring a trained paleobotanist when faculty openings arise.

The real urgency for increased activity and job opportunities in paleobotany is also underlined by the recent survey of research related to petroleum exploration conducted by the Canadian Society of Petroleum Geologists (*see* Barnes *et al.*, 1976, p. 8). It concluded that the present small amount of paleobotanical research is far too low and stressed the future need for applied research in paleobotany.

Palynology

There are almost 70 university-trained palynologists in Canada, distributed approximately as follows: industry (40%), universities (30%), government agencies (25%), and museums (5%). The majority of studies are currently concerned with biostratigraphic applications with emphasis on Mesozoic-Cenozoic sediments in the western interior, arctic, and eastern offshore regions. The bulk of this work remains unpublished. The policy of the Geological Survey of Canada, however, to publish their own palynostratigraphic studies of selected offshore and arctic commercially-drilled wells soon after confidentiality has expired is particularly noteworthy. Published Upper Paleozoic miospore studies from eastern and arctic Canada remain almost exclusively with Geological Survey personnel. Work is underway on Lower Paleozoic marine palynomorphs (acritarchs, chitinozoa) from various parts of Canada in industry, government, and university establishments. Quaternary

studies remain heavily dependant on paleoclimatic interpretation of pollen spectra but innovative work at the Royal Ontario Museum on trend surface analysis of pollen rain is adding rigour to this subject.

Although increasing attention is being given to marine dinoflagellates which in part reflects their utility in offshore exploration programs, terrestrially-derived pollen and spores continue to be used as the only practical tool for correlation across facies boundaries. Regrettably, however, in many cases short-term problem-oriented studies continue to be pursued at the expense of basic research on morphology, taxonomy, phylogeny, stratotype documentation, and a more rigorous approach to paleoenvironmental interpretation.

Of continuing concern is the lack of a suitable publication medium for Canadian studies of Canadian fossils. All substantial Canadian taxonomic studies continue to be published in foreign journals, with the exception of those accommodated in "house" journals. There is a clear need for a national monographic series available to all paleontologists working on Canadian material. A further concern relates to poor taxonomic procedures (e.g. open nomenclature, sketchy descriptions, lack of differential diagnoses) that are becoming increasingly common in some published papers, presumably due to pressures to publish too much too quickly during a time when acquisition of palynostratigraphic data is increasing at an almost explosive rate. Responsibility for this lies with authors and editors alike, and underlines the need for a first-class national journal of paleontology which will exercise top-quality editorial practise. The appearance in English of a comprehensive file of fossil spore-pollen genera (Jansonius and Hills, 1976)—a joint Canadian university and industry venture—is particularly valuable and will significantly help assessment of the voluminous and rapidly growing palynologic literature.

Communication amongst palynologists is facilitated by annual meetings of the American Association of Stratigraphic Palynologists last held in Canada in Calgary in 1974, and to a lesser extent by symposia organized by other geological and botanical societies. The recently-formed Paleontology Division of the Geological Association of Canada has the potential to provide a focal point for national co-ordination and communication amongst both palynologists and paleobotanists.

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VERTEBRATE PALEONTOLOGY

D.A. Russell and A.G. Edmund for the Geological Association of Canada

About fourteen vertebrate paleontologists are currently employed by various Canadian institutions. Graduate degrees in vertebrate paleontology are granted by the University of Toronto, University of Alberta and McGill University. There are at present as many graduate students enrolled in these institutions as there are professional vertebrate paleontologists in the country. It is evident that more people are being trained in this discipline than will be able to find positions within their area of specialization.

The major interest of Canadian vertebrate paleontologists is to elucidate lines of descent among fossil amphibians, reptiles and mammals. The quality of their research in these areas is probably above the international average. However, the discipline is badly compartmentalized, both in regard to academic specialization and geographic (institutional) separation. This is reflected in the fact that, although Canada has produced many of the most important Paleozoic fish assemblages in the world, no Canadian institution is preparing a specialist competent to study them. Canadian Paleozoic fish research is currently concentrated in western Europe.

Taxonomic and phylogenetic studies are usually completed with a commentary on functional-anatomic and biogeographic implications, but fossil vertebrate evidence is seldom sought and focused specifically on problem areas in earth history. More thought is needed on the role of vertebrates in the evolving economy of the biosphere. It is surprising to note so little concern for the Canadian subcontinent as a region developing through time in publications by Canadian vertebrate paleontologists. In view of this, and limitations in employment opportunities for graduate students, society might be better served by expanding the public oriented aspects of our activities. The Province of Québec is to be congratulated for establishing a park at the world-famous lobe-finned fish locality near Miguasha. It is to be hoped that the Alberta government will seek professional counsel in developing the as yet essentially untapped paleontologic potential of Dinosaur Provincial Park.

Institutions and Vertebrate Paleontologists	Major Research Projects
University of Alberta, Edmonton	
R. C. Fox:	Evolution of amphibian, reptilian and mammalian terrestrial microvertebrates during late Cretaceous and Paleocene time, Alberta and Saskatchewan.
M. V. Wilson:	Affinities of middle Eocene freshwater fishes, associated insects, and interpretation of lacustrine paleoenvironments, British Columbia.
Institute of Sedimentary and Petroleum Geology, Calgary	
R. Thorsteinsson:	Biostratigraphy, evolution and paleoecology of Siluro-Devonian fishes, Canadian arctic archipelago (project soon to be terminated).
Saskatchewan Museum of Natural History, Regina	
J. E. Storer:	Changes in mammalian faunas during Miocene time, Saskatchewan.
Manitoba Museum of Man and Nature, Winnipeg	
G. Lammers:	Faunal composition of Late Paleogene mammalian assemblages, western interior of North America.
National Museum of Natural Sciences, Ottawa	
C. R. Harington:	Studies of ice-age and postglacial vertebrate assemblages from an unglaciated refugium, Yukon Territory.
D. A. Russell:	Changes in vertebrate assemblages during the Cretaceous-Paleocene transition, western Canada and abroad, and chronostratigraphy of transition.
Royal Ontario Museum and University of Toronto	
C. S. Churcher:	Studies of Ice-age hoofed mammals from Alberta, and of African horses and giraffes.
A. G. Edmund:	Studies of a giant armadillo and paleoenvironments of peninsular Florida.
C. McGowan:	Systematic revision and biometrical studies of European Ichthyosaurs. Collaborating in the investigation of the Loch Ness phenomenon.
R. Reisz:	Evolution of late Paleozoic reptiles, maritime provinces.
L. S. Russell:	Evolution of Tertiary mammalian faunas of the southern prairie provinces.
Redpath Museum, McGill University	
R. L. Caroll:	Phylogeny and functional anatomy of Paleozoic and early Mesozoic reptiles and amphibians.
Dalhousie University, Halifax	
B. Cooke:	Suid evolution in southern Africa.

PETROLOGY

H.J. Greenwood, G.B. Skippen, and J. Gittins for the Geological Association of Canada

General Remarks

Modern petrologic research in Canada, as elsewhere, is dependant upon the analytical facilities available, as well as upon the personnel and theoretical understanding that can be brought to bear on the problems. The principal analytical techniques in use for such work are mainly the electron microprobe, X-ray fluorescence, and atomic absorption. Of these, the electron microprobe is assuming an ever-increasing share of the load. Excellent microprobe facilities with heavy usage exist at numerous centres but several are operational with varying degrees of usage. Numerous good installations of X-ray fluorescence and atomic absorption exist and produce large quantities of excellent data. It is worth noting that in the case of very expensive installations such as microprobe facilities the rate of usage and production is often not nearly as high as the equipment in existence is capable of maintaining. A substantial part of this under-production may be due to the difficulty of obtaining financial support for technical support of the facility. Microprobes are expensive not only to buy but to operate, as a good technician and preparator are essential if the machine is to operate to capacity. Lack of funds makes such support personnel unavailable to many groups, seriously affecting the scientific returns on the NRC investment.

The level of activity in petrology is indicated in the following partial summary of publications (1975).

Journal	Total Papers	Igneous	Metamorphic	Experimental	Foreign Authors
Can. Min. J. V. 13, 1975	63	2	4	3	3 American
Can. J. Earth Sci. V. 12, 1975	147	21	1	0	13 American
Total, both Canadian journals percentages	100%	11%	2%	1%	8% American
Am. Miner. V. 60, 1975	114	4	5	21	5 Canadian
Bull. GSA V. 86	179	26	8	4	13 Canadian
Total, both American journals percentages	100%	10%	4%	9%	6% Canadian

This tabulation indicates that the level of activity in igneous petrology in Canada is significantly higher than in either metamorphic or experimental petrology, and that the level of activity in experimental petrology in United States is very significantly higher than it is in Canada.

There is a reasonable degree of cross-publication between Canadians publishing in the United States and Americans publishing in Canada.

Igneous Petrology

Basalt Dalhousie University has an active group working on the Joides "Deep Drill 1974" materials, which will appear as a special issue of the Canadian Journal of Earth Sciences documenting the results of a very exciting program.

Alkalic Rocks The Geological Survey of Canada and the University of Toronto remain the most active groups in this field of petrology, with important contributions to the rare-earth mineralogy coming from Ecole Polytechnique and Carleton University. Lakehead University is active in the study of alkalic and kimberlitic rocks, but is poorly equipped. The University of Western Ontario combines experimental and field studies of alkalic systems.

Volcanology The Geological Survey of Canada continues work on Mt. Edziza and other young volcanic centres, and the Universities of Calgary, Edmonton, Toronto and British Columbia have programs invoving volcanic rocks in Western Canada.

Calcalkaline plutonic rocks In spite of the great exposures of such rocks in Canada, both in the Shield and in the Cordillera, surprisingly little work is currently in progress on the problems of their origin. This is particularly noteworthy in view of the current

importance attached to these rocks in theories of plate tectonics. An active group at the University of British Columbia is working with trace elements and Sr 87/86 initial ratios. Active work in the study of Nova Scotia granitic rocks is underway at Dalhousie University.

Theoretical Workers at the University of Calgary are concentrating on a combination of theory and analytical work to deduce pressure and temperature regimes of partial fusion at the magma source, but are hampered in their progress by lack of experimental data on fundamental physical properties of silicate liquids. Too little work is being done to get these data, with the only contributors being Geophysics groups at the Universities of Western Ontario and Alberta. Workers at the Universities of Toronto and Queen's are making progress in application of theory to origin of mafic and ultramafic rocks.

Metamorphic Petrology

Most of the work considered to belong in this category is essentially the application of the principles of phase equilibrium derived from theory and experiment to problems arising from field studies. Most notable in this area are the workers at the Geological Survey of Canada, Carleton University, Queen's University, University of Calgary, University of British Columbia and Memorial University. Work in this field is exciting and the time is at hand when it will be possible to set rather good limits to total pressure, temperature and the constitution of metamorphic fluids by means of solving sets of simultaneous equations of equilibrium. G. B. Skippen at Carleton University has developed such a model for metamorphosed calc-silicate and ultramafic rocks and workers at the Universities of British Columbia, Queen's, and Carleton, and the Geological Survey of Canada, are actively working toward the same goal for pelitic rocks. The frequent confrontation between field estimates of pressure and estimates based on phase equilibria will doubtless become even more striking, and it seems to the writers that estimates based on mineral equilibria may prove to be better.

Experimental Petrology

Strong to modest programs exist at the Universities of Western Ontario, Toronto, Queen's, McGill, McMaster, Carleton, Manitoba, Alberta and British Columbia. The Geological Survey of Canada and CANMET have some equipment but have neither enough time nor personnel to be productive. Most of the experimental petrology groups emphasize the acquisition of phase equilibrium data, in terms of pressure, temperature, and the composition of coexisting phases. At the University of Western Ontario two groups are active. The Geophysics group stresses the acquisition of "fundamental" data, in the sense that such parameters as elasticity, thermal and electrical conductivity, and creep rates are sought at high pressures and temperatures, while the group in Geological Sciences stresses phase equilibria of mafic and alkalic rocks.

Support of experimental petrology in Canada comes largely from the National Research Council of Canada, with the larger laboratories receiving proportionately larger shares of the funds. A feature of the funding arrangement is that few operations are sufficiently well supported that they are able to employ adequate technical staff, nor, especially, post-doctoral fellows. A consequence is that even where expensive laboratories have been provided the rate of productivity is lower than one might expect from such an investment. The usually heavy teaching loads at Canadian universities combine with the lack of technical support to limit severely the amount of data that can be obtained with the available equipment.

Future Needs and Directions

The principal needs to make possible continued and improved excellence in Canadian petrology can at least partly be focussed on funding. Experimental and advanced analytical laboratories cannot be operated at capacity in Canadian universities without adequate technical support staff, particularly because of the heavy teaching loads that exist. Current funding levels are not adequate to provide this staff for most laboratories, with the result that many of them produce data at a quantity far below their potential.

Several Canadian petrologists are world leaders in application of theory to both field and experimental studies. This tendency should be strongly encouraged so that the science does not become mired in empiricism. The contributions to understanding the tectonics of the crust and upper mantle that could be made through petrology are only just being realized.

Increased attention to the collection of "fundamental" data such as viscosities of liquids, elastic constants, thermal and electrical conductivity, optical opacity, and creep rates of solids at high pressures and temperatures should be strongly encouraged, especially in the light of recent advances in the understanding of crystal chemistry which may permit the calculation of thermodynamic parameters from such fundamental properties.

Contributors to this year's summary stressed the importance of scientific quality and minimized the importance of purely "mission-oriented research". The first requirement must be the high quality of the science, and consideration of immediate applicability should be secondary.

Notable Publications

Cooper, A. F., Gittins, J., and Tuttle, O. F.
1975: The System Na_2Co_3-K_2CO_3-$CaCO_3$ at 1 kilobar and its significance in the carbonatite petrogenesis; Am. J. Sci., v. 275, p. 534-560.

Roeder, P. L.
1975: Thermodynamics of element distribution in experimental mafic silicate — liquid equilibria; Fortschr. Mineral., v. 52.

Emslie, R. F.
1975: Pyroxene megacrysts from anorthositic rocks: New clues to the sources of an evolution of parent magmas; Can. Mineral., v. 13, p. 138-145.

Greenwood, H. J.
1975: Thermodynamically valid projections of extensive phase relationships; Am. Mineral., v. 60, p. 1-8.

Froese, E.
1976: Applications of thermodynamics to metamorphic petrology; Geol. Surv. Can., Paper 75-43, 37 p.

QUATERNARY GEOLOGY AND GEOMORPHOLOGY: SOIL RESEARCH

J. Dormaar for the Canadian Society of Soil Science

Contributions to Geomorphology and Quaternary Geology by Canadian soil scientists have been sporadic as their major thrust has been in agriculture and forestry. However, fossil soils (paleosols) and particularly those of the buried variety are of interest in stratigraphic studies because of their importance as stratigraphic markers and as keys to past environments. At least a dozen soil scientists across Canada are aware of the usefulness of paleosols as a means of describing landscapes of the past. The NRC Associate Committee on Quaternary Research is supplying a useful avenue for exchange of information between representatives of a wide variety of disciplines. Soil science has been represented on this Committee for the last eight years.

A Bibliography on Paleopedology in Canada was prepared in 1972. This was incorporated in 1974 in the World Bibliography on Paleopedology edited by A. Ruellan for the Paleopedology Commission of INQUA. The Canadian Bibliography has been updated in 1976 and over 100 references in which paleopedology is either the principal subject or not the principal subject but discussed have now been compiled.

The University of Alberta sponsored a Symposium entitled 'Pedology and Quaternary Research' in 1969. Some of the highlights of this Symposium were the observation that buried Ah horizons may harbour several million bacteria per gram of soil and yet there has been vitually no microbiological data published on paleosols, and the observation that opal phytoliths in soil were a useful tool in describing the probable environment at the time of formation of the opals. The Symposium on Quaternary Stratigraphy to be held at York University in May 1976 should do much to establish the contribution pedologists can make towards the reconstruction of past geomorphology, climate, and vegetation.

QUATERNARY GEOLOGY AND GEOMORPHOLOGY

J. A. Westgate, E. A. Christiansen, A. Dreimanis, and P. F. Karrow for the Geological Association of Canada

The traditional equation of Quaternary geology and geomorphology to purely descriptive studies on glacial phenomena no longer bears an accurate reflection of current activities within the country. On the contrary, investigations in Quaternary earth science today are commonly of an interdisciplinary nature so that the geoscience categories adopted for the purpose of these reviews are not particularly appropriate.

Inventory mapping of surficial deposits, however, still constitutes a large and important part of the activities of federal and provincial agencies, for about one third of the country still remains unmapped. The major effort, including environmental and stratigraphic studies, is by the Geological Survey, whose operations are presently focused on the Arctic Islands. Other areas where extensive mapping and/or terrain sensitivity surveys are now being carried out include the Fraser Lowlands, the central Foothills Belt and the northeastern part of Alberta where coal and tar-sand extraction operations are located respectively, southern and central Ontario and the Lower Ottawa Valley. Canada Centre for Inland Waters staff continue to monitor shoreline erosion and nearshore sedimentation in the lower reaches of the Great Lakes and are engaged in detailed stratigraphical studies of the unconsolidated bottom sediments by means of echo-sounding and coring. Much of this work will undoubtedly appear in the new Journal of Great Lakes Research. Process-oriented studies on Cordilleran lakes fed by glacial melt-waters — a much neglected subject — are now underway (e. g. R. Gilbert, Queens; N. Smith, Chicago Circle) and important contributions on the glaciofluvial environment continue to be made by M. Church (University of British Columbia).

A large number of meetings on Quaternary themes were held in Canada in 1975-76. The Proceedings of the Symposium on Interdisciplinary Aspects of Glacial Till, published by the Royal Society of Canada contains a timely and comprehensive synthesis on the geology of till and as many as four papers on till in relation to mineral exploration. We sense a growing appreciation of the need for detailed studies on the anatomy and chronology of glacial drift for mineral exploration in Canada. This is reflected in the literature (e. g. P. Bradshaw [ed.], 1975), an increased demand for Quaternary geologists by

exploration companies, the 1976 GAC Cordilleran Section theme, "Geomorphology of the Canadian Cordillera and its bearing on mineral deposits", and field programs (e.g. the chief objective of provenance studies of Quaternary deposits on the Shield of northern Saskatchewan is to provide a framework for geochemical prospecting).

The demonstration by P. Fritz (University of Waterloo) at the 1975 Waterloo conference on Quaternary Non-Marine Palaeoecology that ^{18}O and ^{13}C compositions of shells of freshwater invertebrates can provide valuable paleoclimatic and paleohydrologic information should lead to a greater use of stable isotopes in Quaternary paleoecological studies of continental sequences. Another noteworthy contribution at this meeting was that of L.D. Delorme (CCIW) who has developed a paleoecological computer technique based on a comprehensive knowledge of the ecological limitations of specific ostracodes and molluscs in Canada. Stable isotopic studies of speleothems by H. Schwarcz, R. Harmon and D. Ford (McMaster) are likewise yielding valuable paleoclimatic data. Their Castleguard Cave study, communicated at the GAC-GSA Meeting at Waterloo and Symposium on the Thermal Regime of Glaciers and Ice Sheets at Burnaby, B.C., is particularly significant in that it provides a possible method of dating — by means of Th-230/U-234 ratios — the earlier Quaternary glaciations of the Rocky Mountains.

New undertakings of note include: (1) a correlation scheme for Late Wisconsin deposits across the country by the Canadian Working Group of the IGCP on "Quaternary glaciations in the northern hemisphere"; (2) a synthesis of the Quaternary of the Interior Plains, sponsored by ACQR; and (3) a long-term interdisciplinary study of the late Quaternary of the northern Yukon — the site of several Early Man finds — by staff of the University of Toronto, Geological Survey and Museums of Canada.

We perceive several major deficiencies. There should be much greater collaboration with engineering geologists. Large amounts of money are being spent on the acquisition of subsurface information for engineering purposes in urban areas but most of these data remain in consultant's files and in limited-distribution reports. Even where compilations of such information have been undertaken, such as through the EMR urban geotechnical program of 1972, little geological synthesis has been carried out or has been possible because of the lack of involvement of geologically-trained and knowledgeable personnel. Such work should not be undertaken on a project or short-term basis, but rather requires permanent staff and facilities to gain information as it becomes available.

Knowledge of the regional Quaternary stratigraphy and processes that cause the local stratigraphy to deviate from the modal condition are essential for most geotechnological investigations in Canada. However, such stratigraphic frameworks are unavailable over large parts of the country and few Canadian universities provide rigorous study programs on the subject. The important countributions that Quaternary geology can make to geotechnology are thus not being fully realized at present; this unexploited potential has resulted in inefficient and expensive geotechnical investigations.

Geochronological control for Quaternary deposits older than 50 000 years — the limit of the ^{14}C dating method — is very poor in Canada; the application of radiometric (e.g. K/Ar, fission track) and other dating techniques (e.g. amino-acid method), tephrochronological and paleomagnetic methods to Quaternary stratigraphic problems is still very limited. We feel this may well reflect poor communication between the Quaternary geologist, geophysicist and geochronologist.

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Fritz, P., Anderson, T.W., and Lewis, C.F.M.
1975: Late Quaternary climatic trends and history of Lake Erie from stable isotope studies; Science, v. 190, p. 267-269.

STRATIGRAPHY AND SEDIMENTOLOGY

SEDIMENTOLOGY

G.V. Middleton, G.R. Davies, B. Mamet, and R.M. Slatt
for the Geological Association of Canada

If an "active" sedimentologist is defined as a person who either subscribed to one of the two leading international journals (Jour. Sedimentary Petrology, Sedimentology) or who published a paper on sedimentology in 1975, then Canada had at least 282 sedimentologists in 1975. Of these about 50% were in universities (this figure includes students as well as faculty), 30% were in industry, 15% in the Federal Government, and 5% in Provincial Governments. No doubt the number of sedimentologists in industry is somewhat underestimated by the methods used to compile this list.

To provide a "world" perspective, we may note that 9% (60) of the members of the International Association of Sedimentologists reside in Canada. Canadians authored (or part-authored) about 7 to 8 per cent of the papers in the two leading international journals.

It may be estimated that about 6% of "active" Canadian geologists (those who join professional associations) are sedimentologists. In 1975, about 12 per cent of the papers in the Canadian Journal Earth Sciences were on sedimentology. In addition, there are two other Canadian journals that publish much sedimentological material: Bulletin of Canadian Petroleum Geology (about 40 per cent on sedimentology in 1975) and Maritime Sediments. Thus a total of about 15% of papers published in Canadian earth sciences journals in 1975 were on sedimentology.

About 75% of the journal papers published in 1975 by Canadian sedimentologists originated in universities, 15% in industry and 10% in the Federal Government. These figures certainly underestimate the publications of Federal Government sedimentologists: we estimate that about 7% of the geologists in the Geological Survey of Canada are sedimentologists, and in the Reports of Activities (GSC Paper 75-1A, B, 1975) 16% of the projects described might be classified as sedimentology.

These figures establish that Canada has a large, active group of sedimentologists. They are located mainly in the universities (Dalhousie, Calgary, McMaster, McGill, Memorial, Montreal, and Western Ontario, are among the principal centres but the activity is widely distributed with no single university in a clearly dominant position), in industry (particularly in the petroleum companies) and in the Federal Government (including the Geological Survey of Canada at Calgary, at Ottawa and at the Bedford Institute of Oceanography; and the Ministry of the Environment at the Canada Centre for Inland Waters, Burlington, Ontario). Activity in sedimentology in the Provincial Surveys is generally low, though Alberta Research has been a notable exception in the past.

It is less easy to assess the overall quality of the work in sedimentology that is being done in Canada. Canada did not begin to be active in sedimentology until the 1960s: thus there are no senior men of the caliber, for example, of Pettijohn, Krumbein and Emery in the United States, Kuenen and Van Straaten in Holland, or Reineck in Germany. No Canadian has ever been President of the Society of Economic Paleontologists and Mineralogists, or received one of their major honours (Honorary Membership; Twenhofel or Shepard Medal).

There are, however, a number of younger Canadian sedimentologists, mostly aged 25 to 45, whose work has drawn widespread international recognition. The main areas of strength seem to be clastic sediments, particularly Paleozoic and Pleistocene, ancient carbonates and evaporites, and the sedimentology of the Precambrian.

Among major recent developments we note: (i) the Society of Economic Paleontologists and Mineralogists Special Publication 23 on "Glaciofluvial and Glaciolacustrine Sediments", edited and mostly authored by Canadians, (ii) a Royal Society of Canada Symposium Volume on "Glacial Till", an Interdisciplinary study, (iii) a special issue of the Journal of the Fisheries Research Board of Canada (v. 33, no. 3, 1976) devoted to "Lake Erie in the early Seventies" (with several articles on sediments), (iv) the Geological Association of Canada Special Paper 13 on "The Cretaceous System in the Western Interior of North America" (with articles on their sedimentology as well as stratigraphy), (v) Offshore Geology of Eastern Canada, Vol. 2, Regional Geology (GSC Paper 74-30, 1975), (vi) the Canadian Society of Petroleum Geolgists Memoir 4, on Canada's Continental Margins.

Canadian sedimentologists appear to have made good use of the special opportunities that Canada provides for the study of Precambrian sediments, and it may be noted that the first two awards of the GAC's Past Presidents Medal went to sedimentologists working in this field (Paul Hoffman, Roger Walker). Pleistocene clastic sediments, Devonian to Mississippian carbonates and evaporites of Alberta and the Arctic, and the Lower Paleozoic flysch of the Quebec Appalachians have all been the subject of some notable sedimentological studies. Several studies have been of units important for economic mineral deposits (for example, oil and gas and Pb-Zn in Alberta carbonates).

In preparing this report, we noted that many correspondents commented on the relative weakness of Canadian studies of recent sediments. While this is probably still generally true, we would like to draw attention to relatively new programs of study in the Gulf of St. Lawrence (Bedford Institute, McMaster University, University of Toronto), Bay of Fundy (Bedford Institute, McMaster University), St. Lawrence Estuary (universities of McGill and Quebec, Environment Canada at Quebec City), Newfoundland — Labrador Shelf (Memorial University, Bedford Institute of Oceanography), several studies of fluvial sediments (Ottawa and McMaster universities), studies of modern carbonates of Barbados and other regions of the Caribbean (McGill and McMaster universities) and both chemical and physical studies of the sediments of the Great Lakes (Canada Centre for Inland Waters, Lakehead University).

Two major areas of weakness are (i) the West Coast, where much more activity both on recent and ancient sediments would seem to be needed, (ii) the Athabasca Tar Sands, still apparently little studied despite their great economic importance.

In summary, Canadian sedimentology after a late start, appears to have experienced a period of rapid growth since 1960. After an early period when studies of carbonates and evaporites, stimulated by the petroleum industry, were most notable, Canadian sedimentology has become much more diversified, with a strong "eastern" emphasis on clastic sediments (which, in turn, are now becoming of increasing importance to the petroleum industry). Strength has been achieved in the sedimentology of the Precambrian and of the Pleistocene, and further development of these studies is important to Canada for economic reasons. Studies of recent sediments, though still relatively weak, are developing in eastern Canada, and need further support: they are expensive but are important both for economic reasons (e.g. environmental studies) and as a basis for the interpretation of sedimentary rocks and the mineral deposits that they contain.

STRATIGRAPHY

W. G. E. Caldwell, R. W. Macqueen, and P. F. Karrow for the
Geological Association of Canada

In the recent past, too many Canadian geologists have regarded stratigraphy as little more than the description and classification of Phanerozoic sedimentary rocks. A marked widening of their stratigraphical horizons has come about in the last few years for a number of disparate reasons: the concepts and principles of Phanerozoic stratigraphy have been applied to rocks of the Precambrian Shield with dramatic and illuminating results; the distribution of many metalliferous deposits has been found to be stratigraphically controlled; and the key role of stratigraphy (including the new magnetostratigraphy) in interpreting the geologic history of Canada and its flanking ocean basins in a context of modern theories of global tectonics has been recognized. The true challenge and scope of stratigraphy — to provide the basis for a coherent and plausible account of geological history by synthesizing all kinds of available information (geophysical to paleontological) from all kinds of layered rocks — is being appreciated as never before. As a bonus, the misleading, if traditional, terms "hard rock" and "soft rock" happily are being laid to rest.

Appreciation of the true breadth of Canadian stratigraphy has been aided by some signal accomplishments in parts of the country other than the Interior Platform — the Precambrian Shield, the Appalachian and Columbian orogens, and the continental shelf. Stratigraphical studies, based upon systematic mapping and relying to some degree upon different specialized techniques, have helped delineate and explain the origin and growth of the Archean volcanic piles in the Superior Province, the gold-bearing sequences of the Slave Province, and the Proterozoic basins in many parts of the Shield, particularly, however, the Coronation Geosyncline. In western Newfoundland, it was stratigraphical analysis of certain basic igneous and associated sedimentary rocks that led, significantly, to their recognition as allochthonous fragments of Early Paleozoic oceanic crust. In eastern British Columbia, it was stratigraphical analysis mainly of Late Paleozoic lithological assemblages that led to a better understanding of the history of the complex Omineca Crystalline Belt. The place of stratigraphy in future quests for mineral deposits has been underscored by elucidation of the Proterozoic-Early Paleozoic sequence of zinc-, lead-, and copper-bearing sedimentary, volcanic, and metamorphic rocks in the Yukon and Northwest Territories. Progress in understanding the geology of the offshore belts is illustrated best by the developing stratigraphy of the Grand Banks and Scotian Shelf — a stratigraphy based largely on data from boreholes and reflection seismic records. Sufficient data now have been collected to prepare facies and isopach maps of most divisions in the 10 to 12 km-thick sequence and to produce an impressive palynological zonal scheme for beds of mid-Jurassic to Pleistocene age.

To emphasize these regions is not to deprecate advances made in refining the Paleozoic-Mesozoic stratigraphy of the craton (Caldwell, 1972), although the flow of new information from that region has diminished since the halcyon days of major oil discovery. The complex stratigraphy of the deep pocket of Mesozoic-Cenozoic sediments in the Mackenzie River delta is becoming unravelled through co-operative studies between government and industrial geologists. There remains, however, an acute need for a detailed lithological analysis of the sediments in the delta and for a reliable microfossil zonal scheme founded on sound systematics. The stratigraphic approach to both surface and subsurface sections now is widely accepted as the principal means of interpreting Quaternary history, and systematic mapping of Pleistocene-Holocene sediments is in progress in most provinces and territories. The conventional radiocarbon method for dating the younger of these sediments soon may be supplemented by the amino acid method applicable to older beds; and there is a growing interest in dating by thermoluminescence. Beds of volcanic tephra and, to a lesser extent, the paleomagnetic properties and vertebrate fossil assemblages of the sediments, are provinding new insights into Pleistocene correlations, particularly in western Canada.

Some recent, remarkably comprehensive, region- and subject-orientated compendia, published by the Canadian Society of Petroleum Geologists, the Geological Association of Canada, and the Geological Survey of Canada, record many new advances in stratigraphy: for example, Permo-Triassic Systems (1973), Future Petroleum Provinces in Canada (1973), Arctic Geology (1973), Cretaceous System in the Western Interior (1975), Offshore Geology of Eastern Canada (1975), and Canada's Continental Margins (1976). Moreover, the much-improved Report of Activities of the Geological Survey now provides an annual source of many new stratigraphical developments.

Within the country, desirable stratigraphic studies for the future are legion. The time is ripe for regional syntheses of the miogeosynclinal and adjacent foreland sequences of the Appalachian, Cordilleran, and Innuitian orogens, along the lines of the Canadian Society of Petroleum Geologists' (1964) Geological History of Western Canada. There is a need for more work on the calibration (by paleomagnetic, radiometric, or other means) of the thick Proterozoic sequences of the Cordilleran and Innuitian orogens to permit better correlation of these sequences both internally and with similar sequences in the Shield; on the reasons for apparent stratigraphic controls on copper, lead, and zinc mineralization; on the biostratigraphy and lithostratigraphy of the Mesozoic-Cenozoic terrigenous clastic piles (with their actual and potential rich accumulations of coal and hydrocarbons) in both the

onshore and offshore basins; and on new absolute-time calibration of the older Pleistocene deposits throughout the country. Achieving these and other desirable ends will require greater manpower (both professional and support staff); a multidisciplinary approach using research teams; and a somewhat higher level of funding; and it will be accelerated by the wider application to stratigraphical data of improved computer techniques. Not least, university professors, responsible for instruction in stratigraphy, must cease to teach it in terms of the memorization of columnar sections and index fossils but in terms of the concepts, principles, and practices of a dynamic, multidisciplinary field of the geological sciences.

Among the broader issues for the future, there is a need to look beyond the borders of the country. Canadian stratigraphy must be set in continental and global contexts: political boundaries must not be allowed to become scientific boundaries; studies with international implications should be increased in number and scope; international co-operation and participation in international meetings should be fostered. It would be desirable, for example, to begin studies of regional sedimentary patterns related to major unconformities or tectonic events, such as sea-level changes in response to lithospheric plate movements. For a country which has a vast seaboard and is contemplating extension of territorial claim to the 200-mile limit, the decision not to renew active participation in the Deep Sea Drilling Project is to be deplored. Involvement should be restored promptly.

A final political point: stratigraphers, particularly university biostratigraphers, should address themselves to the problem of the increasing number of controls being exercised by various levels of government on access to certain parts of the country for purposes of collection fossils and rocks samples. Ostensibly in the interests of conservation and "protection of our natural heritage", special regulations controlling access to the national and provincial parks increasingly are being administered by government officials remote from any field of science. Regulations controlling collection in the Northwest Territories also are being tightened. Already some tragic examples have come to light of the destruction of important outcrops partly as a result of non-scientific personnel interpreting the law and dispensing their decisions with blind-fold "justice". It should be remembered that conservation and "preservation of our natural heritage" is achieved by "reaping the harvest" as erosion exposes it and before man or nature destroys it.

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STRATIGRAPHY AND SEDIMENTOLOGY

J. Twyman for the Canadian Society of Petroleum Geologists

In assessing the annual flood of literature one is constantly impressed by the high quality of the papers. It is true that few present new concepts, or even a new view of an oil idea, and works of genius as always are rare, yet in the main the editors do a good job. Nonetheless, we tend to avoid reading long, complex stratigraphic papers if the area is unknown to us or if the particular things of interest are not prominently displayed. This is, of course, our loss. Modern stratigraphic work has returned to the definition that "stratigraphy is that branch of geology which treats the formation, composition sequence and correlation of the stratified rocks...". It is interesting to wonder whether "sedimentology" came into existence because "stratigraphy" for whatever reason had become a dry subject that left one geologically unsatisfied. It is easy to become too pious on this point. As an antidote, may I recommend the excitement of a "large scale view" frontier stratigraphic paper such as McWhae and Michel's "Stratigraphy of Bjarni H81 and Leif M48, Labrador Shelf".

Carbonates

Dolomitization with its important porosity implications continues to receive considerable attention in the literature. The Dorag theory that dolomite forms in carbonate rocks when sea-water and meteoric waters mix in certain proportions is examined at length and given geochemical support by Land, Salem and Morrow (1975). An interesting discussion by Carpenter (1976) and a reply by Badiozamani (the original proposer of the Dorag theory) summarizes some of the points at issue. A further contribution regarding the Mg/Ca ratio and salinity can be found in Deelman's (1975) comments on Folk's studies of carbonate rocks during the period from 1964 to 1974.

Evaporites

Little of interest has been published on evaporites during the past year. In Sicily the question of whether the Miocene evaporites of the Sicilian basin are deep (drying up of Mediterranean Sea, waterfalls at Gibraltar) or shallow water origin was examined by Schreiber and Friedman (1976) who found thin shallow water carbonates within the evaporite section. Schreiber and Kinsman (1975) described the Pleistocene evaporites of Sicily which appear to be redeposited from the nearby Late Miocene beds. In addition, the Pleistocene is providing gypsum to the present-day solar salt pans. It appears that recycling of evaporitic deposits may happen more frequently than we suspect.

Clastics

Geologists tend to refer to sand bodies parallel to the shoreline as barriers even though they bar nothing and were deposited in relatively deep water. Berg's (1975) excellent subsurface study of a succession of sand bodies developed at the foot of prograding shale wedges, demonstrates the offshore non-barrier mode of deposition. A useful comparison can be made between the foregoing and Tizzard and Lerbekmo's (1975) study of the Viking of Southern Alberta. Freeman and Visher (1975) also deal with shelf sandstones they believe to be tidal current ridges or sand waves. The object of their study is the Navajo Sandstone, long considered to exhibit all the earmarks of desert aeolian deposition. As an aid in subsurface work, Selley (1976) employs mechanical logs and the presence of carbonaceous particles or glauconite in ditch cuttings to discriminate between deltaic and marine sands. Bhandari and Chowdhary (1975) provide a good subsurface analysis of Eocene clastic wedges (mainly nearshore deposits) amd interesting observations on the association of thick coal sequences and waxy crude oil. The short headed delta described by Flores (1975) is one in which the sediment source and site of deposition are close together. The system contains many interesting features including highly braided channels that may have parallels in the Cretaceous of northeast British Columbia. A description and interpretation of the alluvial plain — lacustrine depositional model for the Precambrian Witwatersrand by Vos (1975) makes a valuable contribution to a little studied environment and in addition illustrates the breadth and excellence of South African subsurface (mine) work. An interesting paper by Edwards (1976) on well exposed deltaic sands and growth faults helps to fill in our pitcure of phenomena usually interpreted from subsurface data. Dailly's (1976) work on the Niger delta is a first-class synthesis of the organic quality of delta evolution on a grand scale. In a similar vein, the tectonic evolution of the North Sea by Ziegler (1975) relates facies to structure with attendant sedimentological implications. On a more local theme, Memoir 13 of the Geological Association of Canada deals with various aspects of the Cretaceous system in the Western Interior of North America. Of particular interest are papers on tectonic control and sand sequences, the Cretaceous system of northeast British Columbia and the Mannville Group in south-western Saskatchewan.

Stratigraphers and sedimentologists working in petroleum exploration are always hungry for information that will help them with their current problems or lead them to new areas for exploration. How can their needs be satisfied? There is a fantastic concentration of expertise in the petroleum industry yet few papers, notes or comments are published by industry personnel in any given year. Some people do publish but it is usually post-graduate work done before having obtained oil company experience. Papers need not be lengthy theses that cover every possible aspect of the subject.

Experienced exploration geologists can make a valuable contribution by publishing on vaguely defined regional observations or inexplicable local phenomena. We all need to know and the most effective way to do it is by exchanging information in print.

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STRUCTURAL GEOLOGY AND TECTONICS

A. Baer, J. Dixon, W. M. Schwerdtner, and G. Eisbacher
for the Geological Association of Canada

Structural Geology and Tectonics have progressed adequately during the year. The number of researchers and research projects has been fairly constant for the last few years, and given the present financial situation, it is not expected to change much in the near future. For many years now, the discipline has not been held in high esteem in this country. Although there are some excellent individuals, no Canadian university or government laboratory is a recognized centre of excellence for structural geology.

In 1975, significant progress was made in documenting the structure of the Cordillera, the tectonic history of the Appalachians and the structural styles of Precambrian rocks of the Canadian Shield. Some of the better papers were:

Cook, D. G.: Structural style influenced by lithofacies, Rocky Mountain Main Ranges, Alberta-B. C.; Geol. Surv. Can., Bull. 233.

Dixon, J. M.: Finite strain and progressive information in models of diapiric structures; Tectonophysics 28, p. 89-124.

Schrijver, J.: Deformed root of a composite diapir in granulite facies; Geotekton. Forsch. H. 49, p. 1-118.

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Classical structural geology accompanied by field work was responsible for about 65 per cent of all projects in 1974 and appeared to maintain its position in 1975. This is appropriate because it supplies much of the data upon which other work rests. Funding, however, is barely adequate to allow most university researchers to operate in remote areas where supplies and local transportation (aircraft and helicopters) are expensive. Structural geology has commonly been considered to be an inexpensive field, but modern methods such as centrifuge modelling are costly. For instance, Canada should have at least one geological centrifuge that could be made available to researchers in the whole country. Computer modelling is also expensive but is a necessary tool in cases where three dimensional reconstitution of strain indicators is established from serial sections, for instance. In many other projects, the three dimensional nature of structural work means that necessary programs are long and expensive.

Less than 10 per cent of projects reported for 1974 had an immediate "practical" application, but many more such projects need to be undertaken and could supply thesis material for graduates. For instance, detailed analyses of fracture patterns in porphyry-copper deposits or detailed structural mapping of mining camps in the Precambrian Shield could be both scientifically important and economically significant.

Geotectonics has been given a tremendous impetus by the development of plate tectonics. Now that the dust is settling, workers in the Appalachians and in the Cordillera are busy checking models in the real world. In the Precambrian, data are scarce and models are abundant. A majority favours some variant of plate tectonics for the Archean, but opinions are quite divided about the Proterozoic, as was apparent at the symposium organized in Ottawa in the honour of C. H. Stockwell. The program of compiling maps at 1: 1 million scale of the Geological Survey of Canada is now well under way and will provide invaluable information for future geotectonic syntheses.

Among all possible reasons for the lack of overall excellence in the field, some can be eliminated fairly easily. For instance, geology students commonly have insufficient training in basic mechanics and dynamics. The situation is improving however, but their professors may not always encourage them enough to use new approaches. The very limited number of projects in mathematical structural geology, in computer modelling and in experimental modelling (7 per cent in all) shows that the country could use three or four more researchers in this field.

Grants in support of research give great freedom to individual researchers, but no enough encouragement to group projects with a major structural component. Some fundamental problems need to be studied by well-co-ordinated groups of researchers. These need not be in the same university but must have closer co-operation than is the case at present. The newly created Division for Structural Geology and Tectonics of the Geological Association of Canada will hopefully play an active role and could organize seminars and field conferences. If could also collate yearly copies of NRC form 560 (data on research projects for exchange of information). This would be a fast and painless method to keep in touch with workers in the field.

More papers on structure and tectonics should be published in the Canadian Journal of Earth Sciences. It is in fact ironic that of the four excellent papers selected by this committee, none was published in that journal. Part of the explanation must lie in the fact that structural geologists do not publish enough of their results, because it is hard to believe that the rejection rate would be much higher for this discipline than for others.

Closer collabortion between workers in rock mechanics, geophysics and those in structural geology is essential, particularly in universities where students in civil engineering and those in geology have commonly little contact with each other.

Many of the comments and recommendations made here are similar to those made over the years by bodies such as the National Advisory Committee subcommittees for structural geology. They have gone unheeded in years past because of two major obstacles. The first one is the lack of adequate financing. This has now reached critical proportions and is slowly destroying the research potential built up painfully over the years. The second is the individualism of scientists and their reluctance to fully commit themselves to joint projects. Greater collaboration and co-ordination of efforts can add a new dimension to the development of structural geology and tectonics.

PART III

CANADIAN GEOSCIENCE COUNCIL 1976 ANNUAL REPORT

Report of the President

The past year has been one of stability and accomplishment. Several of the major goals set during the first five years of the Council's history have been attained and it has now assumed many of the important roles visualized by the **ad hoc** formative committee which met in 1970 and 1971. It has become the co-ordinating body of Canadian earth science societies in fact as well as in name and is now recognized as the political arm of the geosciences where group action is required.

Our major accomplishment of the year, perhaps of our short history, has been the establishment of a committee to study and advise on the operations of the Geological Survey of Canada. The Geological Survey's invitation to the Council to name a committee of distinguished scientists to scrutinize its program and to report on it to the geoscience community is probably a unique occurrence in Canadian government institutions. We are indebted to the six members of the Committee who have now completed their visits to the Survey's establishments across the country and who will present their first report early in 1977. We hope and expect that this mutually beneficial exercise will be emulated by many other scientific establishments in Canada.

The recent active participation of invited university and government scientists as non-voting members in our meetings is also a significant step forward. It makes our Council more truly representative of the entire geoscience community.

Another very important event of the year was the Council's assumption of the role of national representative for international geoscience. It now appoints national delegates to the International Geological Congress and the International Council of Scientific Unions and assumes overall responsibility for national activities concerned with the International Geological Correlation Program. Separate negotiations are underway with the American Geological Institute concerning joint international activities on this continent. All the details of these matters are handled by our newly appointed Foreign Secretary and a standing committee on international science.

The Council has now assumed responsibility for producing the annual report on Activities in Geoscience, the Geological Survey of Canada kindly continues to publish this volume in its new format. Our editorial committee also produced a special interim status report entitled "Aspects of the Geosciences in Canada" with the co-operation of a member society, the Canadian Society of Petroleum Geologists.

The Council has continued to support SCITEC, the Association of the Scientific, Engineering and Technological Community of Canada as it attempts to fill the need for communication and co-operation in national science and engineering. Council's representatives include some of our senior officers, past and present, and they are now playing leading parts in SCITEC's attempts to emerge as a Canadian equivalent of the American A.A.A.S. or the British A.A.S. It is significant that after playing the role of followers in such co-operative efforts for many years, geoscientists are finally emerging as leaders.

A special brief on the financing of non-governmental geoscience was prepared during this year and submitted at their request to senior officials of the Department of Energy, Mines and Resources. This submission is presently being up-dated and augmented by a Council committee of industrial and university geoscientists. Meanwhile, our affiliated group, the Committee of Heads of Canadian Geoscience Departments, is continuing to pursue the special issue of funding of university research through a series of meetings with senior government officials. Your president represented the Council at the first such meeting.

Other noteworthy developments include the organization of a Standing Committee of Provincial Geoscientists at the annual provincial Mines Ministers Conference held in St. John's in August. This group has been invited to join Council as an associate member and we take some pride in having acted as one of the catalysts in its formation. Our education committee has continued to be active and has been most successful in bringing earth science educators from across the country into contact with one another and in disseminating information to secondary school teachers on available literature and other materials. A scheduled series of workshops for teachers has had a mixed record — some outstanding successes where the right local people have been on hand as leaders, and some unexpected and unfortunate cancellations and failures.

One problem of Council has been the maintenance of ties with individual members of our constituent societies. We plan to overcome this problem by holding our meetings, including executive meetings in conjunction with scheduled events of various sections and divisions of our societies across the country. This policy has been successfully implemented already on a few occasions.

Council's plans for the immediate future include a panel discussion in Vancouver in April 1977 entitled "Earth Sciences Serving the Canadian Nation". This will be held in conjunction with the joint annual meetings of three of our member societies and will involve senior government scientists as panellists. Several of our member societies are working in conjunction to stage a major symposium on geochemical and geophysical methods in the search for mineral deposits, entitled "Exploration-'77". Our Council has recently re-established contacts with the Science Council of Canada and has been invited to make suggestions for major projects of that group. A joint meeting with the SCC is planned for early 1977. Much needed continuity of personnel and directed effort is slowly being imparted to the Council by the creation of standing committees. This process will continue and, hopefully, will involve more of our experienced past council members.

A great deal of the success of the Council's activities has been due to the presence of highly competent, well-informed delegates from our member societies. Most have held senior offices in their parent societies and have mandates to speak with authority and to make many decisions without first referring back to their society's executive committees. This and the pleasant informality that has gradually replaced the restraint of our early years makes for productive meetings which we feel are serving our member societies well and, through them, the whole Canadian geoscience community.

E.R.W. Neale
President
December 1976

Report of the Secretary-Treasurer

There were eleven Member Societies in the Council in 1976, a decrease of one from the previous year. The decrease was brought about by virtue of the Canadian Rock Mechanics Group becoming a technical committee of the Canadian Institute of Mining and Metallurgy, which is a Member Society. Table IV lists the Member Societies along with their objectives and activities. Invitations to all Council meetings are extended to the following organizations as observers:

– The Earth Science Division of the Royal Society of Canada
– The Committee of Chairmen of Canadian University Departments of Earth Science
– The proposed organization of Provincial Geoscientists.

Funding of the Council activities are obtained from three sources; a sustaining grant and contract from Energy, Mines and Resources, Canada, fees paid by Member Societies, and a grant from the Canadian Geological Foundation to assist with the activities of the Education Committee. The main expenditures of the Council are in support of the Education and Editorial Committees' activities. The Council pays membership fees to SCITEC, The Association of Geoscientists for International Development, and the Youth Science Foundation.

The Council held four meetings during 1976, the 20th in Ottawa in March; the 21st in Edmonton in May; the 22nd in Winnipeg in October; and the 23rd in Ottawa in December. In addition, it held a special meeting with senior officials of Energy, Mines and Resources, at which the report on the Status of Geosciences in 1976 was presented.

The membership of the Council in 1976 follows:

President – E.R.W. Neale
Vice-President – P.J. Savage
Past-President – R.L. Slavin
Executive Member – G. Perrault
Secretary-Treasurer – W.J. Eden
Executive Director – E.C. Appleyard
Foreign Secretary – W.W. Hutchison
Editorial Committee Chairman – C.R. Barnes
Education Committee Chairman – C.G. Winder
Manpower Committee Chairman – P.J. Savage

Member Society Representatives

Association of Exploration Geochemists
– G.J.S. Govett
Canadian Exploration Geophysical Society
– K.A. Morgan
Canadian Geophysical Union
– R.D. Russell
Canadian Geotechnical Society
– O.L. White
Canadian Institute of Mining and Metallurgy
– G.W. Mannard, A.F. Laurin
Canadian Society of Exploration Geophysicists
– P.J. Savage, W.D. Evans
Canadian Society of Petroleum Geologists
– M.E. Hriskevich, D.L. Barss
Canadian Society of Soil Science
– G.K. Rutherford
Canadian Well Logging Society
– W.D.M. Smith
Geological Association of Canada
– R.W. Macqueen, J. Lajoie
Mineralogical Association of Canada
– G. Perrault

W.J. Eden
Secretary-Treasurer
December 1976

Report of the Foreign Secretary

During 1976 the Canadian Geoscience Council established a position of Foreign Secretary to chair a standing committee on foreign relations. The approved objectives are as follows:

1. To advise the Canadian Geoscience Council, in its capacity as the Canadian National Committee for Geology, on its relations, with international non-governmental geoscience organizations or Canadian national committees of international geoscience organizations.
2. To act as a clearing house for relations among Canadian national geoscience committees and parent international non-governmental organizations in order to avoid possible duplication of effort.
3. To propose action required by the Canadian National Committee for Geology in responding to new international initiatives.
4. To ensure the Canadian National Committee for Geology is adequately represented in discussions of Canada's participation in non-governmental international programs or meetings wholly or in part dealing with geoscience.
5. To ensure that Canada is appropriately represented on international programs, projects or meetings for which the Canadian National Committee for Geology has national responsibility.

The Committee at the present time includes the Chairman of the Canadian National Committee for the International Geological Correlation Program, F.K. North, the Chairman of the Canadian National Committee for the Inter-Union Commission on Geodynamics, R.A. Price, the Secretary (Canada) of the International Union of Geological Sciences, T.E. Bolton, and R.D. Russell who is currently the Secretary-General of the Inter-Union Commission on Geodynamics. Other representatives of National Earth Science Committees will be invited to participate in this standing committee.

It is planned to have a first meeting of the proposed Foreign Relations Committee in the spring of 1977.

W.W. Hutchison
Foreign Secretary
December 1976

Report on International Geological Correlation Project

The title of this international program continues to be somewhat misleading. Far from being concerned wholly with "geological correlation", in the sense normally understood by stratigraphers or subsurface petroleum geologists, the program in fact embraces many aspects of regional, historical, and economic geology. The year 1975-76 saw this illustrated by increasing emphasis on

Precambrian problems and on both "hard rock" and "soft rock" economic geology.

A symposium on "Correlation in the Precambrian", held in Moscow in August and September, 1975, was attended by five Canadian participants and will undoubtedly lead to further Canadian activity. The International Board, at its annual meeting in March 1976, requested Canada to consider the sponsorship of a new project on "Archean Sedimentary Processes". Following consultations between specialists in this field, a project proposal is being submitted, in the name of Jan Veizer, to the International Secretariat's 1977 session. A proposal for a further project, "Sulphide Deposits in Mafic and Ultramafic Rocks", is being similarly submitted in the name of A.J. Naldrett.

Projects in which Canadian participation is so advanced that this country has hosted international meetings for them are those on Ophiolites, the Caledonide Orogen, and Circum-Pacific Plutonism. Other projects in which there is Canadian participation are those on Upper Triassic of the Tethys-Realm; Ecostratigraphy; Correlation of the Precambrian in Mobile Zones; Precambrian-Cambrian Boundary; Archean Geochemistry; Quaternary Glaciations in the Northern Hemisphere; Holocene Sea-level Changes; Correlation of Caledonian Strata-bound Sulphides; Pre-Pleistocene Tillites; Mid-Cretaceous Events; Standards for Computer Applications in Resource Studies; Global Correlation of Epochs of Folding; Genesis of Manganese ore deposits; Permo-Triassic Stage of geological evolution; Upper Precambrian Correlations; and Iron-formations of the Hamersley Basin.

F.K. North, Chairman
E.T. Tozer, Secretary
December 1976

Report of the Manpower Committee

Manpower studies are only useful if they are done extremely well. With the breadth of disciplines involved in the geosciences and the natural reluctance of volunteers to take on a job of this magnitude it would seem that a valid analysis of the Canada's earth science manpower position is beyond the capabilities of our Council. Indicative of some of the problems involved was the storm of protest brewed by the publication of the Technical Service Council's report on Future Supply and Demand of Engineers, etc. and the TSC's subsequent publication on an "improved" version entitled "Further Estimates".

The Canadian Council of Professional Engineers has set up a Canadian Engineering Manpower Council which has so far restricted itself to (a) criticizing the Technical Service Council report and (b) issuing safe, innocuous and relatively useless statistics.

The committee is considering several options for future activity in this regard:

a) Work with the Professional Engineers, if they will broaden their study to include geoscience.

b) Propose to the Science Council of Canada (either directly or through SCITEC) to finance a major study of manpower in the geosciences in particular or, if we work through SCITEC, scientific manpower in general.

c) Propose that either we or SCITEC consult with Statistics Canada with the object of improving their categories, definitions, etc. so that their numbers would be of more use. My conversations with Statistics Canada indicate that they realize how inadequate their data is in this regard and I believe they would welcome input from potential users.

P.J. Savage, Chairman
Manpower Committee
December 1976

Report of the Education Committee

The Resource Document for Secondary School Teachers was published in August 1975. Since that time, 750 have been distributed, most sold at $1.00 per copy. The actual cost of printing and mailing is now about $1.75. The document has become dated principally in the sections on books and literature. However, this is not sufficiently important that a revision cannot be delayed for another year. The rate of sales has dropped to a low level. A file of addresses of 300 teachers in Canada has been established.

The EdGEO program – weekend workshops for teachers – was started in May 1975, consisting of two days of lectures, demonstrations and a field trip. Professional earth scientists act as organizers, speakers and field trip leaders. Earth science teachers are usually in charge of the "hand's-on" workshop. Thus far, sessions have been held in Calgary, Winnipeg (two) and Wolfville, with a total registration of about 143 teachers. The organizers have up to $2000 for each workshop but the total expenditure thus far is less than $6000. During this last year organizations were started in Edmonton, Ottawa, Montreal and Quebec City, but workshops have not been held in these centres yet.

The Education Chairman gave a paper on earth science Workshops in Canada at the IGC Sydney, August 1976. The EdGEO program was described.

The composition of the CGC Education Committee is a Chairman, C.G. Winder, and one representative from each member society. Thus far, seven societies have elected members. A meeting of the committee was held in Edmonton, May 1976.

C.G. Winder, Chairman
Education Committee
December 1976

Summaries of the Main Achievements of the CGC Member Societies in 1976

The Association of Exploration Geochemists

The Association of Exploration Geochemists sponsored two major scientific meetings in 1976. The Sixth International Geochemical Exploration Symposium was held in August in Sydney, Australia as Section 10B of the International Geological Congress; there were four days of technical papers and discussions, with participants from all parts of the world. The proceedings of the Symposium will be published as a special 500-page issue of the Journal of Geochemical Exploration in mid-1977.

In Canada the Association organized the First Regional Meeting on "Exploration Geochemistry in the Appalachians" in Fredericton, New Brunswick. Despite the essentially local character of the topic, the meeting was attended by 190 delegates from 14 U.S. states, 8 Canadian provinces, and from the U.K., France, and Sweden. The proceedings of the meeting were published

as a special 298-page issue of the Journal of Geochemical Exploration.

The official scientific journal of the Association, the Journal of Geochemical Exploration, continues to grow. It now has an average of 800 pages per year, and there are about 1250 subscribers.

Two developments of special significance in the continuing evolution of the Association as a major scientific body occurred in 1976. A permanent office for the Association was established in Toronto, and the terms of a document for incorporation in Canada was approved by the Council. Apart from the importance of these developments in the general affairs of the Association, they are especially significant as an indication of the pre-eminant international position of Canadian geochemists. It is worth noting that despite the international scope and character of the AEG (members in 53 countries), 30 per cent of the members are Canadian, six of the seven presidents have been Canadian, and about 50 per cent of the Council members have been Canadian.

Whereas enormous pride is taken in the Canadian dominance, a large proportion of the leading Canadian exploration geochemists are foreign-trained. Given the importance of the minerals industry in the Canadian economy, there are serious misgivings concerning the continuing lack of adequate Canadian university-level facilities to provide for the expected increase demand for exploration geochemists both in Canada and abroad.

Canadian Exploration Geophysical Society

Throughout 1976 KEGS has maintained its active participation in most aspects of mining geophysics. Technical papers presented at monthly meetings have spanned a wide interest range. This range includes: current airborne geophysical instrumentation, case histories of geophysical techniques leading to the discovery of new orebodies, techniques in ground EM methods, new developments in EM research, and, to further increase the breadth of our members' knowledge, review of the Vibroseis seismic system as used in oil exploration.

In conjunction with the Prospector's and Developer's Association Annual Meeting, a special "Eye Opener" breakfast was held. The guest speaker was Frank Seward from the United Nations who discussed the role of the UN in mineral exploration.

In co-operation with the Toronto Geological Discussion Group, a special meeting was arranged with members of the Geological Branch of the Ministry of Natural Resources of Ontario. This meeting centred on aspects of geophysics and geochemistry in which the Geological Branch was actively involved. A good exchange of ideas on future direction in these areas was generated.

The Minister of Natural Resources of Ontario has requested a general dialogue concerning the apparent decline in the discovery of new orebodies in Ontario. KEGS responded with a request for a meeting to discuss the role of exploration geophysics in providing the basic data in which future ore discoveries are made. An encouraging response has been received from the Ministry and it is anticipated that KEGS will be able to directly address the government officials concerned in early 1977.

KEGS membership has stood at about 150 for the past several years. The Society continues to foster informal settings for meetings at which fellowship of its members is encouraged.

Canadian Geophysical Union

1. Meetings in 1976 and 1977

The Canadian Geophysical Union is a Division of the Canadian Association of Physicists and of the Geological Association of Canada, and has by custom held its Annual Meetings alternately with the CAP and the GAC. The 1976 Annual Meeting was held in June with the CAP at Laval University in Quebec City, June 13-17, 1976. Professor M.K. Séguin was Program Chairman for the CGU. Symposia were convened by Dr. E. Gaucher on Electromagnetic Methods; by Dr. C.E. Keen on the Lower Continental and Oceanic Crust; by Mr. J.L. Roy on Paleomagnetism; by Drs. P. Gagnon and P. Vanicek on trends in Modern Geodesy; and by Dr. E.R. Pounder on General Geophysics. About 150 geophysicists attended the various sessions.

A meeting of the Seismological Society of America, co-sponsored by CGU, was held at the University of Alberta, May 11-14, 1976. Professor E.R. Kanasewich was Chairman of the meeting and Professors E. Nyland, F. Hron and G.L. Cumming are other CGU members who worked to organize a highly successful meeting. Sessions on lateral inhomogeneities, general seismology, recent earthquakes, seismicity, mantle-core structure, wave propagation, seismic risk and engineering seismology, seismic source function and seismic array studies were attended by 131 registrants.

The principle meeting of the CGU in 1977 is planned with the GAC, SEG and MAC in Vancouver, April 25-27, 1977. Dr. R.D. Russell is Program Chairman for the CGU and is representing us on the combined committee. Symposia so far planned include the following likely to interest CGU members: Possible large-scale displacements in the northern Cordillera; Resources for the future; Thermal structure and history of the Cordillera; Geothermal energy; Regional overview of the Northwest Pacific and Margin; Seismology and Rock Magnetism Workshops. General sessions on Geophysics will also be held.

CGU is being represented by Dr. H.O. Seigel in the planning of a Mineral Exploration Technology Symposium. This symposium is planned for October 1977 to coincide with the 10th anniversary of the highly acclaimed "Canadian Centennial Conference on Mining and Ground Water Geophysics". The 1967 Conference was instigated by the forerunner of the CGU.

2. Canadian Geophysical Bulletin

Production of this Bulletin is the responsibility of the Canadian National Committee for the IUGG, but CGU is deeply committed to support of the Bulletin as an organ of communication between researchers in geophysics in Canada. Dr. R.M. Farquhar edited the 1975 Bulletin, whose publication and distribution were taken over from the National Research Council by Earth Physics Branch, Department of Energy, Mines and Resources, through the good offices of Dr. K. Whitham. The National Reporters of CGU compiled various sections of the Bulletin.

3. International Relations

The Canadian National Committee for the IUGG (CNC/IUGG) consists of fourteen members of which five are allocated to the CGU. Our nominees on the CNC/IUGG are:

for IASPEI — Dr. K. Whitham (Chairman, CNC/IUGG)
— Dr. A.E. Beck

for IAG – Dr. J.G. Tanner
for IAGA – Dr. D.I. Gough
for IAVCEI – Dr. R.D. Russell

Two or three of these will be replaced after the IUGG meeting in Canberra in 1979.

Dr. D.I. Gough attended, as CGU representative, a meeting convened in Ottawa by the Royal Society of Canada on January 30, 1976, to consider the formation of a Canadian Council for ICSU (International Council of Scientific Unions). The Canadian Council for ICSU would represent Canadian science in the sphere of ICSU, a function now carried by the National Research Council. The Royal Society has offered to act as contractor to the Government of Canada for financial support of the CC for ICSU, and the services of its secretariat. At the January 30 meeting a first draft describing the CC for ICSU was drawn up and this is now under consideration by scientific societies. The Council as proposed would consist of the chairmen of the National Committees for the Scientific Unions (in our case the chairman of CNC/IUGG) and one representative of the Royal Society. The initiative for this action comes from Dr. G.D. Garland. CGU at its 1976 Annual Meeting unanimously supported the formation of a Canadian Council for ICSU.

Canadian Geotechnical Society

The year 1976 has seen the continuation of the practice of having the technical activities of our society concentrated within local sections established in eleven cities across Canada, yielding a Society membership of over 700 and a total local membership of perhaps twice this number. Each local section has an administrative council which organizes its own technical program, usually consisting of monthly meetings. Each year these programs are enriched by two cross-country lecture tours, conducted by leading geotechnical specialists, and organized and financed by the NRC Associate Committee on Geotechnical Research and by Canadian universities.

The annual Canadian Geotechnical Conference (the 29th) was held in Vancouver and was attended by about 260 people. The conference was concerned with "Slope Stability" and it focused on topics related to regional studies, hydrogeology, analytical techniques, case histories, and sensitive clays. The success of the conference was ensured by the fine work of the organizing committee of the CGS Vancouver Section and the Engineering Geology Division of the Society. Many papers presented at the conference will be published in the Canadian Geotechnical Journal which is in the 17th year of printing, currently under the very capable editorship of Dr. J. Bazett.

Another important communication link between our Society and its members is our Newsletter which is published 6 times each year. It provides information about Society activities, conferences, short courses, publications and vacant positions in the geotechnical field. The Newsletter is written by W.J. Eden of the Division of Building Research, NRC, to whom we are most grateful.

The Canadian Geotechnical Society presented two awards during 1976. The R.F. Legget Award, in recognition of achievements and contributions in the field of geotechnical engineering in Canada, was presented to A.G. Stermac for the very important part he has played in the geotechnical community as editor of the Canadian Geotechnical Journal and as Chairman of the Committee which produced the Canadian Manual on Foundation Engineering. The Canadian Geotechnical Society Prize for the best paper in the Canadian Geotechnical Journal in 1975 was awarded to P.E. Grattan-Bellew and W.J. Eden for their paper "Concrete Deterioration and Floor Heave due to Biogeochemical Weathering of Underlying Shale".

Canadian Society of Exploration Geophysicists

In 1976 the geophysical industry in Canada enjoyed a period of relative stability. As a result the Canadian Society of Exploration Geophysicists (CSEG) was able to concentrate its efforts on the main objectives of fostering technical excellence and fellowship within its membership.

Because of successes in previous years the Society presented the Fourth Annual CSEG Convention. This event again was very successful and provided the membership with many excellent interdisciplinary and specialized papers of current geophysical and geological interest. In addition to the Manor Annual Convention the Society has sponsored and has developed plans for several continuing education courses. These include the New Seismic Interpreter given by Nigel Anstey, a short course on Vibroseis, and Well Logging for Geophysicists.

To provide fellowship and continuing cross-fertilization of ideas between geophysicists and geologists the CSEG and the Canadian Society of Petroleum Geologists (CSPG) have joined forces to sponsor two major technical functions in early 1977. A joint CSEG/CSPG Poster Convention is being organized for March '77. This will provide an opportunity for members of both Societies to discuss recent advances with the authors of important papers who are recognized authorities in their field. Also the two societies jointly invited the Society of Exploration Geophysicists and the American Association of Petroleum Geologists to present their widely acclaimed school on Seismic Stratigraphy in Calgary in April 1977.

In September 1977 the CSEG will organize and host the Annual SEG Convention. The organizational committee made up of CSEG members has spent much of 1976 planning for this event. Several innovations promise to make this Convention one of the best.

In 1975 the Society undertook the publication of A History of Petroleum Geophysics from inception to 1950. Preparation of this history continued through 1976 for publication in 1977. In 1976 the Society undertook to prepare and publish a major technical publication – Geophysical Exploration in Canada. This will be a Thirtieth Anniversary Commemorative Volume to be published in 1979. It is also planned to have the contributions to this publication presented at the Annual CSEG Convention in 1978.

Although the industry has been stable for the past year, government action in 1976 could result in disruptive effects on the industry in years to come. The first action of concern to the industry was the proposed Petroleum and Natural Gas Act and the new Canadian Oil and Gas Land Regulations. Unfortunately many aspects of these proposed regulations are not considered conducive to a healthy petroleum industry. Thus the CSEG in 1976 prepared a representation to the Departments of Energy, Mines and Resources and Indian and Northern Affairs. The second government action of concern to the industry was the Alberta Government announcement to terminate the Alberta Seismic Incentive Program on March 31, 1978. Because of past contributions of the CSEG regarding this program the Society was asked to prepare a brief to a task force which has been established to make recommendations regarding future government programs. This brief has been presented to the task force.

The Society continued to provide assistance in the form of scholarships to students at post-secondary institutions. In 1976 scholarships were awarded to students at University of Alberta, University of British Columbia, and Northern and Southern Institutes of Technology of Alberta.

The CSEG also recognizes members for outstanding contribution. In 1976 awards were given for Best Paper and Meritorious Service.

Canadian Society of Petroleum Geologists

The Canadian Society of Petroleum Geologists comprises 2308 members of which 2049 are active and the remainder are student, honorary, associate, and corporate. During the past four years, membership in the Society has been increasing at an average rate of 100 new members per year.

A number of divisions have been formed within the framework of the Society which deal with special interests such as paleontology, structural geology, geochemistry, geomathematics and computer application, and coal. These divisions arrange for meetings of smaller groups to discuss problems of special interest.

Area representatives are located in Victoria, Edmonton, Saskatoon, Ottawa, Quebec, Dartmouth, and Houston and they keep in touch with the Executive of the Society in Calgary.

Principle Activities

A) Conferences and Symposia

The Society has been instrumental or played a large role in the staging of the following conferences and symposia:

1. CSPG/CIM Joint Symposium on Enhanced Recovery; June 7-11, 1976. The symposium included a core conference dealing with the reservoirs of seven specific oil fields.
2. Core Conference on Clastic Reservoirs of Alberta; June 2 and 3, 1976. Ten oil and gas fields of Alberta which produce from clastic reservoirs were discussed.
3. National Conference on Earth Sciences, with the Banff Centre of Continuing Education, on Sequence Concepts in Petroleum Exploration; May 3-7, 1976. Lecturers were Dr. A.A. Hallam, Oxford, Dr. L.L. Sloss, Northwestern, B.F. Burollet, Compagnie Francaise de Petrole, J.M. Denison, North Carolina, R.M. Mitchum, Exxon, and P.R. Vail, Exxon.

B) Publications

Publications comprise a very important aspect of the Society's activities. Eleven separate committees are involved with publications which range from printing the directory of Members, to publishing the Bulletin of Canadian Petroleum Geology. A number of special editions are in preparation and others are in various stages of planning. The main publications in 1976 were:

1. The Bulletin of Canadian Petroleum Geology, a quarterly publication. During 1976, 28 papers were published.
2. CSPG Reservoir, which is published monthly, brings news to the membership of the Society's activities, reports from the Society's area representatives, etc.

C) Speakers – Technical Program

1. Calgary Program – Perhaps the single most important activity of the Society is the Technical Speakers' Program. During 1976, nineteen luncheon meetings took place in Calgary at which total attendance was more than 8000, with an average attendance of about 400. Subjects discussed ranged from "Chalk Diagenesis" to "Hydrocarbon Potential of the Labrador Shelf".
2. Distinguished Lecture Tour, Link Award Tour, and Business Trip Talks are intended to bring the significant contributions to the study of the Geology of Canada as applied to petroleum exploration geology to the attention of university geology students across Canada. The first two are formalized tours whereas the Business Trip Talks are intended to take advantage of business travel by members of Industry to areas (universities) where talks on petroleum geology can be given to students and staff of universities on rather short notice.

D) Other Education Programs

Other educational programs involve eleven additional committees. These include awards committees, for judging the best published papers, and oral presentations, recommendations for scholarships and prizes for students, special publications, etc.

E) Business Affairs

Twenty-one committees look after the Society's business affairs which include a variety of activities ranging from a committee dealing with revisions of the Constitution and By-Laws to one dealing with Financial Audit.

Canadian Society of Soil Science

The Canadian Society of Soil Science membership comprised 360 in 1976 of which 16 are Fellow-Life Members and 19 are new members. Some 33 are recorded as being presently overseas. Although soil science studies, education and research were initiated and nurtured by agriculture in Canada there is an increasing awareness by members of the CSSS of the importance of soils as perhaps Canada's most important continuing natural resource. The interest in soils is reflected by the range of membership in such fields as agriculture, forestry, land use planning, natural resources, geochemical prospecting, archeology, industry, physical geography, etc.

Activities in which members of the Canadian Soil Science Society are involved or indirectly include:

(i) 11th Congress of the International Society of Soil Science which is to be held in Edmonton in August 1978 when several thousand Canadian and foreign participants will meet. Local, provincial, trans-Canada and Arctic tours are being arranged.

(ii) Soil Methods Manual and Reference Soil Samples. "A Manual on Soil Sampling and Methods of Analysis" has been prepared by Agriculture Canada. A limited number are available from the Soil Research Institute and critical comments and suggestions are canvassed. Reference soil samples have been prepared for elemental and general soil analysis and earth science workers are welcome to apply for subsamples to Mr. B.H. Sheldrick, Soil Research Institute, Agriculture Canada, Ottawa, K1A 0C6.

(iii) National Film Board "Soils of Canada". This film sponsored by Agriculture Canada is being produced for 1978 and will demonstrate the many faces and uses of Canadian soils and indicate the problems confronting Canada's limited soil resources.

(iv) Textbook. The CSSS has appointed a subcommittee to investigate the possibility of producing a textbook on the soils of Canada, their properties, uses and future problems. The Canadian Geoscience Council's report for 1977 will be titled "Soil Science" and is edited and produced in association with members of the CSSS.

(v) Relationship to parent body The Agriculture Institute of Canada. As many members of the CSSS are not engaged in agricultural activities of any kind, the Society is somewhat concerned over the proposed reorganization of the Agriculture Institute of Canada and is following this development closely.

(vi) Soil and Earth Science Information System (CANSUS). This information computing and retrieval system (CANSUS) is becoming operational and it is hoped that all earth science workers will contribute to this vital knowledge bank which is being established. Information may be obtained from Dr. J. Dumanski, Soil Research Institute, Agriculture Canada.

(vii) International Conference on Land for Waste Management. The proceedings of this conference which was co-sponsored by the CSSS are now available from Agriculture Canada.

(viii) Honours. The CSSS honoured two members with Fellowships for their contribution to Canadian soil studies. One able member was honoured by an Agriculture Institute of Canada Fellowship for his work in soil fertility and soil chemistry.

(ix) Annual Meeting. The annual meeting was held at Halifax in association with the Agriculture Institute of Canada's annual meeting. In addition to member paper sessions a Soil Users Symposium was held which included invited papers on Soil Survey Information for Canadian Forestry, the potential production of marine sediments, soils surveys for urban and rural planning and land use planning.

Canadian Well Logging Society

The Canadian Well Logging Society awarded the "President's Award" for the first time during 1976 to Al Heslop of Imperial Oil, Calgary, for his paper on shaly sand analysis. The award attracted considerable attention among the Society members and a number of good papers in Petrophysics resulted in 1976. Technical presentations during 1976 were limited to the luncheon meeting format but plans have been formulated for a seminar series in 1977. The technical papers presented in 1976 were often of outstanding quality. Papers on over-pressure problems on the one hand and gas recovery problems on the other reflected the wide interest and varying background of Society members.

The CWLS plans to hold a Symposium in September, 1977. The chosen theme is "Formation Evaluation – The Team Approach". A two or three-day meeting is planned and some twenty technical papers will be presented.

During 1976 the Rw Catalogue was again reviewed and updated by the Society. The CWLS Journal was again published early in the year and contributions to the 1976 Journal will be received until the end of the Calendar year.

Geological Association of Canada

Membership of the Geological Association of Canada continued to increase throughout the year, reaching 2756 in November, 1976. The Association held a successful annual meeting in Edmonton during May, in conjunction with the Mineralogical Association of Canada, which was attended by over 750 geoscientists.

The Logan Medal was awarded to Dr. R.J.W. Douglas of the Geological Survey of Canada for his considerable contributions to the advancement of the geosciences in Canada. The Past President's Medal was presented to Dr. H. Williams of Memorial University of Newfoundland, in recognition of his outstanding work in Canadian Appalachian geology.

Beside the regular publications of the Association, Geoscience Canada and Geolog, several other books were made available to geological workers. Special Paper No. 14, a 660 page volume, entitled "Metallogeny and Plate Tectonics", appeared in the summer of 1976. This book, edited by D.F. Strong, was preceded by two other, smaller publications. Respectively, these were "Garibaldi Geology" by W.H. Mathews, and Information Circular No. 2, "Status of Women Geoscientists in Canada" edited by N. Allman. Two other GAC Special Papers, "Conodont Paleoecology" edited by C.R. Barnes and "Volcanic Regimes in Canada" edited by W.R.A. Baragar are currently in page proof stage and should be out early in 1977. A Special Paper entitled "Siluro-Devonian Fossils" edited by A.C. Lenz, D.E. Jackson and A.E.H. Pedder is nearing completion. Information Circular No. 3 on sources of free or inexpensive materials for use by instructors in the geological sciences is also nearing completion.

The 1977 meeting of the Association will be held with the MAC and the Society of Economic Geologists in Vancouver in late April. The 1978 meeting, which is expected to be a major conference, will be held in October in Toronto, jointly with MAC and the Geological Society of America, together with attendent Associations and Societies. The 1979 annual meeting will be held in Quebec City and the meetings for 1980 and 1981 will be held in Halifax and Banff respectively.

TABLE IV. Data on member societies of the Canadian Geoscience Council

SOCIETY AND MEMBERSHIP	OBJECTIVES	MEETINGS, ACTIVITIES & COMMITTEE (attendance in parentheses)	PUBLICATIONS
ASSOCIATION OF EXPLORATION GEOCHEMISTS P.O. Box 523 (Metropolitan Toronto), Rexdale, Ontario, M9W 5L4 Active membership in Canada 175 Student membership in Canada 15 Corporate members in Canada 5 World membership 552	To represent the professional interests of persons specializing in exploration geochemistry; to advance mineral exploration applications of geochemistry; to disseminate geochemical information and ideas among professional geochemists.	– Annual General Meeting Fredericton, N.B. (30) – Sixth International Geochemical Exploration Symposium, Sydney, Australia – First Regional Meeting, "Exploration Geochemistry in the Appalachians", Fredericton, N.B. (190) – Five Council Meetings COMMITTEES: Admissions Case History Geochemical Analysis Research and Education Bibliography Computer Applications Membership Technical Meetings	Journal of Geochemical Exploration (6 issues/year) Newsletter (quarterly to members only) Exploration Geochemistry in the Appalachians (298 p., Amsterdam: Elsevier) Selected Mineral Deposits of New Brunswick, 108 p. Field Guidebook for Exploration Geochemistry in the Appalachians Special Volume No. 4. Applications of Probability Graphs in Mineral Exploration Special Volume No. 5. Exploration Geochemistry Bibliography, Period January 1972 to December 1975
CANADIAN EXPLORATION GEOPHYSICAL SOCIETY (KEGS) c/o Ken Morgan Secretary-Treasurer Gulf Minerals Canada Ltd. Suite 1400 110 Yonge Street, Toronto, Ontario, M5C 1T4 Active members in Canada 121 Members outside Canada 9 Student members 14 153	To promote mining geophysics, to encourage the flow of information between mining geophysicists, to represent mining geophysicists, when possible, in representations to governments on matters directly involved in the performance of mining geophysics, and to promote high professional standing and fellowship among its members.	– Eight meetings (60), all business/technical meetings are held on the second Tuesday of each month from October to May – "Eye Opener" Breakfast (85) featuring a guest speaker in conjunction with the Prospector's and Developer's Annual Meeting in Toronto, March. A Committee (3) is receiving suggestions on metric conversion, particularly with regard to mining geophysical surveys	No formal journal. Abstracts, summaries, and complete papers of talks given to KEGS are appended to the monthly notice of meetings and announcements mailed to all members.
CANADIAN GEOPHYSICAL UNION c/o Dr. R.F. Mereu (Secretary-Treas.) Department of Physics University of Western Ontario London, Ontario, N6A 3K7 Active membership in Canada 291	To advance the science of geophysics and to promote a better understanding thereof throughout Canada.	– Inaugural Symposium, Ottawa 22 February 1974 (100) – Annual Meeting (with CAP) 10-13 June 1974, St. John's (50) – Annual Meeting (with GAC) May 1975, Waterloo (100) – Symposia (with CAP), June 1975, York (50) – Annual Meeting (with CAP) 14-17 June 1976, Laval (100) – Symposia (with SSA), 9-11 May 1976, Edmonton (40) SUBDIVISIONS: Gravity, Seismology and Physics of the Earth's Interior; Exploration Geophysics; Geomagnetism, Geochronology and Stable Isotope Studies; Geodesy; Mathematical Geophysics.	Canadian Geophysical Bulletin
CANADIAN GEOTECHNICAL SOCIETY c/o Dr. G. Ballivy (Secretary) Civil Engineering Department Sherbrooke University Sherbrooke, Quebec Members 632 Student members 88 Affiliates 34 Of the 754 total membership, 550 are members of the Engineering Institute of Canada of which the Canadian Geotechnical Society is a constituent society.	To stimulate activities and cooperation among engineers and other professionals for the advancement of knowledge in the geotechnical field in Canada. This includes the study of the properties of soil, rock muskeg, snow and ice, the influence of environmental factors on such properties and the application of this knowledge in practice.	– 29th Annual Canadian Geotechnical Conference, Vancouver, 13-16 October 1976 included annual business meeting and presentation of awards (260) – One session of Annual Congress of Engineering Institute of Canada arranged by CGS in Halifax on October 8, 1976 (40) – Board of Directors met twice – Local sections meet approximately 9 times per year for technical sessions.	Canadian Geotechnical Journal published by National Research Council is part of the membership fees Society Newsletter is circulated every other month
CANADIAN INSTITUTE OF MINING AND METALLURGY c/o E.G. Tapp (Executive Director) Suite 400, 1130 Sherbrooke St. W., Montreal, Quebec, H3A 2M8. Total CIM membership 11 000 In Geology Division 2750	(Geology Division). To stimulate and advance the application of geology, geophysics, and geochemistry in the exploration for, and development and exploitation of, mineral resources by arranging technical discourses, lectures, and discussions; by publication of technical papers; by sponsoring field excursions; and by the promotion and encouragement of research and education in the earth sciences.	– Numerous Branch Meetings COMMITTEES (Geology Division): Publications; University Visiting Lecturers; Technical Program; Barlow Memorial Medal; Mineral Deposits Research; Student Essays; Geophysics; Geochemistry; Distinguished Lecturers; Program Policy; GAC-SEG Liaison; Nominating.	The Canadian Mining and Metallurgical Bulletin (CIM Bulletin) – monthly The Journal of Canadian Petroleum Technology – quarterly The Canadian Metallurgical Quarterly – quarterly The CIM Directory – yearly Special Volumes – 75 to date

TABLE IV (cont'd.)

AWARDS	BRIEFS AND POSITION PAPERS	ASSOCIATION WITH OTHER ORGANIZATIONS Canadian and (non-Canadian)	OTHER INFORMATION
Constitution provides for Honorary Members.	AEG has taken the position of defining the qualifications of the professional Exploration Geochemistry and is distributing this information to membership. This definition will be used in future presentations to licensing bodies in an attempt to establish an equitable and satisfactory standard of professionalism in exploration geochemistry on a world-wide basis.	Canadian Geoscience Council	The Association of Exploration Geochemists (AEG) was founded in 1970 in Toronto as an international organization. Although about 30 per cent of the members are Canadian, the Association has members in 53 countries. The leading position of Canadian exploration geochemistry is indicated by the fact that six of the seven presidents and approximately one-half of the Council members to date are Canadians.
– Don Salt Memorial Scholarship is awarded to the most promising third and fourth year students in geology or geophysics at the University of Toronto.	Letters to the Minister, Ontario Ministry of Natural Resources, concerning the recent decline in exploration activity in Ontario and suggesting a meeting to discuss ways of encouraging mining geophysics in Ontario which is the basis of nearly all exploration activity.	Canadian Geoscience Council Society of Exploration Geophysicists	KEG was formed June 8, 1953 by a small group of mining exploration geophysicists in Toronto. Members probably represent, by their employment, 90% of the mining exploration in Canada. Approximately one quarter of the members now reside outside Toronto with members living in most provinces in Canada and as far abroad as South Africa.
		– Joint Division of the Geological Association of Canada and the Canadian Association of Physicists – Canadian Geoscience Council	
– R.F. Legget Award to an individual for significant achievements to Canada in the field of geotechnical engineering; not given every year – Society Prize awarded annually for the best paper published in the Canadian Geotechnical Journal.		Canadian Geoscience Council Constituent Society of the Engineering Institute of Canada Links with the National Research Council of Canada Associate Committee on Geotechnical Research International Society of Soil Mechanics and Foundation Engineering (Engineering Geology Division – International Association of Engineering Geology)	12 local sections of CGS exist at major cities and are partially supported by a rebate from Headquarters.
CIM awards pertaining to Geology Division: Distinguished Lecturer Award, Barlow Memorial Medal Prize, Student Essay Awards and the President's Gold Medal.		Canadian Geoscience Council Canadian Standards Association (World Mining Congress) (Council of Commonwealth Mining and Metallurgical Institutions) (A.I.M.E. Council of Economics) Mining Society of Nova Scotia	The Geology Division is an integral part of CIM which is a technical society covering the entire range of mining and mineral processing technology. In addition to those in Geology Division, many geoscientists belong to other CIM Divisions and Societies, notably the Coal Division, the Industrial Minerals Division and the Petroleum Society. Large numbers of others participate in the activities of the 54 branches.

TABLE IV (cont'd.)

SOCIETY AND MEMBERSHIP	OBJECTIVES	MEETINGS, ACTIVITIES & COMMITTEE (attendance in parentheses)	PUBLICATIONS
CANADIAN SOCIETY OF EXPLORATION GEOPHYSICISTS P.O. Box 117, Calgary, Alberta, T2P 2G9 Active membership 1200+ Honorary Members 6 Corporate Members 40	To promote the science of geophysics especially as it applies to exploration in the fields of petroleum, mining, and groundwater, and to promote fellowship and co-operation among those persons and organizations.	– One General Meeting per year (500) – One Executive (10), and one or more Technical Meetings per month (300) – One National Convention per year (800) (Withdrawn in favour of SEG Convention in 1977) COMMITTEES. Approximately 25 committees administer the professional technical and social affairs of the Society. – Registered Scholarship Fund to administer scholarships to deserving students. – Sponsor Continuing Education Program including one or two courses per year.	Journal of the Canadian Society of Exploration Geophysicists – published annually on a regular basis plus special editions. Monthly newsletter, "CSEG Recorder".
CANADIAN SOCIETY OF PETROLEUM GEOLOGISTS c/o Miss K. Leskiw (Secretary) 612 Lougheed Building Calgary, Alberta, T2P 1M7 Active Members in Canada 1959 Active Members – Foreign 98 Associate Members – Canada 54 Associate Members – Foreign 1 Student Members in Canada 116 Student Members – Foreign 2 Honorary Members 17 Emeritus Members 6 Corporate Members 71 2324	To advance the science of geology especially as it relates to fossil fuels; to promote the technology of exploration for these resources; to foster scientific research, to disseminate relevant information; to inspire and maintain a high standard of professional conduct.	– Annual Meeting (300) – Technical Meetings, 20 luncheon meetings (avg. 350) – Technical Symposia, two, one CSPG – CIMM Enhanced Recovery Symposium (555) CSPG Core Conference (500) COMMITTEES: Membership, Technical Program, Medal and Merit, Link Award, Geological Research, Stratigraphic Nomenclature, Discipline, Printing, Paleontology Div., Structural Geology Division, Geochemistry Division, Geomathematics Division, Coal Division, 1976 CSPG/CIM Convention Committee, 1978 International Convention Committee.	Approximately 40 special committees administer business, social and technical functions as well as liaison with other organizations. Bulletin of Canadian Petroleum Geology – quarterly Reservoir – monthly newsletter Symposia and Memoirs on special subjects. Field trip guide books.
CANADIAN SOCIETY OF SOIL SCIENCE c/o Dr. G. Wall, Department of Soil Science Guelph University Guelph, Ontario Total membership 360 Active in Canada 330 Honorary 16	To foster all branches of soil science: to provide a forum to enable soil scientists to make known their views on matters pertaining to earth science: to voice concern over use of earth materials as a vital continuing natural resource in Canada.	– Annual Business Meeting Brandon, Manitoba, June 25, 1975 – Three Technical Sessions 23 25th June, 1975 – Two Council Meetings February and June 1975 COMMITTEES: Journals, Awards, International Activities, Rules. SUBCOMMITTEES: Ad hoc committees for resolutions, collecting of data on members professional interests.	Canadian Journal of Soil Science Three issues per year. Average pages per issue, 150.
CANADIAN WELL LOGGING SOCIETY c/o Secretary P.O. Box 6962, Postal Station D Calgary, Alberta, T2P 2G2 Active members 310 Honorary members 5 Corporate members 15 (about 5-10% eligible are members, most from the Calgary area)	To further the science of formation evaluation by providing regular meetings with discussion of related subjects and encouraging research and study.	– nine Luncheon Meetings (avg. 115) – Annual Meeting in February (75) – nine Executive Meetings COMMITTEES: Membership, Publication Sales, CWLS Journal Editor and Business Manager, Nominating Award, 1977, Formation Evaluation Symposium Organizing, Water Resistivity Catalogue, Well Log Standards.	The CWLS Journal – annually CWLS Symposium transactions – published occasionally, next – 1977 Formation Water Resistivity Catalog-published occasionally revision in 1975 Guide on Metric Conversion for Well Logs
GEOLOGICAL ASSOCIATION OF CANADA c/o Dr. A.V. Morgan (Secretary) Department of Earth Sciences University of Waterloo Waterloo, Ontario, N2L 3G1 Fellow 1750 Associates 830 Retired 48 Honorary members 7 Life members 4 Patrons 1 2640 Corporate members 86 2726	To advance the science of geology and closely related fields of study and to promote a better understanding thereof throughout Canada.	– Annual Meeting, May 1975, Waterloo (1213) – Annual Meeting, May 1976, Edmonton (750) – Council and Executive Meetings, Sections and Divisions meet independently COMMITTEES: Finance, Program, Projects Membership, Editorial, Public Information, Professional Status, Status of Women, Education, Logan Medal, Past Presidents' Medal.	Geolog – Newsletter published quarterly Geoscience Canada – published quarterly Special Papers – Fourteen so far in series Canadian Journal of Earth Sciences – Published by National Research Council and included in GAC membership fees
MINERALOGICAL ASSOCIATION OF CANADA c/o Secretary, Department of Mineralogy and Geology, Royal Ontario Museum 100 Queen's Park Toronto, Ontario, M5S 2C6 Ordinary members 664 Life members 25 Student members 182 Corporate members 569 Sustaining members 31 Total membership 1471	To advance the knowledge of mineralogy, crystallography, petrography, geochemistry, economic geology and applied disciplines of the earth sciences.	– Executive Committee Meetings – Technical Meetings – Business Meeting COMMITTEES: Finance, Membership, Nominating, By-Law Revision, Hawley Award and Standing Committees for Canadian Geoscience Council Annual Reports.	Canadian Mineralogist – quarterly Newsletter – semi-annually.

TABLE IV (cont'd.)

AWARDS	BRIEFS AND POSITION PAPERS	ASSOCIATION WITH OTHER ORGANIZATIONS Canadian and (non-Canadian)	OTHER INFORMATION
– Best Paper Award, Honorary Membership, Meritorious Service Awards – Student Scholarships	Semi-Annual reports to both Provincial and Federal governments on Geophysical Activity in Canada. Semi-Annual reports to both Provincial and Federal governments on crew availability. Annual reports to Provincial and Federal governments on geophysical data trading in Canada. Annual report to Provincial and Federal governments on geophysical data processing in Canada. Position papers as required.	Canadian Geoscience Council Association of Professional Engineers, Geologists and Geophysicists of Alberta Canadian Exploration Geophysical Society (As to statistics) Other geological, mathematical and physics Societies as to joint meetings (Society of Exploration Geophysicists) (World Petroleum Congress)	Will host the Society of Exploration Geophysicists' International Convention in September, 1977.
– Medal of Merit, annual for best published paper related to geology of sedimentary areas of Canada. – Link Award, annual for best oral presentation of geological paper to the society by one of its members. – Research and Graduate Student Awards for postgraduate theses of merit. – Undergraduate Award, a certificate awarded to one undergraduate from each of the 34 degree-granting institutions in Canada for outstanding competence in petroleum geology or related fields. – Western Inter-University Award, annual for best oral presentation by a student at the Western Inter-University Geological Conference.		Canadian Geoscience Council Saskatchewan Geological Society Association of Professional Engineers, Geologists and Geophysicists of Alberta (American Association of Petroleum Geologists) (World Petroleum Congress)	
– Fellowship Award, Fellow of the Canadian Society of Soil Science. – CSSS has input into various Agricultural Institute of Canada awards, Royal Bank Award, and Ministry of State for Science and Technology award in Agriculture and Technology		Agricultural Institute of Canada – affiliated, joint meetings and office services Canadian Geoscience Council SCITEC Canadian Society of Agronomy (International Soil Science Society) (1978 ISSS Congress to be hosted by CSSS) (North East Section, American Society of Agronomy)	
President's Award ($500) for best paper in formation evaluation. First presentation in 1976.		Canadian Geoscience Council Annually a joint luncheon meeting is held with the Petroleum Society of CIM (Society of Professional Well Log Analysts – U.S.A.)	
– Logan Medal – annual for outstanding contributions to the Earth Sciences. – Past Presidents' Medal, annual for a single outstanding achievement in the Earth Sciences. – Youth Science Foundation, two awards given annually for the best Earth Science exhibit at National Science Fair.	Information Circular No. 2 entitled "Status of Women Geoscientists in Canada" was published in 1976. Information Circular No. 3 describing sources of free geological literature and materials is currently under preparation.	Canadian Geoscience Council SCITEC Joint Annual Meetings with Mineralogical Association of Canada and bi-annually with the Canadian Geophysical Union Annual Meetings are frequently organized with other associations: 1977 the Society of Economic Geologists, 1978 the Parent Body of the Geological Society of America, 1979 Canadian Geophysical Union (American Commission on Stratigraphic Nomenclature) (World Petroleum Congress)	Divisions of GAC: Environmental Earth Sciences, Geophysics (Canadian Geophysical Union), Paleontology, Precambrian Stratigraphy, Structural Geology, Volcanology. Regional Sections of GAC exist in Edmonton, Newfoundland, Winnipeg and Vancouver (Cordilleran), with a branch of the Cordilleran Section in Victoria.
Hawley Award – presented annually to the author(s) of the best paper printed in the Canadian Mineralogist during the preceding year. Awarded in 1976 to Ralph Kretz.		Joint meetings with Geological Association of Canada Canadian Geoscience Council (International Mineralogical Association) (Joint Committee on Powder Diffraction Standards) (Joint meetings with Mineralogical Society of America)	It is interesting to note that of the ordinary membership, approximately 45% is in Canada, 40% in the U.S. and 15% in other countries.