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Annual report and review of Soil Science

Prepared by
The Canadian Geoscience Council

Edited by: G.K. Rutherford, B.P. Warkentin and P.J. Savage

Energy, Mines and Resources Canada
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THE GEOSCIENCES IN CANADA, 1977
ANNUAL REPORT AND REVIEW OF SOIL SCIENCE

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Preface

In this, the fourth annual report of the Canadian Geoscience Council, the importance of the geosciences to Canada is again well documented. Part 3 consists of the Council's annual report, summaries of our member society's activities and achievements, and significant position papers and reports. Part 2 is the in-depth report Soil Science in Canada. Part 1 is a Rationale for the Soil Science report followed by a summary and analysis of that report. In addition, information is tabulated on the significant hydrocarbon and metallic mineral discoveries in Canada during 1975-1977.

To most Canadians our soil, while admittedly useful, is something that will always be there. Its permanence as a natural resource is taken for granted. Perhaps we should recall W.C. Handy's "you'll never miss the water till your well runs dry". The Geoscience Council, through efforts of the Canadian Society of Soil Science, presents the Soil Science in Canada report in the hopes that the understanding of this resource will be enhanced and that its proper management will not come too late.

In past reports our Council has made a number of significant comments and recommendations, which have been generally well received, although response has not always been as prompt as we feel the national interest demands. Some examples that bear repeating are:

(a) Reports on Coal Geology have pointed out that Canadian universities continue to be oblivious to the growing need for specialists in this field.

(b) University theses are a vast untapped source of information on mineral deposits and energy resources. Recommendations to such organizations as the Canadian Institute for Scientific and Technical Information that such theses be carefully indexed and made available to the public has been largely or wholly ignored.

(c) Provincial and Federal parks departments have shown little inclination to consult earth scientists when establishing restricted areas.

(d) Canada's lack of financial support for the JOIDES program of scientific offshore drilling is a continuing source of embarrassment to Canadian geoscientists. This program is now at the crossroads. Canada could have been in at the exciting beginning, but failed. It still has a chance to be a part of exciting future plans and our government must take advantage of this opportunity. Marine geoscience has provided and will continue to supply answers to some of the fundamental questions concerning the evolution of our planet and the distribution of its resources. We can not afford to continue to withhold national support for so vital a program.

We draw our readers attention to Part 3, the reports of our member societies. These reports contain a concise overview of current geoscience activities in Canada. This is a unique compilation and excellent reference for those concerned with our position in this field. One report dealing with Geosciences in the Provinces is taken from a submission by the Geological Association of Canada to the 34th annual Mines Ministers Conference. The importance of this document can not be understated. It reviews the condition and relevance of our discipline in the Provinces, and makes specific suggestions for improved use of our adequate but underdeveloped manpower resources. The graduation statistics and patterns of employment described in a report from the Committee of Chairmen of Canadian Earth Science Departments provides data not available in any other compilation. It should be of vital interest to administrators in the universities, business, and government who are concerned with manpower utilization and trends.

When reading the individual reports in this publication one cannot but be impressed with the level of activity and excitement surrounding the Earth Sciences in Canada. The contribution of geoscientists to the welfare of this country is obviously immense. It is a continuing story and one that demands the attention of all Canadians.

P.J. Savage
Past-President
March 1978

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RATIONALE

Few Canadians fully appreciate the fundamental role of soil science in their life. Agricultural and forest products together contributed 21 billion dollars to the economy in 1976, and accounted for 40% of the value of our exports. The soil resource is basic to both industries.

Contrary to popular belief, the soil resource base for production of food and fibre in this vast country is limited. Less than 28% of the land area has soil and climate suitable for commercial forest production and only about 8% is suitable for cultivated agriculture. On a world scale, Canada accounts for only 5% of the agricultural land, and much of it is near the climatic fringe. The efficient use of this country's limited soil resources is absolutely necessary if we are to maintain food and fibre production for Canadians and contribute significantly to our balance of trade.

While the agricultural and forest industries employ about 8% of the labor force, the soil resource is important to the Canadian economy in many other ways. Soil is a major medium for the absorption and purification of wastes. This use has assumed increasing importance as man has become aware of the disastrous effects of wholesale direct disposal of wastes in water. Construction of buildings and transportation corridors involve the use and management of soils. Preservation of wilderness areas and maintenance of parks require an understanding of the delicate environmental balance of which soil is a part. The rehabilitation of land disturbed by mining operations involves manipulation of soil-forming processes.

The expenditure for research in Canada, in 1976, was approximately $184 million in Agriculture and $62 million in Forestry. The soil science component of this was only about 10%. Yet, in Agriculture alone, probably over 35% of the productivity increases achieved over the past 40 years have resulted from improvements in soil management practices. The expenditures on soil research are at present little more than 0.1% of the $21 billion contributed to the Canadian economy by Agriculture and Forestry. Such a low investment in a discipline that contributes so vitally to the feeding and housing of the nation is grossly inadequate.

Nature and purpose of soil science

Soil science is the branch of natural science that focuses on the fragile, thin, living skin of the earth, the soil. On it, man grows crops for food and fibre, builds his habitations and constructs his roads. Soil science uses principles and tools specific to its own discipline in addition to those of physics, chemistry, geology, and biology to determine the nature of the soil and to develop principles for the wise use and management of soil resources. Summaries of research on various aspects of soils in Part 2 of this document reveal much about the nature of soil science.

They also show its scope to range from broad geographic studies of the soil resource to research on specific mineral, organic and microbial components, and from basic studies of water transmission in soils to application of soils and other information to land evaluation.

Soil is not a commodity except in the limited sense of topsoil for gardens but it is a natural renewable resource basic to the production of food and fibre and to the storage and purification of wastes. The motivation behind most soil research is the planning and management of the use of soil resources.

RATIONALE

Peu de Canadiens apprécient pleinement le rôle fondamental jouer par la science du sol dans leur existence. Les produits agricoles et forestiers ont contribué pour 21 milliards de dollars à notre économie en 1976, et pour 40% de la valeur totale de nos exportations. Le sol est une ressource primordiale pour ces deux industries.

Contrairement à la croyance populaire, les sols propices à la production de nourriture et de fibres dans notre immense pays sont très limités. Moins de 28% du territoire possède le sol et le climat permettant la production forestière et seulement 8% pour la production agricole. A l'échelle mondiale, le Canada compte pour seulement 5% de terres agricoles, et la plupart sont situées à la limite des zones climatiques. L'emploi judicieux des terres est absolument indispensable si l'on désire maintenir la production de nourriture et de fibres pour les canadiens et aussi contribuer significativement à notre balance commerciale.

L'industrie agricole et forestière emploie environ 8% de la main d'oeuvre, par contre le sol joue un rôle important dans l'économie canadienne de plusieurs autres façons. Le sol est un médium important pour l'absorption et la purification des déchets. Ce fait a joué un rôle déterminant lorsque l'homme a pris conscience des effets désastreux de se débarasser des déchets dans les eaux des lacs et des rivières. La construction d'édifices et de corridors routiers impliquent l'utilisation et la gestion des terres.

La préservation de régions sauvages et l'entretien de parcs récréatifs exigent une compréhension du milieu écologiques dont le sol fait parti. La réhabilitation des terres dérangées par l'exploitation minière implique les processus de formation du sol.

Le coût de la recherche au Canada, en 1976, fut approximativement de 184 millions de dollars pour l'agriculture et de 62 millions de dollars pour la foresterie. La science du sol n'a eu que 10% de ces sommes. Pourtant, l'agriculture seule a augmenté sa productivité de plus de 35% dans les 40 dernières années par l'amélioration de ses pratiques culturales. Le coût de la recherche sur le sol est à présent un peu moins de 1% des 21 milliards de dollars contribués à l'économie canadienne par l'agriculture et la foresterie. Un tel niveau d'investissement dans un domaine qui contribue largement à l'alimentation et à l'habitation des canadiens est totalement inadéquate.

Nature et objet de la science du sol

La science du sol est cette composante des sciences naturelles qui se préoccupe de la délicate et mince couche vivante à la surface de la terre. Le sol d'où l'homme tire la nourriture et les fibres, construit ses habitations et ses routes. La science du sol utilise des principes et des outils spécifiques à sa discipline en plus de ceux fournir par la physique, la chimie, la géologie et la biologie pour déterminer la nature du sol et pour développer des principes qui permettent une meilleure utilisation et une meilleure gestion du sol. Un résumé des différents aspects de la recherche dans la deuxième partie de cette article révèlera la nature de la science du sol.

Ce résumé démontre aussi l'écart entre une étude géographique de la distribution des terres jusqu'à la recherche

Problems and research needs

The major issues involved in the use of Canada's resources are all closely interrelated but have been separated into three categories. These are the requirement for: soundly-based land use policies; more effective soil management for increased production of food and fibre; and protection of the soil resource and the environment when soil is used for waste disposal or subjected to intensive management.

Land use policies are essential to arrest the loss of prime agricultural land to urban and industrial uses. If the most productive lands continue to be lost from Agriculture, the result will be significant increases in food prices due to less efficient production on poorer lands. Such policies can be developed and implemented effectively only if there is sound geographic information on land quality, a basic aspect of which is soil.

With the projected large increases in Canada's population in the next 25 to 50 years, the requirement for vastly increased food and fibre production will be met mainly by higher productivity of land currently in use, hence the need for sustained improvement in soil management. Some increased production will come from developments in new areas, but this will involve higher costs. Highly efficient soil management will be necessary to guarantee production of forest and agricultural exports at competitive costs. The export of such renewable products will, in time, assume a larger importance in foreign trade, perhaps replacing nonrenewable commodities such as mineral resources.

A marked increase in waste disposal problems follows increasing urbanization and industrial development. Improved technology of waste disposal on land coupled with the more intensive agricultural and forestry production to utilize the plant nutrients in the waste is essential to avoid pollution of both soil and other components of the environment.

Substantial increases in support for soil research are essential if the major problems outlined are to be resolved. The development and implementation of land use policies depends critically on better integration of information derived from soil, agronomic, economic, climatic, forestry, environmental, and urban studies. The technical skills exist in Canada to integrate this information and to develop new approaches to land research and its use. Increased financial support both for research and education to accelerate this integrated research is essential to the responsible husbandry of our land resources. Failure to act rapidly in relation to land use policy will result in continued retreat of agriculture from the less than 1% of Canada's land area where the unique soils and climate particularly favor specialized food production, for example, in the Fraser and St. Lawrence lowlands. Perhaps of equal urgency is the development and implementation of the principles of ecologically sound land use in the sensitive northern terrain that comprises about one third of Canada's land area.

The continually improved soil management necessary for intensified food and fibre production will be dependent upon research which strengthens the subdisciplines of soil science but also which provides for integrated programs. For example, increased research on the resolution of soil physical problems such as compact subsoils and poor drainage must be integrated with studies of fertilizer response and tillage practices. Intensive production will accelerate the development of problems such as minor element deficiencies and salinity in irrigated areas. Research aimed at predicting possible problems through improved understanding of soil chemistry, physics, biology, and hydrology will be essential.

sur un minéral spécifique, de la composante organique et microbiologique, et d'une étude sur la transmission de l'eau dans le sol applicable aux sols et d'autres informations sur l'évaluation des terres.

Le sol n'est pas une marchandise exception faite de la couche arabe utilisée pour le jardinage, c'est une ressource naturelle renouvelable pour la production de nourriture et de fibres et pour l'entreposage et la purification des déchets. La planification et la gestion dans l'utilisation des terres est une source de motivation pour la recherche sur le sol.

Problèmes et nécessités de la recherche

Les objectifs majeurs de l'emploi de la ressources au Canada sont tous inter-reliés mais on les sépare en 3 catégories. Ce sont une politique cohérente de l'utilisation des terres, une gestion plus efficace pour augmenter la production de nourriture et de fibres et la protection des terres et de l'environnement, lorsque le sol est employé pour disposer des déchets ou sujet à un emploi abusif.

Une politique sur l'utilisation des terres est essentiel pour arrêter la perte de terres agricoles pour des fins urbaines et industrielles. Si les terres les plus productives continuent d'être soustrait à l'agriculture, il en résultera une augmentation substantielle des prix des aliments car le rendement est moins élevée sur les terres plus pauvres. Une telle politique peut-être développée et implantée efficacement que si nous possèdons une information géographique adéquate sur la qualité des terres, un aspect important dans la connaissance du sol.

La projection d'une forte augmentation de la population dans les 25 à 50 prochaines années, exigera une augmentation énorme de la production de nourriture et de fibres. Ceci ne pourra se faire que par une productivité accrue des terres déjà exploitées, par conséquent il est nécessaire d'améliorer nos méthodes de gestion des terres. Une partie de l'augmentation de la production proviendra de régions nouvellement exploitées, mais à des coûts plus élevés. Une meilleur gestion des terres sera nécessaire pour assurer l'exportation de produits forestiers et agricoles à des coûts compétitifs. L'exportation de produits renouvelables nous assurera une place importante dans les échanges commerciales, peut-être pour remplacer des produits non-renouvelables tels que les ressources minérales.

Une augmentation marquée du problème des déchets suit le développement urbain et industriel. Une technologie développée pour l'élimination des déchets jumelée à une production agricole et forestière intensive utilisant les nutriments pour les plantes contenus dans les déchets est essentielle afin d'éviter la pollution du sol et des autres composantes de l'environnement.

L'augmentation substantielle du support pour la recherche sur le sol est essentielle pour résoudre ces problèmes. Le développement et l'implantation d'une politique sur l'utilisation des terres dépend d'une meilleure intégration de l'information sur le sol, acquis par le biais d'études agronomiques, économiques, climatiques, forestières, écologiques et urbaines. Les spécialistes existent au Canada pour intégrer l'information et pour développer de nouvelles approches pour la recherche et l'utilisation des terres. L'augmentation du support financier à la recherche et à l'éducation afin d'accélérer cette recherche intégrée est essentielle à l'utilisateur de nos terres. Le manque d'une action rapide pour une politique sur l'utilisation des terres résultera en une perte continue de terres pour l'agriculture qui constitue moins de 1% de la superficie des terres du Canada où le sol et le climat favorise la production spécialisée des aliments, par exemple les basses terres du Fraser et du St-Laurent. Tous aussi nécessaire serait le développement et l'implantation de principes écologiques

Effective and increasing use of land for waste disposal will require some of the same types of research as are mentioned above. In addition, prime importance must be given to improved understanding of transformations that occur when heavy metals, organic components, and living organisms are added to the soil. Monitoring of changes in availability and translocation of metals under different soil management practices will be required. The hazards of groundwater pollution by fertilizers or by substances derived from wastes must be avoided. The more intensive land management associated with increased forest production will bring pressures on environment due to fertilization as well as hydrologic changes caused by logging practices. Environmentally sound management depends on more soil research integrated with forest management.

Development of Soil Science

Because of the multi-use character of soil, several diverse agencies in Canada are involved in soil science. Priorities are usually defined on the basis of problems pertinent to the particular agency and its use of soil. Soil science has consequently developed in a somewhat fragmented manner, with a wide range of strengths in different aspects of the discipline. Up until now, federal, provincial, and university agricultural agencies have been most active in teaching, research, and extension of soil science. However with increasing recognition of soil as an important aspect of land and increasing concern about protection of the environment, other agencies are contributing a larger proportion of the total activity in soil science, notably those responsible for forestry, environmental protection, and geography. While most aspects of this diversity are healthy, some cause difficulty for development of the science. The orderly development of soil science and the coordination of activities of the many agencies should be the mandate of a broadly based soil science society. Such a role was proposed in 1972 for the Canadian Society of Soil Science, but it has not yet fully assumed that responsibility. The independent development of soil science and soil engineering has resulted in too little use and understanding by each of the other's discipline.

A look ahead

The evidence is encouraging that soil science in Canada is moving toward a more mature role in developing the discipline to serve society more effectively. The emergence of a more active and broadly based scientific society is one essential step in this direction. Its links with the Canadian Geoscience Council in addition to those with the Agricultural Institute of Canada have broadened the scope of the Canadian Society of Soil Science and increased its appeal to many scientists. Preparations for the hosting of the Eleventh Congress of the International Society of Soil Science to be held in Edmonton in 1978 have demonstrated the ability of Canadian soil scientists to respond to a challenge. Soil scientists from many agencies and subdisciplines are cooperating in developing the conference theme 'Optimum Soil Utilization Systems under Differing Climatic Restraints'. The momentum toward an active society that encompasses, fosters and coordinates most aspects of soil science should continue.

In addition to the continuing roles in agriculture and forestry, the increasing recognition of the soil science contribution to environmental and planning concerns demonstrates the need for more soil scientists in the future. The number of students specializing in soil science has remained constant over the past few years, although increasing numbers of students now study introductory soil science and courses related to soil resources. Clearly, the prospects of

applicables à l'utilisation des terres dans les régions septentrionales qui constituent environ le tiers des terres au Canada.

Le perfectionnement des méthodes de gestion du sol afin d'intensifier la production de nourriture et de fibres dépendra d'un programme de recherche intégrée avec les disciplines concernées. Par exemple, une recherche accrue pour résoudre des problèmes de physique du sol tels que la compacité des sous-sols et le drainage devrait être intégrée à des études sur l'emploi des fertilisants et à des études sur les pratiques culturales. La production intensive accélèrera le développement de problèmes tels qu'une déficience en éléments mineurs et de salinité dans les régions irriguées. La recherche vise à prédire les problèmes possibles par une compréhension améliorée de la chimie du sol, de la physique, de la biologie et de l'hydrologie.

L'emploi grandissant et plus efficace des terres pour disposer des déchets requièrent le même type de recherche. De plus, une importance particulière devrait être donner pour comprendre les processus de transformations qui interviennent lorsque des métaux lourds, des composantes organiques et des organismes vivants sont ajoutés au sol. Le contrôle des changements de disponibilités et de translocations des métaux sous différents aspects de la gestion du sol sont essentiels. On doit éviter de polluer les eaux souterraines par l'emploi de fertilisants ou par des substances dérivées des déchets. L'emploi intensif des terres et une augmentation de la production forestière accentueront les pressions sur l'environnement associer à l'emploi des fertilisants tout aussi bien que par les changements hydrologiques associer aux méthodes d'abattages. Une bonne gestion de l'environnement dépend d'une plus grande recherche sur le sol intégré à la gestion des forêts.

Le développement de la science du sol

Vu les usages multiples du sol, plusieurs agences au Canada participent au développement de la science du sol. Les priorités sont établies suivant les problèmes qui rélèvent de chacun de ces agences. Par conséquent, la science du sol s'est développée de façon fragmentaire et inégale selon les différents aspects de la discipline. Jusqu'à maintenant, les agences fédérales, provinciales et universitaires ont été plus actives dans l'enseignement, la recherche et le prolongement de la science du sol. Par contre, reconnaissant l'importance du sol et par souci de la protection de l'environnement, d'autres agences contribuèrent dans une grande proportion aux activités de la science du sol, notamment les responsables de la foresterie, de la protection de l'environnement et de la géographie. Pendant que la plupart des aspects de cette diversité sont en santé, d'autres créent des difficultés pour le développement de la science du sol. Le développement ordonné de la science du sol et la coordination des activités de plusieurs agences devrait être le mandat de la société de la science du sol. Un tel rôle fut proposé en 1972 par la Société canadienne de la science du sol, dont elle n'a pas totallement assumé cette responsabilité. Le développement indépendant de la science du sol et du génie des sols a eu comme résultat une mauvaise utilisation et une mauvaise compréhension par chacun de l'autre discipline.

Une perspective

La science du sol au Canada devrait être encourager à jouer un rôle dans le développement de la discipline afin de mieux servir la société. Une société scientifique plus active avec des assises plus large sera un pas essentiel dans cette direction. Ainsi, ces liens avec le Conseil canadien des sciences de la terre en plus de ceux avec l'Institut d'Agriculture du Canada ont élargis l'importance de la Société Canadienne de la science du sol et augmentés l'intérêt de employment are excellent for an increasing number of well-trained soil scientists. A vital soil science society should insure high standards of training and should monitor the proper utilization of skills in the profession.

The need for increased support of soil research is obvious to the soil scientist. Prospects of receiving such support depend to a major extent on how well they organize themselves to co-ordinate their work and apply their science, and publicize its achievements and its potential to alleviate some of the major problems of our time.

G.C. Topp
President
Canadian Society of Soil Science

plusieurs chercheurs. La préparation du 11ième congrès de la société internationale de la science du sol qui sera tenu à Edmonton en 1978, a démontré l'habileté des chercheurs canadiens à surmonter un tel défi. Les chercheurs en sol de plusieurs agences et de disciplines connexes ont collaborés aux développements du thème du congrès qui s'initule "L'utilisation optimum du sol sous différentes conditions climatiques". Le momentum d'une société active qui entoure, élève et coordonne la plupart des aspects de la science du sol devrait continuer.

En plus de son rôle permanent dans l'agriculture et la foresterie, la reconnaissance accrue de la contribution de la science du sol au développement de l'environnement et à sa planification démontre la nécessité pour plus de chercheurs dans l'avenir. Le nombre d'étudiant spécialisé dans la science du sol demeure constant depuis quelques années, quoiqu'un nombre grandissant étudie les notions de basse de la science du sol et ceux reliées à la ressource. La prospective d'emploi est excellente pour un nombre grandissant de chercheurs bien entraînés. La société de la science du sol, si vital soit-elle, doit assurer un haut niveau d'entraînement et doit voir à une utilisation judicieuse des aptitudes dans la profession.

Le besoin de plus de support pour la recherche sur les sols est évident pour le chercheur. Toutefois la prospective de recevoir un tel support dépend de la façon dont ils s'organisent pour coordonner leur travail et appliquer leur science, et dont ils informent et proposent des remedes possibles aux problèmes de notre temps.

G.C. Topp
President
Société Canadienne de la science du sol

SUMMARY AND ANALYSIS OF SOIL SCIENCE IN CANADA

Although the loss of prime agricultural land to urban sprawl has focused public attention on our soil as a national resource, it has done so in a limited manner, leading to simplistic solutions to the immediate and visible problem. Although these short term solutions having been proposed, and occasionally applied, public concern for the long term state of this critical resource has returned to its previous state of ignorance and apathy.

In the reports that follow it is apparent that Canada's useable soil resources are much more limited, and the problems associated with their use much more complex, than most of us have realized. To a degree not generally recognized, Canada's future depends on our soils — on how we understand and how we use them.

This report has essentially two main components. One is a descriptive overview of our country's soils. The other is an examination of the state of soil science and what should be done to help it better serve the country's needs. This analysis addresses itself to the latter.

Soil surveys

The mapping and classification of our soils are of fundamental importance to the Soil Sciences. In recent years significant progress has been made by the Soil Survey Units, the Canada Soil Survey Committee, the Soil Research Institute (Agriculture Canada), and other similar groups through the Canada Land Inventory program and the Canadian Soil Information System. The framework is in place. What is now essential is an increased effort to render the survey data for all lands useable by planning agencies. The national/provincial co-operation in this field stands as a refreshing example to other disciplines.

The report 'Canada's soil inventory program' herein expresses the concern of the Canada Soil Survey Committee as to the adequacy of soils information in the following areas:

Atlantic Provinces — where major land improvement programs are being planned or implemented without adequate specific information on the soil and its properties.

Ontario and Quebec — where there is an urgent need for detailed surveys for land planning and management in urban-rural pressure areas.

Prairie Provinces — where the updating of soil surveys is an essential foundation for agricultural management, salinity control, and water management.

Increased research is needed to establish the relationship between the land components and the soil. Studies in the rock-soil relationship, in particular, could yield immediate results. In remote areas soil maps are generally exploratory and could be refined if supported by concurrent studies involving soil scientists, biologists, and surficial geologists. This research, coupled with investigations into soil-vegetation relationships could improve the predictive capacity of aerial imagery for land resource mapping.

Joint geological and pedological (soil) surveys have proved so useful to soil engineering that it would be unfortunate if future soil and geological surveys were not planned for the benefit of other related disciplines. The field identification and classification of soil for engineering purposes would be a major desirable addition to the current standard pedological (soil) surveys.

Table 1.1

Confirmed significant hydrocarbon discoveries 1975-1977

Region/Area	Well Name	Discovery Year	Formation/Type	Operator/Participants
Williston Basin	Tableland 11-14-2-9W2	1975	Winnipegosis/oil	Dome et al.
Alberta Basin	Rosevear 11-37-53-15W5	1975	Beaverhill Lake/gas	Shell Canada
Alberta Basin	Fox Creek 10-13-62-18W5	1975	Beaverhill Lake/gas	Chevron/Gulf
Southern Foothills	Limestone AZ-13-5-18-34-10W5	1975	Mississippian/gas	Shell Canada
Northern Foothills	Findley 5-26-57-6W6	1975	Miss./Tri./Jur./gas	PanCanadian et al.
Southern Foothills	Wilson 4-11-33-10W5	1975	Mississippian/gas	Shell Canada et al.
Northern Foothills	Bullmoose d-77-E; 93-P-3	1975	Triassic/gas	British Petroleum et al.
Mackenzie Delta	Kamik D-48 68°57'12.59"N, 133°27'29.86"W	1976	Cretaceous/oil	Gulf/Mobil
Mackenzie Delta	Garry P-04 69°30'N, 135°30'W	1976	Not released/oil, gas	Sun/SOBC/Bow Valley
Williston Basin	Minton 11-2-3-21W2	1976	Winnipegosis/Ord./oil	Dome, Tenneco et al.
Alberta Basin	Pass Creek 7-13-61-18W5	1976	Beaverhill Lake/gas	Chevron/Gulf
Alberta Basin	Gulf Pacific Fina Hamelin 11-8-47-17W5	1976	Swan Hills/gas	Gulf/Pacific/Fina
Alberta Basin	Gulf et al. Erith 6-31-47-17W5	1976	Swan Hills/Cambrian	Gulf et al.
Williston Basin	Torquay 15-12-4-12W2	1977	Mississippian/oil	Shell Canada
Alberta Basin	Blackie 10-16-20-27W4	1977	Mississippian/oil	Ipex et al.
Alberta Basin	Pembina A-11-22-49-12W5	1977	D2/oil	Nairb (Chevron)
Northern Foothills	Kotaneelee YT H-38 60°07'11"N, 129°06'03"W	1977	Miss./Dev./gas	Columbia Gas et al.
Beaufort Basin	Ukalerk C-50 70°09'07"N, 132°43'52.5"W	1977	Not released/gas	Dome, Gulf et al.
Beaufort Basin	Nektoralik K-59 70°28'36"N, 136°16'59"W	1977	Not released/oil, gas	Dome, Hunt

Research

Common to most reports of this nature is the call for increased research. Given the importance of the subject to the national well-being, this is not a call that can be easily dismissed. An increase in research effort is inextricably linked to the increased mapping effort mentioned above. Some obvious priorities can be gleaned from these reports.

Improvements in soil productivity, mainly by increased use of fertilizers and fossil fuels for farm power, have accounted for most of Canada's increased food production in the past. Given our limited area of arable land and the rapidly escalating cost of fertilizers and fuels additional research effort must aim for other improvements to soils and soils management. Much neglected have been the limitations to crop productivity caused by the soil physical conditions. The recent advent of forest management for increased production has created a need for new information requiring applied and basic research.

Demands for resource management alternatives point up many deficiencies in our knowledge. This is particularly true of soil genesis and deterioration, slope stability, and behaviour of soils in relation to resource utilization.

Research to determine the suitability and the capability of soil resources requires a properly designed and co-ordinated team approach. The urgent need for this information demands adequate commitments of current funds and personnel.

The message from scientists reporting herein comes through clearly. If soil science is going to contribute to our future well-being, as it should, it can not do so in isolation. It must be as part of a team with engineers, geologists, chemists, physicists, and biologists.

Multidisciplinary action

As C.J. Acton herein notes (in his article on 'Soils of the Canadian Shield'), "An inter- or multi-disciplinary approach to resource inventories and research.....is essential to facilitate the co-ordination, integration, and exchange of data. Moreover, use and management of natural resources requires knowledge of the entire ecosystem. Soils.....(are a).....vital component of this complex system". Although lip service is paid to this maxim, it is unfortunate that many universities continue to teach land use and environmental studies without sufficient input from soil science. This happens even when a university has an agricultural college with a competent faculty.

Too often advances in knowledge of soils that could benefit other earth sciences are lost through poor interdisciplinary communications. While land use and environmental studies are among the most apparent areas in need of information on soils, the science can contribute in many other less obvious ways. Two examples have been extracted from the report:

1. Although Arctic communities rely largely on local food sources (meat from local wildlife), the importance of arctic soils in relation to this food production has generally been ignored. Studies to determine soil properties and the resulting wildlife capability should be carried out co-operatively by biologists, wildlife managers, soil scientists, and ecologists.
2. Joint research in soil science and geochemical exploration would be most fruitful. Although the primary objective of the research would be to develop reliable soil geochemical exploration techniques, the spinoffs from studies, such as of the element dispersion in soils, would have wide-ranging applications.

Table 1.2

Significant metallic mineral discoveries 1975-1977

Among its accomplishments in the 1975-1977 period, Canada's mining exploration community lists the following significant mineral discoveries. This list is an up-date of a similar list published in 1977 covering the 1974-76 period.

Name and Year of Discovery	Responsible Companies	Location	Type of Deposit	Grade and Reserves*
Detour Lake Gold (1975)	Amoco	125 mi NE of of Timmins, Ontario	Gold in Archean volcanic rocks	9 million tons @ 0.2 oz. Au
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
Bosquet-Thompson (1975)	Long Lac Minerals Expl.	Cadillac area, Quebec	Gold in Archean volcanic rocks	500,000 tons @ 3 oz Au
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, Quebec	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, Saskatchewan	Uranium adjacent to Athabasca Sandstone	500,000 tons @ 4.54% U_3O_8, 3.84% Ni
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, Saskatchewan	Uranium adjacent to Athabasca Sandstone	12 million lbs U_3O_8, 8 million lbs Ni
DY Prospect (1977)	Cyprus Anvil	Anvil Dist., Y.T.	Massive sulphides	(not available)
West Bear (1977)	Gulf; Noranda; Sask. Govt.	Rabbit Lake area, Sask.	Uranium in or near Athabasca Sandstone	(not available)
Maurice Bay (1977)	Uranerz; Inexco Oil & Gas; Sask. Govt.	Lake Athabasca	Uranium	10 million lbs U_3O_8
Hydraulic Lake (1976)	Tyee Lake Resources	Kelowna area, B.C.	Uranium in Tertiary channel deposits	1.5 million lbs U_3O_8
Blizzard (1977)	Norcen et alia; (Lacana option)	Kelowna area, B.C.	Uranium in Tertiary channel deposits	More than 3.0 million lbs U_3O_8
No. 4 Zone (1977)	Riocanex	NE of Port aux Basques, Nfld.	Gold veins in Proterozoic volcanic rocks	200,000 tons @ 0.3 oz Au and 0.74 oz Ag to 500' depth
Nadaleen River (1977)	McIntyre	80 mi E of Keno Hill, Y.T.	Pb-Zn-Ag in Proterozoic carbonate rocks	(not available)
Dismal Lakes (1977)	Imperial Oil	S of Dismal Lakes, N.W.T.	Uranium	(not available)

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

Peer review of research grants and activities is a well established and effective monitoring device within most branches of Canadian science. Special care should be taken to ensure that multidisciplinary projects receive proper scrutiny for relevance, new contributions, and regular reporting.

Food production

At the present time only a small fraction of the total agricultural research effort is devoted to the evaluation and management of the agricultural land base which should ensure its most effective use in order to meet national food objectives. It is a common concern of soil scientists that it will not be possible to maintain, let alone increase, agricultural productivity unless greater attention is given to the management of soil resources.

The increasing use of energy, including nonrenewable resources, in food production is a trend that can not be allowed to continue. Our reporters have indicated that, while it is difficult to single out any one approach as being of first priority, the problem must be tackled on many fronts such as:

- Physical and chemical limitations to crop productivity is a much neglected area of study. Joint studies with hydrologists and geochemists are recommended.
- Studies of soil microbiology and biochemistry are particularly pertinent. Plant microbial association, such as nitrogen fixation and phosphorous uptake, can utilize the photosynthate of growing plants to replace much of the fossil fuel energy now used for the production of fertilizer.
- Research is needed into the proper storage and application of manure in order to prevent the loss of nitrogen, which may be as high as 50% under currently utilized systems.
- Solid wastes, as fertilizer, are a valuable energy resource and techniques need to be developed for suitable composting and application. Research in this field must be tied to the problem of the disposal of urban wastes. The potential toxicity of these wastes needs careful study.

Waste disposal

In view of the increasing rates of urban waste production and the spiralling costs and problems of waste disposal, research is required to provide positive and constructive solutions.

Land applications of these wastes appears to be the only practical method of disposal. The application, however, of digested sludges containing heavy metals could introduce toxicity into plants and endanger the food chain. The removal of metal toxicity from soils is most difficult and, therefore, heavy metals coming from point sources should be removed before entering waste water. Those heavy metals which cannot be traced to point sources must be handled in other ways. *It is recommended that Agriculture Canada, Environment Canada, and Provincial governments increase research funding to:*

1. *define those soil factors that determine the ability of plants to absorb metals.*
2. *encourage and support plant breeders to investigate a possible discriminatory function by vegetation (or the blocking effect) which tends to concentrate metals in various parts of the plant.*
3. *investigate the feasibility of introducing compounds into industrial wastewaters for the purpose of immobilizing known toxic metals.*

Municipal governments should be encouraged, and supported, to monitor old and current land disposal sites. Once land has been contaminated renovation costs are prohibitive.

Again, it is obvious that waste disposal is a problem that can only be solved by multidisciplinary action. Research efforts should include soil scientists, geologists, hydrogeologists, biologists, geotechnical engineers, and chemists.

Forestry

The importance of forests to the Canadian economic position is well known. The accelerated use of forest products has outstripped the capacity of the land and climate to produce them. Clearly improved management systems and regeneration practices founded on sound research are urgently required. An objective base from which to evaluate the interaction of soil with the growth of new forest stands is presently not available.

The shortening of rotation age and the introduction of complete tree harvesting result in increased nutrient loss from the land. The possibility of soil exhaustion has become a question of immediate concern. Essential to effective soil management under forestry is an understanding of those reactions that affect nutrient cycling, one of the most important processes in the soil forest system.

Soil mapping and classification have, to date, been concentrated on agricultural areas. If we are to properly utilize our forest resources, knowledge of the soils in the forested areas is essential. *It is recommended to both Federal and Provincial governments that Soil Surveys be extended into forested areas as a matter of high priority.*

Soil degradation

Although there is widespread concern about soil degradation the actual extent and progression of the processes, and their effect on soil productivity is not known with any degree of certainty. It is essential, for example, to know how much soil erosion is taking place under the cropping systems used in eastern Canada, and to establish the extent and progress of soil salinization in the prairie provinces. Even less is known about the extent of other degradative processes, which could cause serious and permanent losses of soil productivity.

In view of the limited amount of arable land in Canada, high priority must be given to a program to assess the extent and nature of soil degradation. Such a study should not only examine the effects of erosion and salinization but should also include industrial pollution, urban wastes, transportation corridors, etc.

A program, such as that proposed above, would not be complete if it did not examine in detail the social and economic implications of both the problem and, in particular, the proposed solutions. In Western Canada, where soil salinization appears to be an increasing problem, some of the currently proposed solutions involve decreased use of summer fallow, especially during years with above average rainfall. This increased crop production however would increase the problem of selling cereal grains abroad. This situation is a good example of why research can not exist in disciplinary isolation.

Education and manpower

At the present level of activity our universities appear to be graduating sufficient soil scientists, although in a decade or so more will be required to fill the retirement gaps. It is, however, one of the underlying theses of this report that soil science should contribute increasingly to this country's well-being. To the extent that that argument is accepted, graduates with knowledge of soil science should be in greater demand. The relationship is critical and should be monitored by such organizations as the Canadian Society of Soil Science and the Canada Soil Survey Committee.

Even though it is generally agreed that a basic knowledge of soils is essential to land use and environmental studies many universities teach these subjects without sufficient attention to soil science. More and more, society is demanding that governments and research agencies look closely at the uses of land and the state of our environment, yet many graduates who will be dealing with these matters will have little appreciation of the soil-land resource in its entirety unless significant changes are made in their training. It is time that university faculties recognized their responsibilities to society and made every effort to develop the truly interdisciplinary programs required.

The absence of a suitable textbook dealing with Canadian soils demands the immediate attention of our soil scientists.

The teaching of soil science has traditionally dealt with specific aspects of soils relating them to the local scene or to direct applications in agriculture. The broader extrapolations, or global approach, have been neglected to the detriment of those graduates who will work in developing areas.

There is a need to promote greater input of soil subject material in secondary and high school science courses. This approach has the double advantage of making students aware of career possibilities in Soil Science and the general public more conscious of our soil resources, their utilization, and conservation.

Soils engineering

Although Canada, at times, has been a world leader in this field, continuing research is needed into the design of special vehicles to travel over a variety of organic terrains. Development of our hinterlands consistent with our concern for their ecology will require improved methods of transportation. This must be one of the first orders of business.

Canada has many extensive regions wherein major soil engineering problems exist because of surface geology and the related soil conditions. Danger to human life is very real in these areas, whether from landslides, or from instability of foundations for buildings, roads, bridges, and dams. Up until now soil science and soil engineering have not made sufficient use of each other's expertise. The addition of engineering classification to soil surveys, as recommended earlier, can be achieved effectively when those agencies responsible for the engineering aspects of soils provide the support arrangements to the soil survey program now in Agriculture Canada.

Research funds in the geotechnical field continue to be small. This is not consistent with the demands of increased urbanization and development that this country faces.

The complex engineering problems created by permafrost requires detailed knowledge of both areal and site specific soil properties. This knowledge should not only include the soil materials, the effects of slope, vegetation, drainage, and ice content but also the physical-mechanical properties and their geotechnical implications. While much good work has been and is being done in the study of permafrost, increased effort is required if our engineering abilities are to keep up with the demands of development. More work needs to be done to determine the distribution (extent and thickness) of permafrost and in particular we need an improved understanding of the freezing and thawing processes in perennially frozen soils. Engineering design criteria need to be established for building foundations, municipal services, roads, railways, and airstrips; as well as for warm oil and chilled gas pipelines. Pertinent building codes and land use regulations are dependent on increased knowledge, as are operating criteria for mining and petroleum exploration and production.

Soils in the Arctic not only support the biological life and man-made structures, but also protect the underlying permafrost. The soils are thin and fragile, hence their role in both the Arctic ecosystem and in land use is much a more critical factor than in temperate regions.

G.K. Rutherford *B.P. Warkentin*
E.R.W. Neale *P.J. Savage*
G.C. Topp *O.L. White*

The Canadian Geoscience Council Editorial Committee.

SOIL SCIENCE IN CANADA

INTRODUCTION

B.P. Warkentin[1] and G.K. Rutherford[2]

Background

Soil science is one of the Geosciences, but since it is the medium for plant growth, it is of major concern to agriculture. The thin mantle of weathered and altered material on the earth's surface, which we call soil, is vital to our production of food and fiber, agricultural crops, and forests. Soil science shares some of the methods of investigation with the other geosciences, but also uses methods which are peculiar to the study of soils. Soil science can, therefore, be considered as a separate discipline.

Most of the support for study of soil science comes through agricultural institutions, so most of the Canadian soil scientists are associated with agricultural institutions. However, the Canadian Society of Soil Science attempts to bring together all those people who are studying soils in Canada.

Objective

This report was written for several audiences; some papers are more pertinent to one audience than to the others. However, three primary objectives were accepted when the report was planned:

a) To communicate soil science information to fellow Canadian geoscientists. It is generally agreed that soil science knowledge is very limited among other geoscientists. But the diversity of soils and the fascination of the subject makes this communication important.

b) To alert those in Canada who have responsibility for policy and budget in Canadian science to some of the important aspects of soil science, to its nature, and to its requirements for support. These requirements are touched on in several of the papers.

c) To draw together Canadian soil science information for communication among Canadian soil scientists and among foreign soil scientists. An immediate example is that the International Society of Soil Science will meet for the first time in Canada in June 1978 in Edmonton. This report will be very useful in pointing out to international soil scientists the work which is being done in Canada and how soil science is viewed in Canada. We have a great diversity of soils and a diversity of research needs; at the same time, we have a small group of soil scientists who are dealing with this diversity.

This report then is an attempt to state our concern for the problems we see in soil science: with land use; with wise decisions on preservation of agricultural land; with our frustrations at not understanding completely the physical, chemical and biological properties of soils which would allow us to make better inputs into management decisions; with our lack of research personnel and financial support to develop this understanding in the next few years; with our concern that the study of soil science is neglected when most of the manpower is diverted to dealing with immediate problems. It is a status report of how a group of leading Canadian soil scientists view their discipline.

Soil Science defined

To the native Huron cultivator, soil meant the production of corn for food, enabling him to travel far into the lands of his Algonquin friends who did not cultivate the soil. The fertile black soils of the Prairies have a special significance for the Prairie farmer, but so does the "quick clay" for the civil engineer, the sturdy plastic clay for the brickmaker, filter silts for the water engineer, sandy moulding material for the iron founder, and corrosive acid soil for the archaeologist. Mothers of small children and city maintenance personnel may refer to it as "dirt".

Communication among different groups, which is one of the objectives of this report, is made difficult because of the specialized language used in soil science. New words and jargon, the special and technical language of a discipline, are all hindrances to communication. Possibly a short introduction to this language will help the reader.

The definition of soil is different in the different geosciences. R.F. Legget has discussed this several years ago. To a geologist or to a soil engineer, a soil is the unconsolidated surface material on the earth. To a soil scientist, a soil extends only to the depth that soil-forming processes influence the soil. The soil as a living body is a concept inherited from German and Russian soil scientists such as von Humbolt and Doukuchaev working 100 years ago.

A soil scientist views a soil profile, a vertical cut into soil, as a series of horizons or layers with different properties. These properties arise from the six soil forming factors — parent material, climate, vegetation, topography, time, and man. Canadian soils arise from a large range in all of these factors except time — most soils date from the retreat of the last ice cover and are, therefore, relatively young. The processes acting on the parent material are dominantly those of leaching and of accumulation. Bases leach first, and then sesqui oxides, finally oxides of iron and aluminum. These leached materials may accumulate in lower horizons, while organic matter accumulates dominantly in upper horizons.

A soil is composed of three dominant horizons; a surface or A horizon with organic matter accumulation and loss of easily leached constituents; a B horizon which is a zone of accumulation of leached materials, including clay grains, from the surface horizon; and a C horizon which is the weathered parent material on which the soil-forming processes are acting.

Soil Science is a field-based study, and the description of soils as they occur in nature is the basis for classification. This classification is based on the properties and sequence of horizons. Soils are classified in a hierarchical system, with the names often derived from foreign languages. For example, the soils formed on the Prairies by the dominant soil-forming processes give rise to dark-coloured soils because of accumulation of organic matter. These are given the name chernozem from the Russian language indicating a black color. Under the leaching conditions of the forested areas of eastern Canada, the dominant soil is called a podzol, a name derived from the leached, ash-colored layer just below the layer of organic accumulations.

Soil Science is also a laboratory study. The form and amounts of chemical constituents in soils are measured and

[1]Department of Renewable Resources, Macdonald College, McGill University, Sainte-Anne-de-Bellevue, Quebec.

[2]Department of Geography, Queen's University, Kingston, Ontario.

related to plant nutrition. The rate of release of certain plant nutrients is a common soil measurement. These soil chemical measurements are applied to problems of soil fertility. Physical properties of interest have to do with the structure of the soil and the fluxes of water, gases and suspended and dissolved materials in the voids of the soil. The size, shape and stability of this continuous system of voids is a fundamental property of a soil. The fundamental chemical property is the buffering action of soil against any rapid change in concentration of ions in solution. Biological properties are also studied because the biological activities of the soil are responsible for the vital transformations which occur in soils – the decomposition of organic matter to release carbon and nutrients, and the cycles of nutrients such as nitrogen in the soil. Phosphorus and sulfur are also partly in organic form and partly in inorganic form. The identification of the mineral makeup of soils is a well-developed laboratory discipline, depending upon methods of identification and characterization of crystalline materials of very small size.

The International Society of Soil Science has divided the discipline into seven divisions – soil physics, soil chemistry, soil biology and biochemistry, soil fertility, soil genesis and classification, soil management, and soil mineralogy. In addition, the Soil Science Society of America has groups on forest soils and on fertilizer technology. The Canadian Society of Soil Science has resisted separating forest soils as a separate unit because the principles of soil science apply equally to the growth of trees as to the growth of field crops.

Soil science activity in Canada occurs dominantly in the universities and in the research branches in several federal departments. Teaching and some research is carried out in the Departments of Soil Science, of faculties of agriculture in seven Canadian universities. In addition, several departments of Geography, of Forestry, and of Civil Engineering have significant soil science activity. The research is concentrated in the federal Departments of Agriculture and Environment and in the research stations maintained by the Research Branch of Agriculture Canada.

Highlights

The paper topics were chosen to show who is doing what, where and why in Canadian soil science. The who question is answered by the names of the authors and the references in the papers. The what is in the content of the articles. The where is in the geographic basis for the papers. The why is stated by the authors in their individual terms. The authors were chosen because of their knowledge in the area and their standing among their peers. No attempt was made to achieve uniform style or a uniform format. The papers, therefore, represent the authors' individual expressions. It is comforting to note that a fairly uniform curriculum of soil science teaching in Canada has not obliterated the individuality of Canadian soil scientists. Part of the individuality and diversity in Canada is of course in language, so the paper which deals with the soils of the St. Lawrence Lowlands is present in the language of work of the group of Canadian soil scientists who work dominantly in that area.

The papers fall into five sections. The first section consists of a geographic view of soils followed by some detailed information on the inventory of soils in Canada. The second section is on use of soils for food, fiber, byproduct recycling and as industrial material. The third section relates soil science activity to some of the other geosciences. The fourth section contains a look at the future, education in soil science and some projections on Canada's soil resources. The fifth section describes the activity in six specific disciplines in soil science.

a) The papers on soils of the different physiographic regions in Canada all have descriptions of the landscape – geomorphology, vegetation and climate – which is required to put the discussion of soils into context. The soils in the Appalachian region are dominantly developed on glacial till, are coarse grained and often stoney, are acid and have low natural fertility, and have the limitation of compacted layers in the soil. They are dominantly podzols. Forestry is the dominant land use except for special areas of agricultural production. Beke and Hilchey discuss the research needs, which must be viewed in a systems approach. A more complete inventory of the soils and the capabilities, and methods of amelioration of the physical limitations of compacted layers are the urgent needs.

The soils of the St. Lawrence Lowlands are developed on glacial tills, fluvioglacial deposits, and glaciomarine deposits. The materials originate from the Canadian Shield, and contain dominantly hydrated mica and chlorite. There is a range of grain sizes, but many fine grained soils are present, and inadequate drainage is one of the main limitations for intensive agriculture. Some organic soils exist, and are a resource for intensive vegetable production. The dominant concern according to Laverdière and Martel is that non-agricultural uses are pre-empting the best soils in the Windsor-Quebec City corridor. Land use planning, based upon soil properties as well as economic and social considerations, is required to maintain the high agricultural productivity which is possible on these soils.

The Canadian Shield region occupies about half of Canada's land area. While forestry and wildlife are the main land uses, the clay belt of Northern Ontario and Quebec contains a large area of potential agricultural land which could be developed if the need arises. Short growing season and wet soils are the main limitations for crop growth. Acton describes the soil forming processes on the glacial and periglacial parent materials. The soils are predominantly coarse grained and shallow; in many areas the soils are too thin or too weakly developed to be classified as soil – these areas are termed Rockland. The main research need is for a complete resource survey, including soils. It will not be useful to consider soils in isolation. The resource information can then be used to determine development impacts and decide on resource use.

The largest land area for food production in Canada is in the Prairie region; and production can be increased considerably. The dominant clay mineral is montmorillonite, which imparts particular properties to the soil. Low precipitation and short growing season are the main limitations for agriculture. Soil salinity and soil degradation are increasing problems. The greatest need is for new soil and crop management practices which will conserve moisture and retain organic matter in the soils. Rennie states that these practices will result in higher yields.

Tarnocai points out that the separation of the Arctic into Low, Mid and High Arctic regions, based upon vegetation, is also significant for soils. The main cryogenic processes affecting soils, such as cryoturbation and gelifluction, or movement of soil downslope, result in mixed horizons as well as patterned ground. Some of the interesting processes are described briefly. The soils often have high amounts of organic matter and are usually water-saturated. The soil has a critical role in the Arctic ecosystem, it protects the permafrost. The land "clearing" commonly used in the south cannot be used. Research is required on terrain sensitivity. Soil characterization is necessary as part of a sustained, long-term inventory program. Many other research requirements are detailed in the paper. Many more soil scientists must be trained in Arctic soils – our effort in this is pitifully small in view of the large area and its potential importance in the future.

The Cordilleran region is characterized by large variation in landscape, soil-forming processes, and soils. Soils of every order in the Canadian classification system are represented. The climate varies from the driest and warmest areas of Canada to permafrost. Some of Canada's most productive forest soils occur in the Cordilleran region. Major volcanic ash deposits occur in this region. Urban pressures are felt in the valleys; land use conflicts among agriculture, forestry, wildlife habitat, and mining require more detailed soil resource information and management information for their resolution.

Soil survey was, from the beginning, a provincial endeavor and although activity in this field increased after 1930 there was very little co-ordination on a national scale until the formation in 1940 of the National Soil Survey Committee. However, from 1945 to 1960, the influence of this Committee was far-reaching in co-ordinating the efforts of soil surveyors throughout the country who had been wrestling with the problems of conveying effectively, by means of maps and reports, the complexities, differences and similarities of the soils in the areas they mapped.

The Canada Land Inventory (CLI) programs began in 1963 under the terms of the Agricultural Development and Rehabilitation Act (ARDA). In essence, the program involved an interpretive classification of the occupied 20 per cent or so of Canada. The capability of land for agriculture, forestry, recreation, and wildlife was estimated and capability maps at a scale of 1:250 000 were prepared. The CLI program focussed attention on the limited areas of land in Canada having a high capability for the production of field crops and on land as a valuable natural resource.

In the period from 1960 there was increasing public awareness of the limited area of prime agricultural land in Canada and of the irreversible utilization of such land for other purposes. There has been greatly increased participation of soil surveyors in multidisciplinary surveys of areas such as possible pipeline corridors in the Arctic, urban fringe areas and parks.

Day describes the extent of Canada's soil survey program, where the maps are available, and what information can be obtained from the maps. The objectives of the survey have changed during the 60 years of its existence from mapping for agricultural development, to the Canada Land Inventory, and now to detailed soil inventories in critical areas such as rural/urban boundaries for planning activities. While the needs differ in different parts of Canada, it is critical that the information be obtained quickly for the land planning and land management problems which face us. Land degradation is one of those problems.

In order that the maximum use may be made of endeavors of more than sixty years of soil survey, a central data storage program was clearly necessary. The Canadian Soil Information System (CanSIS) described by Kloosterman and Dumanski is a computerized collection of national and provincial data systems which are compatible. It could be extended to include other earth science inputs. The system is being watched with interest in many countries, an indication of the international need for such a system of ready retrieval information on the soil resource.

b) Canada is considered by many to have almost limitless land resources, but as Clark points out, only 8 per cent of the area is suitable for crop production. It is Canada's small population rather than its large land resource that makes us a modest exporter of food. The tables show the amount of land available in different capability classes, from I, which is the most productive land, to Class IV which has about one-half the productivity. Urban uses and urban "shadows" often use the more productive lands. Increased food production to feed the expected population increase in the future will likely come from more intensive use of land rather than from putting new land into production. Soil management changes such as increased fertilizer use account for most of the increases in production in the past 25 years. A strong case is made for much more support of soil management research to increase production in the future and to prevent soil degradation. Tillage, moisture conservation, and nutrient management are some of the soil management factors requiring more information.

Forestry is the largest land user for harvested crops in Canada, with British Columbia producing the largest volume of forest products. Krause points out that soil was considered as one of the factors in site index of productivity in earlier forest land classification systems. Water available for the trees and rooting depth are the two main soil properties usually considered, but fertility is also a factor as shown by the large response to added nitrogen fertilizer. As management of forests becomes more intensive, the need for soil information increases. The soils information usually obtained in soil surveys must be interpreted for forestry. The research needs are in studies of nutrient cycling, especially in monoculture stands replacing indigenous stands. Both the trees and the soils determine this cycling. Biological nitrogen fixation will need to be an important source of nitrogen for trees.

One of the functions of soils in the ecosystem is to provide the habitat for the micro-organisms that decompose organic wastes on the earth's surface and recycle the nutrients. As human activity becomes more concentrated, special efforts must be made to redistribute these wastes economically and assure that the soil's capacity for recycling is not exceeded. Webber discusses the reasons for renewed interest in land application of urban wastes, the potential hazards, and the guidelines for successful operation. Garbage as well as sewage sludge can be used; the limitation on garbage is often social acceptance, while the limitation for sludge is the content of heavy metals. Webber is well-qualified to write on this topic; his work on waste recycling in soils was among the first in North America.

Sand and gravel are important soil materials for Canada's urban, industrial society. Guillet points out that this resource is not unlimited, and deposits near urban areas should be safeguarded against uses which make them inaccessible, e.g. urban housing. Clay is still used for tile and some bricks, as well as specialized uses.

c) In spite of the wide extent of permafrost, and of its importance in Canadian soil science, we do not have sufficient information on the extent and properties of permanently frozen soils in the zones of discontinuous or continuous permafrost. Brown has led the Canadian effort in these studies.

Penner identifies some of the areas in Canada which pose unusual soil engineering problems. The marine deposits of the St. Lawrence Lowlands, which often have high clay content, cannot be adequately described by methods of study presently available. Permafrost is the other large concern in engineering activities with soils. Soil survey information is presently used for highway planning, and for locating gravel deposits. A greater use of the soil survey report in soil engineering activities will require more interpretation for engineering purposes, including the field identification and classification used for engineering purposes in Canada. Specific research needs are associated with resource development, transportation, and urban and regional planning.

Rutter discusses the information which archaeologists can get from study of paleosols, but cautions about the difficulty of such interdisciplinary work. The soil factor in archaeology is important both in the preservation of artifacts and in the siting of the prospecting for archaeological sites. In Canada, a considerable volume of knowledge on the preservation of Indian and European artifacts in soil materials is accumulating. The use of chemical soil analyses and soil geomorphological techniques is becoming routine in the archaeological research. Identification and sampling techniques are crucial. Soil scientists must teach soil science to archaeologists and must co-operate in field studies.

Dormaar cites 120 references to paleosols developed in earlier times. The properties of these soils are useful as stratigraphic markers and as indicators of past landscapes, climate and vegetation. The observed properties are often difficult to interpret or are ambiguous, and continuing studies are needed of more paleosols to make the maximum use of the information they can give.

d) Soil science is taught in detail in Faculties of Agriculture, but is not satisfactorily integrated into curricula of earth science programs. Soil mechanics is taught in isolation from other soil science courses. Soil science information, which has expanded significantly in the last twenty years, is, therefore, available largely only to soil science students in Agriculture. Some courses are now being given by soil scientists on the use of soils information in environmental concerns, but most of the teaching in this area is done without adequate soil science input. St. Arnaud lists some of the major needs: A means for greater soil science input into land-use decisions, getting information to those who need it, and teaching soil science in high schools and through continuing education programs.

e) Much of the research required will involve multidisciplinary teams of soil scientists along with other specialists. The strength and quality of the soil science input depends critically on the strength of the individual disciplines within soil science. Four authors have described the disciplines of physics, chemistry, biology and biochemistry, and mineralogy. From these papers it is easy to get a picture of the extent and type of activities. The remaining two papers on land reclamation and chemical soil testing are two examples of soil science applied to soil management problems. Anderson emphasizes that most of the involvement in land reclamation is recent and many procedures are under development. On the other hand, Bates describes chemical soil testing for assessing fertilizer requirements which is one of the earliest applications of soil science.

f) The impressions from these papers can be summarized as follows. There is a diversity of interests which varies with the region and the particular aspect of soil sciences being considered, but two points appear over and over again. i) The need for getting more soil science input into land use decisions. Under Canada's limitations of climate, it is important for us to recognize that basic fact about land "they ain't makin any more". ii) In view of the diversity of soils and soils-related problems in Canada, the resources we devote to soil science studies are critically inadequate. Arctic soils is an obvious, but not the only, example. Basic studies of chemical, physical and biological properties of soils are required, the results to be applied to a wide range of problems.

The gaps

Inevitably, some aspects of soil science have been omitted. We have had to be selective in the choice of papers; completeness would have produced a document too large and too detailed to be read by many people. This would have been inconsistent with the objectives we set for ourselves. There is, for example, no detailed discussion of the mineral composition of soils, although this is an important part of the soil inventory. Soil zoology has been neglected; there are very few people working in Canada characterizing the biological populations in soils and their energy relationships. The question of soil pollution has not been adequately discussed. While pollution of soils is restricted in extent, there are significant soil problems associated with accumulation of pesticides and accumulation of heavy metals in soils. An increasing problem brought about by increased surface mining activity for coal and other minerals has created a need for reclamation of soils. A very important study in Canada, that of permafrost in soil, has received only a few pages. Methods of geophysical mapping of soils and of measuring soil properties have not been discussed. Also omitted has been the relationship of soil science to atmospheric sciences. The radiation balance at the soil surface is important in a number of geosciences, and has given rise to the subdisciplines of micrometeorology or agricultural meteorology in which soil scientists have been very active.

General concerns

It is also appropriate in this introduction to make brief mention of some of the general concerns which the discipline of Soil Science has in Canada. The first concern is with the professional organization of soil science. The Canadian Society of Soil Science (CSSS) attempts to reach all people working in soil science. The CSSS is, however, still dominantly a group concerned with the agricultural use of soil.

A strong concern among soil scientists is the trend for research support to be given only for applications of soil science to immediate and short-term problems. This will mean that basic studies in soil science will continue to be neglected. This has become a serious problem in the past few years. It will result in insufficient background information for the applications which will be required in future years, and it also affects the training of graduate students in soil science. Too much work at the Ph.D. thesis research level is now being done on specific applications of soil science rather than on the principles of soil science. This comes about because research funding is more easily available for these problems, and the relative amount of funding from sources such as the National Research Council has decreased. While it is possible to do good basic studies in soil science as part of the solution of very practical problems, this is not often the case where research grants with specific objectives and restrictive time limits are the source of funds for Ph.D. research projects.

A further concern in student training, as well as in research work, is the small size of most soil science groups. Only a few groups in Canada are large enough to supply the breadth of interest and research activities which should form the environment for a Ph.D. student.

With this introduction to set the stage, we commend to you the papers in this report. While they are descriptive samplings of soil science activity, they will provide a good view of Canadian soil science – its achievements, its frustrations, and its needs.

SOILS MAP OF CANADA

J.G. Ellis[1]

The publication in 1972 by Clayton et al. of the map entitled 'Soils of Canada', which accompanies the 1977 Agriculture Canada publication 'Soils of Canada', is the culmination of four decades of soil inventory and interpretation in Canada. As acknowledged on the map, its compilation was the result of information obtained "from reconnaissance and exploratory surveys and schematic interpretations supplied by the regional Soil Survey organizations in the Provinces, supplemented by other surveys and investigations in the Northwest and Yukon Territories".

As recorded in Volumes XII, XIII, and XV of Scientific Agriculture, the first production of a soils map of Canada was undertaken in 1932 by the Soils Group of the Canadian Society of Technical Agriculturists. By 1936, this group had prepared a 'Soil Zone Map of Canada' and a 'Generalized Climatic Map of Canada'. Unfortunately, the soils map was never published for distribution; possibly because the soil scientists involved, realized the need for a Canada wide soil classification system. It is interesting to note that the present soils map of Canada is also accompanied by a map entitled 'The Soil Climates of Canada'.

The National Soil Survey Committee of Canada, which developed the soil classification system utilized in the production of the 1972 map of the Soils of Canada, also expressed the need for the preparation of a soil map of Canada in their 'Proceedings of the First Conference of the National Soil Survey Committee', held in 1945. The classification criteria needed to document a soils map of Canada was made available in 1970 when the Canada Department of Agriculture published the National Soil Survey Committee criteria in the book 'The System of Soil Classification for Canada'. This publication was subsequently amended and a revision published in 1947. A third revision presently in press will be available in 1978.

The National Soil Survey Committee was formed in 1940, by the National Advisory Committee of Agriculture Sciences, due to the initiative of the then Director of the Experimental Farm Services. It was renamed the Canada Soil Survey Committee in 1969.

Likewise, the soils section of the Experimental Farm Services became known in 1959, as the Soil Research Institute, Ottawa, and is a section of the Research Branch, Canada Department of Agriculture. These two present day organizations are co-operators in the two publications entitled 'Volume 1. Soil Report', and 'Volume 2. Inventory', which accompany the soils map of Canada.

It is necessary to utilize both volumes with the soils map to properly evaluate its cartographic presentation.

The biophysical environment of Canadian soils and the classification system utilized in the preparation of the soils map, are the dominant subjects described in Volume 1.

Map users are conveniently directed to Volume 2 for details of the Map Units delineated on the soils map by a series of Reference Numbers which appear in the map legend. Each individual Map Unit area delineated can be located on a soils map by a geographic grid reference, and credit is given in Volume 2 to the source of the information edited and its reliability at each designated location on the map.

The soils map is extended from the Order and Great Group categories of the Canada system of soil classification to the Subgroup category by means of Volume 2. This book also contains other noncartographic adjuncts to the Map Units delineated, such as its correlation with the FAO/UNESCO classification, the dominance of its soil Subgroups, its stony or rocky phases, its areal extent, its physiographic location and elevation, its soil climate, its topography and landform, the texture and character of its parent material, and finally its vegetation and landuse.

The first published soils map of Canada entitled 'Soil Regions' appeared in the 1957 Atlas of Canada. As stated on the map, it was "compiled from information supplied by the Experimental Farms Service, Department of Agriculture..." The second appearance of a soils map of Canada occurs in the 1974 National Atlas of Canada. As stated therein, "this map is a reduced adaptation of the "Soils Map of Canada" produced by the Soil Research Institute, Canada Department of Agriculture, and the Canadian National Soil Survey Committee". This latter map and the present map, were compiled and edited under the supervision of J.S. Clayton, formerly of the Soil Research Institute, and until his retirement in 1972, an active member of the Canada Soil Survey Committee.

The sections which follow document, in a general way, the physical, biological, and climatic environments of selected regions across the country, and provide a capsule view of the use, and misuse of the regional soils.

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[1]Saskatchewan Institute of Pedology, University of Saskatchewan, Saskatoon, Saskatchewan.

SOILS OF THE APPALACHIAN REGION

G.J. Beke[1] and J.D. Hilchey[2]

The Appalachian region of Canada encompasses the Island of Newfoundland, the provinces of Prince Edward Island, Nova Scotia, New Brunswick, and southeastern Quebec. It covers a land area of about 316 000 km^2. Most of this area is in the form of a barrier between the Atlantic Ocean and the Gulf of St. Lawrence (Fig. 2.1).

The region consists of detached, northeast-southwest trending highlands and uplands separated by valleys and broad lowland areas. Most of the lowland areas in the region are less than 120 m (400 ft) in elevation. The surrounding uplands generally range between 150 and 820 m (500 and 2700 ft) with the exception of the Notre Dame Mountains where the elevations exceed 1220 m (4000 ft) (Cann and Millette, 1960; Clayton et al., 1977).

Vegetation

The Appalachian region is basically a forested region comprising the Southern Mixed Forest Region, the Boreal Forest Region, and the Tundra and Boreal Forest Transition (Clayton et al., 1977; Rowe, 1972).

The Southern Mixed Forest Region includes all of Nova Scotia, New Brunswick, and Prince Edward Island as well as part of the Gaspé Peninsula. This forest is of a very mixed nature, characterized by red spruce, balsam fir, yellow birch, and sugar maple. Red and white pine and hemlock occur to a lesser but significant degree.

The Boreal Forest Region includes the greater part of the Island of Newfoundland and the northeastern part of the Gaspé Peninsula. A dominance of conifers characterizes this Region with white and black spruce as the main species. Although dominantly coniferous, there is a wide distribution of broad-leaved trees, particularly white birch, aspen, and balsam poplar. The wide distribution of aspen is partly due to its ability to quickly regenerate after fire, cutting, or other disturbances.

The portion of the Island of Newfoundland included in the Tundra and Boreal Forest Transition consists of sparsely forested heath-and-moss barrens. They owe their existence, in part, to wind exposure, perhumid conditions, and temperature limitations. Two main tundra types occur; namely, Lichen-Moss and Heath tundra. Lichen-Moss tundra forms a virtually continuous vegetative cover and is found in apparently well-drained, upper slope positions. The characteristic species are lichens, particularly reindeer moss. Heath tundra occupies more humid or less well-drained sites than the Lichen-Moss association. It is characterized by the occurrence of numerous ericaceous species such as rhodora

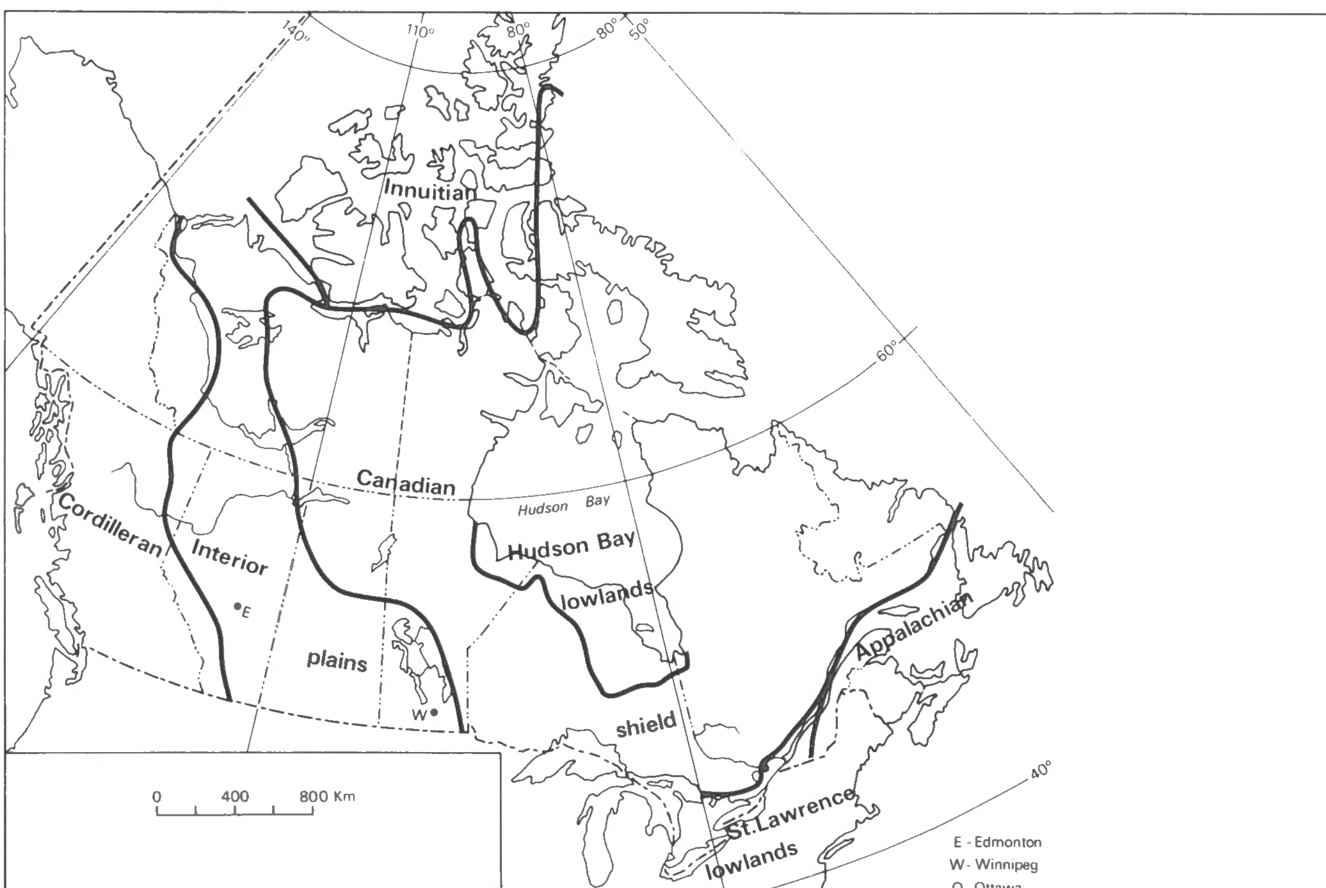

Figure 2.1. Major physiographic regions of Canada.

[1]Atlantic Soil Survey, Agriculture Canada, Nova Scotia Agricultural College, Truro, Nova Scotia.

[2]Nova Scotia Department of Agriculture and Marketing, Truro, Nova Scotia.

and sheep laurel. The forest vegetation within this Transition area consists mainly of dwarfed coniferous species with occasional good stands of trees sheltered, well-drained, and usually upper slope positions. Vegetation associations similar to the above are encountered in the Cape Breton Highlands and the Nova Scotia and New Brunswick Barrens (Clayton et al., 1977; Rowe, 1972).

Parent soil materials

By far the most extensive surficial deposit in the region is glacial drift which rarely exceeds 5 to 7 m (15 to 21 ft) and is more often 1 to 2 m (3 to 7 ft) thick. In areas of more resistant rocks, the bedrock may be exposed.

The till deposits of the region are chiefly ground-morainal in origin. Such tills normally consist of two distinct members. The lower member or basal till usually has a pseudo-platy structure and is much more compacted than the upper member or ablation till (Dreimanis, 1976). The thickness of this ablation till presently averages about 40 cm (16 in) and ranges from a few centimetres to over 2 m. The basal tills generally have a sandy clay loam or coarser texture and are highly compacted with low permeability. Tills with dominantly sedimentary coarse skeleton have mica as the predominant clay mineral, undifferentiated chlorite plus kaolinite and vermiculite-smectite occurring in lesser quantities. Tills with metamorphic coarse skeleton have a similar clay mineral suite as above. Those containing granitic coarse skeleton contain a poorly defined 14 nm mineral with properties of interstratified vermiculite-chlorite as well as (3.5 nm) amorphous materials (Brydon et al., 1968; McKeague and Brydon, 1970).

The rise in sea level during the deglaciation process has had a marked effect on the parent materials of coastal areas. Postglacial isostatic rebound has exposed large areas of marine and marine-modified deposits along the Bay of Fundy and the Gulf of St. Lawrence coast. On-going tidal action has produced thousands of acres of salt marsh. Postglacial denudative processes have produced aeolian, colluvial, and alluvial deposits. Bog formation has been active throughout but particularly so in the eastern portion of the region (Cann and Millette, 1960).

Soils of the Appalachian region

The prevalent soil-forming process on the undisturbed, better drained materials of the Appalachian region produces horizon sequences characteristic of the Podzol (Canada Soil Survey Comm., 1974).

The soil characteristics and the degree of podzolic development on the better drained materials differ considerably within the region. Podzols of the uplands and highlands usually have coarse textures, are stony, acid, have a firm to compact subsoil, and are shallow to bedrock. Podzols of the lowland areas vary in texture from sandy loam to sandy clay loam, have reddish brown colours, and compact subsoils frequently with fragipan horizons. Ortstein horizons, when present, are usually weakly developed and discontinuous. Along the Atlantic seaboard and in the "Barrens" areas they frequently contain well-developed, continuous ortstein and placic (iron pan) horizons. In general, they contain more organic matter in the B horizon than their lowland counterparts.

Deviations from podzolic development are common owing to such causes as soil disturbance by uprooting of trees, amount of loose soil overlying compact subsoil, the generally compact nature of the till parent material, and the extensive occurrence of fragic (Wang et al., 1974), ortstein (Wang et al., 1978; Wells and Heringa, 1972), and placic (McKeague et al., 1968) soil horizons. Tree-throw results in dynamic rejuvenation of the soil's morphological expression and produces a hummocky microrelief (Lyford and MacLean, 1966). Shallow, loose soil overlying compact subsoil on well and imperfectly drained sites provide horizon sequences characteristic of Luvisols (Canada Soil Survey Comm., 1974). These Luvisols differ considerably from those in central and western Canada (McKeague et al., 1972) owing in part to weak structures as well as the marginal amount and narrow zone of clay accumulation in the Bt horizon. The compact subsoil and the ortstein, fragic, and placic horizons favour pseudo-gley and gley development characteristic of Gleysols and eventually organic accumulation.

The Gleysols in the region usually have a leached mineral horizon underlain by an iron enriched horizon. Notable exceptions are the Gleysols occurring in reclaimed salt marsh areas which often show "acid-sulphate soil" (Van Breeman, 1973) features. Many poorly drained soils along the Atlantic seaboard and on the Island of Newfoundland have a sufficient build-up of organic material to be classified as Organic Soils (Canada Soil Survey Comm., 1974). The accumulated organic debris is normally of the raw humus type derived principally from sphagnous vegetation (Nowland, 1971; Pollett, 1968).

Soil properties

The physical, chemical, and mineralogical attributes of the soils of the Appalachian region depend, in part, on the degree of profile development.

Soils of the uplands and highlands tend to be excessively stony whereas lowlands soils are non- to moderately stony. This, and the preponderance of sandy loam textures explain, in part, the higher degree of compaction of lowland soils as compared to highland ones. In addition the soils are susceptible to water erosion owing partly to the coarse textures and low organic matter contents of the surface mineral horizons. In this respect, measured soil losses over a two-year period in Prince Edward Island for a potato crop ranged from 7.4 t/ha to 19.3 t/ha on study plots with slopes of 7 per cent and 12 per cent, respectively (Stewart and Himelman, 1975).

The mineralogy of the clay fraction from well-developed soils shows a general weathering trend of alteration of indigenous mica to expansible minerals and further alteration of the expansible minerals to smectite (Brydon et al., 1968, McKeague et al., 1973). Under natural conditions relatively low amounts of potassium are fixed by the clay minerals, but an increase of soil pH, e.g. through liming, increases the rate of potassium fixation (Hilchey, 1970). Ammonium fixation likely follows a similar trend as for potassium.

The soils of the region are acid with low cation exchange capacity and, base saturation is usually less than 50 per cent. As a consequence, the soils are deficient in many of the elements essential for plant growth.

Nevertheless, the inherent fertility of the soils varies widely and appears related to the composition of the soil's parent material. Preliminary studies (E. Bailey, Nova Scotia Department of Lands and Forests, Truro, Nova Scotia) have shown a high correlation between the kind of coarse (> 2 mm) soil material and forest growth. For instance, soil developed in till with schistose coarse skeleton produces better forest growth than when the same kind of till contains granitic coarse fragments.

Land use

Approximately 85 per cent of the lands in the Appalachian region are unimproved. Most of these unimproved lands are suitable for forestry. Total merchantable timber (> 5 cords/acre in trees > 4" d.b.h.) constitutes about

5 per cent of the national total. Approximately one fifth of the total merchantable timber in the region consists of hardwoods. In general, the merchantable timber in the northern half of the region consists primarily of merchantable pulpwood (> 4" d.b.h.) whereas up to about 40 per cent of the timber in the southern half consists of merchantable saw-timber (> 10" d.b.h.) (Atlantic Development Board, 1968. Forestry in the Atlantic Provinces, Ottawa).

Agricultural land use is presently restricted to the Annapolis Lowland, the Maritime Plain, the Eastern Quebec Uplands, the portion of the New Brunswick Highlands to the west of the St. John River, and to alluvial plains and terraces in uplands and highlands. Dairy or mixed farming is the most important agricultural enterprise in Newfoundland and the Eastern Quebec Uplands. The portion of the New Brunswick Highlands to the west of the St. John River is known for its potato production. Tree fruits, cash crops and mixed farming mark the agriculture carried out in the Annapolis Lowland. The growing of grain, potatoes, and tobacco as well as dairy farming occupy most of the cleared land in the Maritime Plain.

Much of the land base is best suited to forestry, recreation, and wildlife. It is unfortunate that urbanizing pressures bear most strongly on those acres of land best suited for agricultural production. When so-called conflicts in resource use are examined, a strong feeling develops that these alternate uses of land are not necessarily conflicting at all, and, in many cases, are supportive in nature. The prime concern in any case should be the long term effect of a change in use on the land base and whether or not the use will permanently impair the capability of the land to provide food, fibre, and a quality environment.

Capability of the Appalachian region to produce farm and forest crops

The dominant soil limitation to crop production is low fertility. Generally, lime and fertilizers need to be applied on an annual basis as residual effects of such inputs are usually short-lived (MacKay and Munro, 1964).

Poor structure is the second limitation. It affects approximately one third of the arable soils and appears to stem from cemented or compact subsoil layers, such as ortsteins, fragipans, and basal tills. These resist penetration of plant roots and percolation of rainfall and cause excess moisture, low trafficability, shallow rooting of crops, and consequent undesirable nutrient and moisture regimes. Tile drainage and, more recently, mole drainage and subsoiling are being applied in attempts to overcome these effects of poor structure.

Excessive stoniness, steep topography, and wetness are the other limitations. Stoniness and wetness can be ameliorated by mechanical means, if economically feasible. Steep slopes and complex relief patterns seriously impede the use of large areas for most crops due to the difficulty of operating machinery and the hazard of erosion (Hilchey, 1970; Nowland, 1975).

Climatic factors impose a ceiling on the productivity of all soils in the region. The climate is unusually variable owing to the movement of low-pressure air masses across this section of the continent. The maximum summer temperatures and accumulated heat along Atlantic coastal areas are lower than desirable for cereal and certain fruit crops. The mean frost-free period ranges from about 80 days in interior Newfoundland, northern New Brunswick, and the interior of the Gaspé Peninsula to over 130 days in coastal areas. Total precipitation during the growing season is usually adequate for crop production. However, monthly rainfall during the growing season varies widely from its mean, affecting crop production (Hilchey, 1970).

Research needs

Past emphasis on agricultural soil research in the region has concentrated on soil improvement from the nutritive standpoint. Until recently, little work has been carried out on soil physical problems. It is now apparent that further improvements in crop production may best be attained through a concentrated research effort directed towards comprehending and ameliorating the known physical limitations.

The information available on the soil resource of the Appalachian Region shows it to be a resource beset with many peculiar characteristics, each of which imposes certain specific managerial practices. Unfortunately, knowledge of the distribution of the various soil types is incomplete as large areas of the region have not been surveyed as yet. In addition, most soil surveys carried out to-date were conducted at too small a scale to permit differentiation between certain types of soil development. Consequently, new surveys as well as re-surveys are urgently needed in order to provide adequate resource information.

Intensive land use of some form or other has been practised in the region for more than 200 years. Nevertheless, recorded information on the suitability of the soil resource, is scarce or non-existent. If available, the information often cannot be related to specific soil types owing, in part, to the non-existence or general nature of the resource information and to the lack of synthesis of research results.

Developmental research has focused primarily on crop production. Past emphasis in agricultural soil research in the region has concentrated on soil improvement from the nutritive standpoint. Until recently, little work has been carried out on soil physical problems. It is now apparent that further improvements in crop production may best be attained through a concentrated research effort directed towards comprehending and ameliorating the known physical limitations. These principal physical soil limitations to crop production pertain to the cemented and compacted layers, the complex relief patterns, and the variability of the soil moisture regime during the growing season. Research on cemented or compacted layers should, in the first instance, be directed towards identifying the procedure or procedures to improve the specific condition.

The research effort must include the economics of the amelioration procedures and the likely change in soil nutrition, soil moisture regime, and soil suitability as well as changes in crop productivity and palatability. In other words, the research effort should be conducted on a systems basis so that the research end products provide prediction models. Thus in the case of a complex relief pattern the research effort should include evaluation of structural and cultural soil conservation practices as well as the economics thereof. In a similar vein, introduction of new techniques or modifications in resource use elsewhere in the production system should be evaluated for their effect on the soil resource. Pertinent examples include introduction of new crops, equipment, and pesticides as well as intensification of recreational use, adaptation of monocultural practices, and suitability of land resource consolidation programs.

The indicated research requirements for determining the suitability and the capability of the soil resource could be attained through instigation of a well designed, well co-ordinated team approach to research. Considering the urgent need for this information, adequate commitments of funds and manpower are required in addition to possible re-direction of current funds and personnel. The multidisciplinary approach to research will be most efficient when research proposals are subjected to greater scrutiny to ensure that results from projects conducted elsewhere are used and that research projects provide a synthesis of the work done on a regular basis. Meanwhile input into the recently instigated land evaluation program should be greatly increased not only to permit rapid access to and synthesis of on-file research data but also to provide a standardized approach to meaningful resource data collecting ongoing projects.

The systems approach to research and development is a standard practice in the nonrenewable resource industries. This is normally conducted in-house and includes legal and marketing aspects. Unfortunately, most primary or renewable resource industries do not have direct control over their R and D. Conceivably, therefore, practical application of results arising from systems research will not be forthcoming until improvements are made to the business climate in which the primary industry is required to function.

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LES SOLS DES BASSES-TERRES DU SAINT-LAURENT

M. Laverdière[1] et Y. Martel[1]

Les basses-terres du Saint-Laurent, souvent appelées les basses-terres des Grands Lacs et du Saint-Laurent, sont localisées dans trois provinces canadiennes: l'Ontario, le Québec, et Terre-Neuve. Elles sont limitées au nord et au nord-ouest par le Bouclier Canadien, à l'ouest par le lac Huron, au sud par les lacs Erié et Ontario, à l'est par les Appalaches et au nord-est par le détroit de Belle-Isle. S'étendant sur une superficie de près de 155 000 km^2, elles représentent 1.5% de la surface totale du Canada et constituent la plus importante région industrielle et agricole de l'est du pays.

Les basses-terres du Saint-Laurent sont sectionnées par des inclusions du Bouclier Canadien en trois régions appélees les basses-terres de l'ouest, de centre et de l'est. Les basses-terres de l'ouest sont situées dans le sud-est de l'Ontario et sont divisées en deux secteurs par l'escarpement du Niagara. Les basses-terres du centre couvrent l'extrême est de l'Ontario et chevauchent le Saint-Laurent jusqu'à l'est de Québec. Les basses-terres de l'est se situent à la hauteur du golfe Saint-Laurent.

Les matériaux de surface de cette region ont fait, depuis vingt ans, le sujet de plusieurs travaux de recherches. Ces études avaient généralement pour but de classifier les sols, de déterminer leurs principales propriétés et d'évaluer leur potentiel agricole (Clayton et al., 1977; Etudes pédologiques des comtés du Québec, dates diverses; Lajoie, 1975; Legget, 1961; Matthews et Baril, 1960; Nowland, 1975; Soil Survey Reports of Ontario, dates diverses).

Le climat, la végétation, la physiographie

Le climat des basses-terres du Saint-Laurent peut être qualifié de semi-continental car il est influencé par la proximité des Grands Lacs en Ontario et du fleuve Saint-Laurent au Québec. La température moyenne de janvier varie de -3.5°C dans la partie ouest à -9.5°C à l'extrême est de cette région. La température moyenne du juillet varie de 23.5°C au sud-est de l'Ontario à 13.5°C à l'ouest de Terre-Neuve. Le nombre de degrés-jours cumulatifs, lequel représente la sommation des températures moyennes journalières au-dessus de 5.5°C excède 4000 unités dans la région de Windsor mais ne dépasse pas 2500 unités à l'est de Québec et 1500 unités sur les côtes du détroit de Belle-Isle, ce qui est marginal pour plusieurs cultures. Les précipitations qui varient de 800 mm en Ontario à 1100 mm dans la région de Québec sont bien réparties tout au cours de l'année et préviennent ainsi les sécheresses excessives (Chapman et Brown, 1966; Hare et Thomas, 1974).

La forêt dominait la végétation naturelle de cette région mais une grande partie a été défrichée depuis d'arrivée des colons, il y a 350 ans, pour faire place à l'agriculture. On la retrouve principalement aujourd'hui sur les sites les moins propices à la culture afin de protéger les sols contre l'érosion ou pour servir de sites récréatifs. La forêt naturelle est composée surtout de feuillus dans l'Ontario et d'un mélange de feuillus et de résineux dans le Québec et Terre-Neuve. Les principales espèces retrouvées sont les pins blancs et rouges (**Pinus strobus** L. et **Pinus resinosa** Ait.), le merisier (**Betula lutea** Michx. f.) et la pruche (**Tsuga canadiensis** L.). On retrouve en plus, plusiers espèces de décidus dans le sud-ouest, telles les érables à sucre et rouge (**Acer** spp.), l'orme (**Ulmus** spp.) et le chêne (**Quercus** spp.) et des espèces boréales à l'est, telles les épinettes noires et blanches (**Picea mariana** Mill. et **Picea glauca** Moench), le cèdre (**Thuya occidentalis** L.) et le peuplier à grandes dents (**Populus grandidenta** Michx.) (Rowe, 1972; Marie-Victorin, 1964).

Du point de vue physiographique, les basses-terres du Saint-Laurent s'apparentent à une plaine. Elles ont été soumises à plusiers glaciations pendant la période du Quaternaire et ont ainsi été recouvertes de dépôts glaciaires, fluvioglaciaires et glacio-marins. La majorité des assises rocheuses constituées de grès, de dolomite, de schiste et de calcaire, datent du Paléozoïque, à l'exception des Montérégiennes qui ont été mises en place au Mésozoïque supérieur (Fairbridge, 1975). Les basses-terres de l'ouest ont une texture variable due au retrait des glaciers qui ont entraîné la déposition et le remainiement des matériaux originels. Les basses-terres du centre et de l'est ont un socle souvent recouvert de till de fond, de dépôts fluvio-glaciaires et marins ou fluviatiles. L'origine de ces matériaux est reliée à la dernière glaciation qui a pris fin il y a environ 11 000 ans et au retrait de la mer de Champlain suite au relèvement isostatique: l'épisode Champlain se situe entre 9000 et 11 000 ans B.P. (Gadd et al., 1972; Prest, 1970).

Les sols des basses-terres du Saint-Laurent se sont développés principalement à partir de matériaux originant de Bouclier Canadien. Le transport et le remaniement de ces matériaux par l'eau et les glaciers ont permis une distribution variable du quartz, de la hornblende et des feldspaths dans presque tous les profils de sol (Clayton et al., 1977).

Dans les sols bien développés sur tills glaciaires et sur dépôts fluvio-glaciaires (Podzols), le mica hydraté de type illite est le minéral dominant de la fraction fine ($< 2\ \mu m$). Des quantités relativement constantes de kaolinite sont également présentes dans tous les horizons de nombreux Podzols. De plus l'horizon d'éluviation (Ae) est caractérisé par la présence de montmorillonite et l'absence de chlorite alors que la vermiculite chloritisée est très courante dans les horizons d'illuviation (B). Les sols qui se sont développés sur des matériaux à texture moyenne et possédant un bon drainage (Luvisols et Brunisols), contiennent de la montmorillonite et de la vermiculite dans leur fraction argileuse, bien que le mica hydraté demeure la composante majeure. La chlorite se retrouve dans certains horizons d'éluvation contrairement aux Podzols alors que la kaolinite semble distribuée de façon identique. Les sols formés à partir de sédiments lacustres et marins (Gleysols et Régosols) ont une texture plus fine que les dépôts mentionnés précédemment et contiennent dans plusieurs cas des carbonates. La fraction argileuse de ces sols contient des micas hydratés, de la vermiculite, de la montmorillonite, de la chlorite, de nombreux interstratifiés en plus des mineraux primaires typiques mentionnés précédemment.

Sols des basses-terres de l'ouest du Saint-Laurent (Région des Grands Lacs) (fig. 2.2)

Les sols de cette région se sont développés sur trois types principaux de matériaux meubles: les tills glaciaires, les dépôts fluvio-glaciaires et les sédiments lacustres.

Les tills glaciaires modérément pierreux dominent dans la partie nord de cette région. Les sols y ont une texture variant de loam sableux à loam et des pH moyennement acides à faiblement alcalins (Hoffman et al., 1964). Un peu plus au sud, les sols se sont développés sur des tills plus fins

[1]Station de Recherche, Agriculture Canada, Ste-Foy, Quebec.

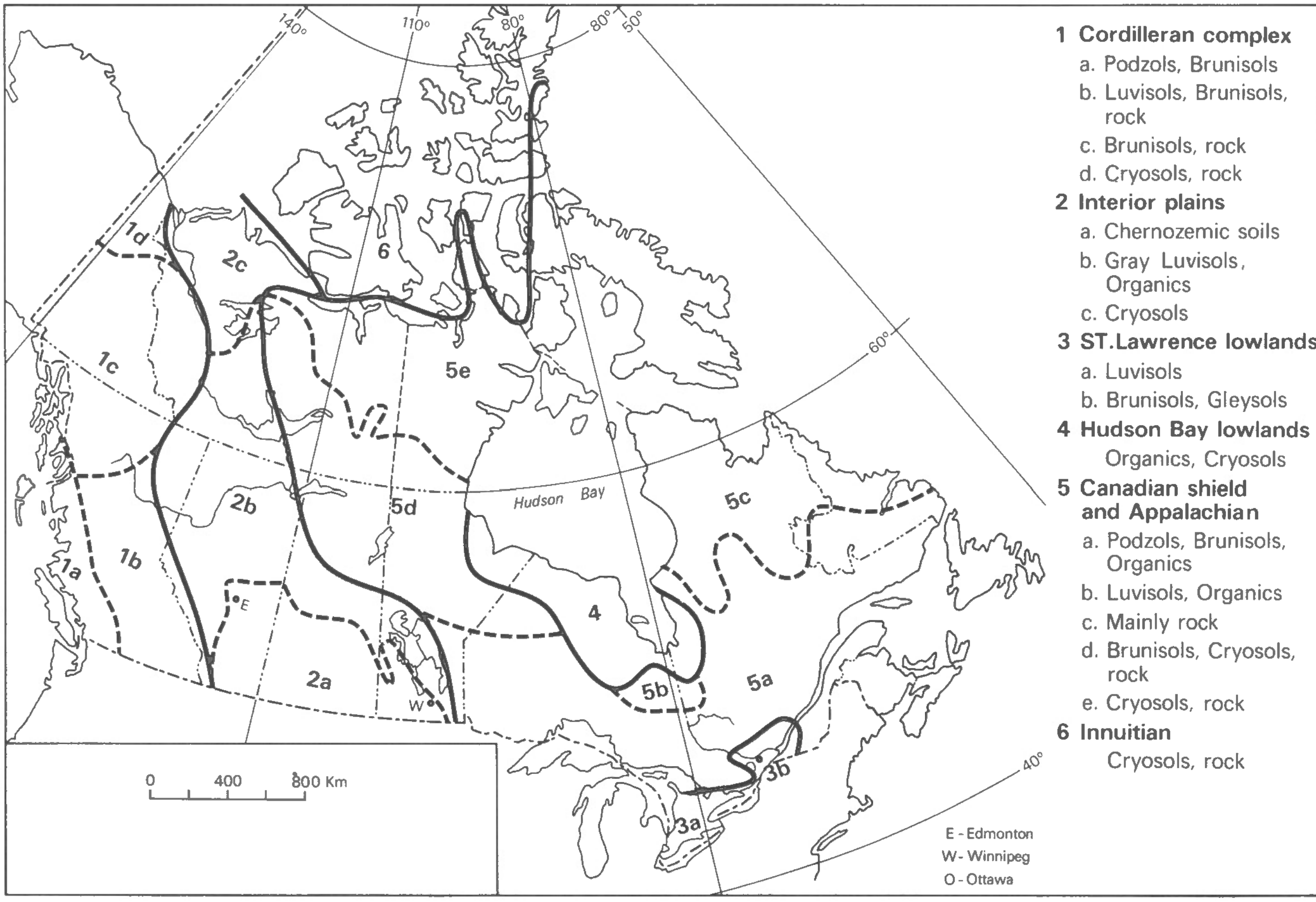

Figure 2.2. Principales zones de sol du Canada.

ou sur des sédiments lacustres à texture variant de loam à loam argileux. La présence de carbonates et les conditions de drainage relativement bonnes de ces sols, classifiés principalement comme des Brunisols mélaniques et des Luvisols gris brun en font des sols agricoles de catégorie A. Cependant, la présence de nombreux drumlins séparés par d'étroites bandes de sol mal drainé et marécageux ainsi que l'existence d'assises rocheuses à proximité de la surface (1 m et moins) contribuent à donner à cette région une quantité relativement importante de sols agricoles de catégories B et C (Nowland, 1975).

Les dépôts fluvio-glaciaires dont la texture varie de sable moyen à grossier se retrouvent principalement le long des rives du lac Erié. Ces dépôts forment également une bande étroite en direction nord vers le Bouclier Canadien. Dans la région de Guelph cependant, la texture du matériau de recouvrement est limoneuse au lieu de sableuse. Plusieurs facteurs limitatifs tels le bas niveau de fertilité, le faible contenu en matière organique ainsi que la susceptibilité à l'érosion en font des sols réservés le plus souvent pour les pâturages et la grande culture. La majorité de ces sols classifiés comme étant des Luvisols gris brun et des Podzols ont un drainage excessif qui en font des sols agricoles de catégories B et C.

Les sédiments lacustres ont une texture variant de loam argileux à argile et se retrouvent près de Kingston et dans les péninsules de Windsor et de Niagara. Les sols qui s'y sont développés ont habituellement un drainage imparfait mais possèdent une bonne fertilité. Les sols gleysoliques prédominent en terrain plat alors que sur les pentes ou dans les endroits plus sableux dex Luvisols peuvent s'y retrouver (Matthews et Baril, 1960). La plupart des sols de cette région sont pauvres en matière organique et présentent des pH faiblement acides dans leurs horizons de surface. Bien qu'ils nécessitent une bonne régie, ces sols sont généralement classifiés dans la catégorie A.

***Sols des basses-terres centrales du Saint-Laurent** (fig. 2.2)*

Les sols de cette région se sont développés sur deux types principaux de matériaux meubles: les sédiments marins et les sables deltaïques.

Les sédiments marins déposés par les eaux de la mer de Champlain se retrouvent à moins de 175 m d'altitude. Ils ont rempli les dépressions laissées par les dépôts morainiques produisant ainsi de vastes étendues de terrain plat comme on en rencontre dans la région d'Ottawa, à l'est de Montréal, et en bordure du Saint-Laurent. Ces dépôts ont une épaisseur variable qui atteint 90 m dans la région du lac Saint-Pierre (Ministère des Transports, 1971). À cause de leur texture argileuse (généralement plus de 50% d'argile), ces dépôts présentent en plusieurs endroits des problèmes d'égouttement d'eau, qui peuvent être corrigés par un drainage de surface ou souterrain. Ces sols, dû à leur fertilité naturelle se regroupent principalement dans la catégorie A.

Les sables deltaïques recouvrent près de la moitié du territoire délimité par les sédiments de la mer de Champlain (Lajoie, 1975). Ils ont été déposés par les cours d'eau descendant des hautes-terres bordant le plaine du Saint-Laurent. Ces dépôts qui ont une épaisseur variant de 1 à 3 m présentent un relief habituellement plat, sauf dans les régions où des vents violents ont favorisé la formation de dunes. Ces sables sont classifiés principalement comme des Podzols plus ou moins bien drainés et se regroupent dans la catégorie B dû à leur bas niveau de fertilité et leur faible taux de matière organique.

Sols des basses-terres de l'est du Saint-Laurent

La région des basses-terres de l'est du Saint-Laurent n'apparaît pas sur les figures 2.1 et 2.2. Elle comprend les îles d'Anticosti et Mingan, quelques petites zones sur la rive nord du golfe Saint-Laurent et la partie côtière nord-ouest de Terre-Neuve. Cette région est peu habitée et peu cultivée, du aux hivers longs et rigoureux et aux courtes saisons de végétation.

Potentiel des basses-terres du Saint-Laurent

La région des basses-terres du Saint-Laurent représente environ 13% de la superficie habitée du Canada mais regroupe plus de 50% de toute la population du pays. La majorité des sols de cette région avait été déboisée avant la mécanisation de l'agriculture de sorte que les superficies cultivées étaient à leur maximum dès les premières décennies du vingtième siècle. Depuis lors, ces superficies n'ont jamais cessé de décroître. Une trop grande pierrosité, une topographie trop accidentée ou un drainage inapproprié ne permettaient plus d'assurer ou de maintenir la rentabilité de nombreuses fermes. Une grande partie de ces sols abandonnés ont alors été reboisés.

La très forte demande de superficie pour l'expansion urbaine et le développement de zones industrielles, d'aéroports et d'autoroutes contribuent également à diminuer l'étendue de sols cultivés. En Ontario, par exemple, considérant que 80 ha de terrain sont nécessaires pour chaque accroissement de la population urbaine de 1000 personnes, Crerar (1970) a estimé que cette province perdra 148 600 ha d'ici 1981 et 333 300 ha d'ici 1991. Ceci signifierait que 5% de tous les sols agricoles de catégorie A de cette province seront cédés a l'urbanisation d'ici 1991 (Crerar, 1970). Au Québec durant la même période, on estime que les pertes de sols agricoles de catégorie A en faveur de l'urbanisation pourraient atteindre 10% (Nowland, 1975; Tardif et Paquin, 1976).

Dans le même ordre d'idée, la spéculation sur les terres constitue un problème sérieux. Déjà en 1966, dans la région sud de Montréal, 136 000 ha des meilleures terres agricoles avaient connu une destructuration alors que les besoins de l'urbanisme n'étaient que de 10% de cettesuperficie. Déjà en 1971, l'agglomération de Montréal avait à sa disposition une étendue disponible pour l'urbanisation presqu'aussi grande que la superficie déjà urbanisée. En 1975, plus de 340 000 ha situés dans les basses-terres du centre du Saint-Laurent étaient entre les mains des spéculateurs et possiblement inutilisés par l'agriculture (Tardif et Paquin, 1976).

Devant l'augmentation de la population et de ses besoins dans las basses-terres du Saint-Laurent, les pressions exercées pour soustraire à l'agriculture les terres de catégorie A, ne cesseront de s'accroître. Paradoxalement, un accroissement des superficies cultivées dans cette région semble nécessaire pour assurer un minimum d'autosuffisance agricole surtout en ce qui concerne la production de légumes, de produits frais et de céréales. L'importation de tels produits implique non seulement un coût de transport élevé mais aussi une dépendance des marchés agricoles des Etats-Unis et du Mexique principalement. Une utilisation plus rationnelle des sols des basses-terres de l'ouest et du centre du Saint-Laurent s'impose donc et la règlementation ou le zonage des terres agricoles apparaît comme une urgence dans le contexte actuel.

Une planification générale de l'agriculture dans les basses-terres du Saint-Laurent suppose non seulement des restrictions économiques et sociales pour les agriculteurs et les consommateurs, mais exige également une meilleure connaissance de la productivité de nos sols par région et par type de sols. Cette productivité devrait être évaluée en tenant compte de diverses contraintes telles le climat, les exigences du sol, l'énergie nécessaire à la ferme, les risques de pollution de l'eau par l'emploi de doses massives de fertilisants et de pesticides. Même s'il apparaît raisonnable d'affirmer qu'une meilleure régie des sols et l'emploi de variétés à rendement plus élevé pourront augmenter la productivité des sols et compenser pour la perte de superficie de terres agricoles, ceci n'est cependant pas sans limite. Ainsi, il apparaît déjà impossible de relocaliser la production fruitière de la péninsule de Niagara car elle est la seule région à posséder le climate adéquat. Par contre, l'élevage des bovins de boucherie pourrait être repoussé vers les zones plus marginales occupées par des sols de catégories B et C.

Parmi les différents types de sols qui demandent une attention spéciale, on retrouve les sols organiques,lesquels sont présents aussi bien dans les basses-terres de l'ouest et du centre que de l'est du Saint-Laurent. Grâce à des régies de plus en plus specialisées, ces sols ont atteint une productivité très élevée à l'hectare, surtout pour la production de légumes frais. Dans les basses-terres du centre, par exemple, les sols organiques occupent 81 000 ha (Rompré, 1971). De cette étendue, 53 000 ha sont situés dans la région de Montréal (Baril, 1971) et environ 5000 ha sont intensivement utilisés pour la production de légumes (Lajoie, 1975). Le degré de décomposition et l'épaisseur de ces dépôts, font que les sols organiques ne sont pas tous utilisables pour l'agriculture. Des recherches sont nécessaires pour compléter nos connaissances actuelles afin de mieux classifier ces dépôts organiques en fonction de leur utilisation agricole.

Un aspect qui prendra de l'importance dans les basses-terres du Saint-Laurent où l'agriculture est pratiquée sous une forme intensive, est le bilan énergétique de production. Si d'une part, l'assimilation de l'énergie par la photosynthèse doit préoccuper les phytologistes, les quantitiés d'énergie nécessaires sous forme mécanique et chimique pour produire une tonne de nourriture doivent préoccuper les spécialistes en sol. Une facon d'augmenter l'efficacité énergétique sur la ferme, serait d'étudier les relations entre les racines des plantes et le sol. Peu d'études au Canada ont été effectuées sur ce sujet. Pourtant, les taux d'utilisation des fertilisants tels le phosphore et la potasse sont relativement bas, 30% dans le cas de P, et 50% dans le cas de K, alors qu'il est de 80% pour N (Barber, 1976). Ainsi, la régie des sols aurait avantage à étre étudiée non seulement en fonction des rendements optimum mais également en fonction des besoins d'énergie.

Si beaucoup d'efforts doivent être consacrés à augmenter la productivité agricole, un minimum d'attention doit porter sur les effets de l'agriculture moderne vis-à-vis les sols. Les sols argileux des basses-terres du Saint-Laurent ont un haut niveau de productivité qui aurait avantage à être maintenu mais qui risque d'être affecté par la culture intensive continue, l'utilisation de doses élevées de produits chimiques et des régies trop agressives de culture. Dans cet ordre d'idées, l'étude plus poussée des propriétés biologiques, chimiques et physiques des sols devrait être poursuivie en considérant que les sols sont une richesse naturelle qui doit être protégée afin de répondre aux besoins des générations futures.

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SOILS OF THE CANADIAN SHIELD

C.J. Acton[1]

The Canadian Shield comprises the largest major physiographic region of Canada with an area of approximately 1.7 million square miles (4.6×10^6 km^2). Its vastness becomes more apparent when stated that it encompasses nearly one-half of the nation's land area. The extent of the region can be seen in Figure 2.1, occupying parts of five provinces (Alberta, Saskatchewan, Manitoba, Ontario, and Quebec) and the Northwest Territories. It is flanked by the Appalachian Region on the east, the Interior Plains to the west, and by the Arctic Lowlands on its northern boundary (Douglas, 1970).

The Shield landscape

The Canadian Shield is the physiographic region underlain by stable crystalline Precambrian rocks, that outcrop on the land surface, or directly underlie unconsolidated glacial sediments. Granitoid rocks make up about two thirds of the exposure, the rest being a volcano-sedimentary complex that has been metamorphosed in one or more orogenic episodes.

Glaciation has strongly modified the ancient bedrock surface with the Wisconsin stage being the most important as far as landforms and glacial materials are concerned. The effect has been rounding and levelling of the rock ridges, scouring out hollows and depositing shallow layers of glacial till. Throughout the morainic areas, eskers, drumlins and glacial fluted landforms also can be found. Vast areas of the Shield also were completely denuded of soil material during glaciation leaving barren bedrock plains. The rather uniform summit levels of the hilly landscape gives the Shield the overall appearance of an eroded peneplain. In scattered areas the relief is mountainous, as in uplifted areas along the eastern rim of the Shield. Even in these areas, however, remnants of the old erosion surface are evident on the summits.

[1]Ontario Institute of Pedology, Agriculture Canada, University of Guelph, Guelph, Ontario.

Sorting of sediments during deglaciation has given rise to glaciofluvial and lacustrine materials in glacial spillway channels and freshwater glacial lakes. The largest glacial lake confined solely within the Shield boundary was the former Lake Ojibway-Barlow in northeastern Ontario and northwestern Quebec, the area now referred to as the "Clay Belt". Former Lake Agassiz sediments in eastern Manitoba and northwestern Ontario, and those of old Lake Algonquin along the north shore of the present Lake Superior also lie within the Shield region. In addition, large lake basins formed to the west of Hudson Bay, as well as in the Hudson Strait and Ungava Bay vicinity (Clayton et al., 1977). The usual level to undulating topography of these glacial lacustrine landforms is in striking contrast to the irregular steeply sloping and hilly glacial till modified landscapes throughout most of the Canadian Shield region.

Glaciation has also contributed to the enormous numbers of lakes and streams in the region by damming streams and valleys with glacial debris. The main streams flow in the direction of the general slope of the land surface, commonly following fracture zones and faults in the bedrock.

Soils of the Shield

For the purpose of this discussion, that portion of the Canadian Shield within the Arctic region will not be included. It is discussed in the section on the Soils of Arctic Canada.

Because the soils of Canada are generally young in age, the soil parent material has a dominant influence on the nature and distribution, despite re-sorting by glacial and periglacial processes.

Glacial till derived from Precambrian bedrock is most widespread in the Shield region. Soils developed from these materials have a wide variety of characteristics resulting from variations in the parent rock, thickness of the deposit, stoniness, slope, and drainage. The most common situation is one where the soils are very sandy and gravelly, shallow to bedrock, acid, and low in moisture holding capacity and fertility. The content of medium and coarse sand in the till is high and there are many stones and boulders. Where the bedrock from which the till is derived becomes more basic, similar soils, but of higher silt content can be expected to occur. These too are often shallow to bedrock, acid and stony or bouldery.

The topography in these soil landscapes is rough, often with short, steep, and irregular slopes. Water rapidly runs off the steep slopes and the portion that enters the soil percolates freely through the porous soil materials. This has contributed significantly to soil development.

In the undisturbed state the most common soil of the Shield has a thin, dark coloured surface composed of the remains of leaves, twigs, and other plant residues in various stages of decomposition. This is underlain by a thin ashy-grey layer and reddish or brownish B horizons. The C horizon commonly is a greyish coloured,stony glacial till, strongly to moderately acid in reaction. Soil development has been influenced to a large extent by the humid to perhumid moisture regime and cool temperatures. This has contributed to the formation of amorphous complexes of organic matter and iron and aluminum compounds, which have accumulated in the podzolic B horizon. Consequently, the well and imperfectly drained soils largely are classified in the Podzolic Order, Humo-Ferric Podzol Great Group. Intergrades to Brunisolic soils, Dystric Brunisol Great Groups, are not uncommon where development of the podzolic B horizon is less strongly expressed.

On glaciofluvial parent materials derived from Precambrian rocks, the soils have many similar characteristics to the foregoing. However, the soils are generally considerably deeper to the underlying rock, consequently the land surface tends to be less steeply sloping and irregular, less stony and bouldery than their glacial till counterparts.

Throughout large areas of the Shield, particularly in its northern extremes, the minimal soil development is due to the colder climates of the area as well as the closer proximity of the Precambrian bedrock to the soil surface. Taxonomically these are referred to as Regosolic soils where profile development is too weakly expressed to meet the requirements for classification in any other order. They have shallow solums, are coarse textured, stony and bouldery, and commonly occur on rough topography with bedrock controlled morainic landforms. Progressive thinning of the unconsolidated glacial materials has given rise to land classified as Rockland which is too thin or weakly developed to be taxonomically classified as soil. This includes very thin deposits (10 cm) overlying bedrock, to none on exposed bedrock surfaces. It occurs as the dominant land type over large areas in the eastern Shield region including northern Quebec and Labrador. It also is prevalent throughout other parts of the Shield as a subdominant component in association with Podzols, Regosols, Brunisols, and to a lesser extent Luvisols, Gleysols, and Organic soils. Many lakes, ponds, and swamps are associated with Rockland as a result of the disruption of drainage brought about by glaciation.

The glacial lacustrine derived soils provide striking contrast to those formed on glacial till and glaciofluvial materials in the Canadian Shield. They are fine textured soils, generally on level to undulating landscapes and are neutral to alkaline in reaction. Poor drainage is their single most important soil-characteristic; which can be attributed to the fine texture and impermeability of the material and the generally level topography. Consequently Gleyosolic soils are most predominant on these materials. However, Luvisolic soils of the Gray Luvisol Great Group can be expected where the land surface is undulating to rolling, this type of development being brought on by the improved drainage condition in these landscapes.

Over extensive areas of the Shield, deep accumulations of organic materials have developed in the period following deglaciation. Many of these deposits occupy undrained areas of former glacial lake basins or in depressions in the bedrock surface where vegetative remains have built up under anaerobic conditions. Most commonly these environments are mildly to strongly acid, and in a highly undecomposed state such that soils of the Fibrisol Great Group of the Organic Order occur.

Land use

Land utilization throughout the Canadian Shield region is affected by one or all of the factors including unfavourable climate, steepness, and irregularity of the land surface, shallow soils, stoniness or rockiness, and excessive wetness.

The main land use throughout the Shield region is for forestry or wildlife activities, such as hunting, trapping, and recreation. Productive stands of coniferous and mixed forest are generally restricted to the more southern areas of the Shield, in the boreal forests dominated by jackpine, white spruce, black spruce, balsam fir, and trembling aspen. Utilization of the forest resources for logs for the sawmill industry and pulp and paper industry has been extensive in this area during the past half century. Throughout colder regions of the Shield (Cryoboreal to Subarctic temperature regimes) productive forest becomes less common as tree distribution and size decreases giving way to stunted forest cover, ferns, bogs, and eventually tundra vegetation.

The severity of the soil and climate limitations is such that agricultural land use is virtually non-existent throughout the Shield region. The few exceptions arise where a significant thickness of glacial till or lacustrine sediments overlie the bedrock, such as occurs in the vicinity of Dryden-Kenora, Thunder Bay, Lake Nipissing, or in the "Clay Belt" areas of northeastern Ontario and northwestern Quebec. Agricultural use is primarily based upon mixed farming operations where the crops are restricted to coarse grains, hay and pasture for livestock feed. The major limitations to agricultural use in these areas are the shortness of the growing season, excessive wetness as a result of the poor natural drainage condition of the soil, and occasional low fertility levels.

Needs for research

The combined effects of the physical resources and climate of the Canadian Shield region contribute to it being, an environmentally, sensitive area. A matter of additional concern, which further accentuates this problem, is the fact that there is little information on the land resource base for much of the Shield region.

Research needs to be initiated to examine relationships between components of the lands resources such as, geological-soil relationships. As any soil maps for the region are, to a large degree, speculative and based on gross extrapolation, this predictive approach based upon research in geological-soil relationships should allow a considerable refinement of our knowledge of the soils of the region. Likewise, soil-vegetation relationships must be clearly established in order to improve the interpretive and predictive capacity of aerial imagery for land resource mapping.

There is a need for further research to provide more complete resource information, particularly in areas where prospective development, or natural resource utilization in the Shield is likely to occur. These should include soil, geological, forestry, wildlife, and possibly climatic studies to fully characterize the resource base, and to document development constraints. This resource-base information can then be utilized to determine what impact land development, or resource use, may have on the local environment, or what measures need to be taken to prevent or minimize environmental damage as a consequence of these activities.

An inter- or multidisciplinary approach to resource inventories and research in regions such as the Shield is essential to facilitate the co-ordination, integration, and exchange of data. Moreover, use and management of natural resources requires knowledge of the entire ecosystem. Soils can be considered to be the vital component of this complex system.

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SOILS OF THE PRAIRIE PROVINCES

D.A. Rennie[1]

Approximately 84 per cent of the cropped land in Canada is in the Prairie Provinces, representing a total of 32.9 Mha (Table 2.1). In addition, 14.7 Mha of potentially new crop land, the majority of which is in Alberta, could in the future be used for food production (Fig. 2.3). Western Canada, for the past 25 years, has accounted for very close to half the total cash receipts from all Canadian farming operations, and in 1975 this rose to an all time high of 53 per cent.

The soils of Western Canada

Practically all the Chernozemic, Luvisolic, and Solonetzic soils in Canada are found in the Prairie Provinces

Table 2.1

Distribution of crop land*

Province or region	Crop land ha x 10^6	Percentage of Total
British Columbia	0.5	1
Prairies – seeded – fallow	22.1 10.8	84
Ontario and Quebec	5.5	14
Atlantic Region	0.4	1
TOTAL	39.3	

*Daviault, R., 1977: Area of pasture is not included.

(Clayton et al., 1977). These are the same soils which provide the resource base for Western Canadian agricultural production.

The Chernozemic soils, which include the Brown, Dark Brown, Black, and Dark Gray great soil groups, include an area of 41.6 Mha (Table 2.2). These soils have developed under a grassland ecosystem and include some of the most fertile soils in the country. In contrast, the 39.7 Mha of Luvisolic soils, which developed under a forest cover, are comparatively infertile and require extra soil management for sustained economic agricultural production; these soils were formerly known as Gray Wooded soils. The Solonetzic soils, which include an area of 6.5 Mha, have developed on saline parent materials; they are primarily located within the agriculturally settled area of the Prairies, and their agricultural value is adversely affected by the undesirable structure of the surface soil, and the tough impervious nature of the subsurface or B horizon. While the Brunisolic soils include a significant area (24.9 Mha), they are primarily located in the more northern regions where the short growing season sharply limits their agricultural capability; these soils include some of the best forest stands in Western Canada. Similarly, the Podzolic soils generally occur beyond the perimeters of agricultural development. These soils have generally developed on sandy materials and are moderately to strongly acid. All poorly drained soils which have developed under hydrophitic vegetation are grouped within the Gleysolic order. A significant number of the 5 Mha of these poorly drained soils occur within the agriculturally developed region. Where flooding is intermittent these soils have been brought under cultivation, but frequently the leached plately surface horizon, together with a rather tough impervious B horizon,

[1]Saskatchewan Institute of Pedology, University of Saskatchewan, Saskatoon, Saskatchewan.

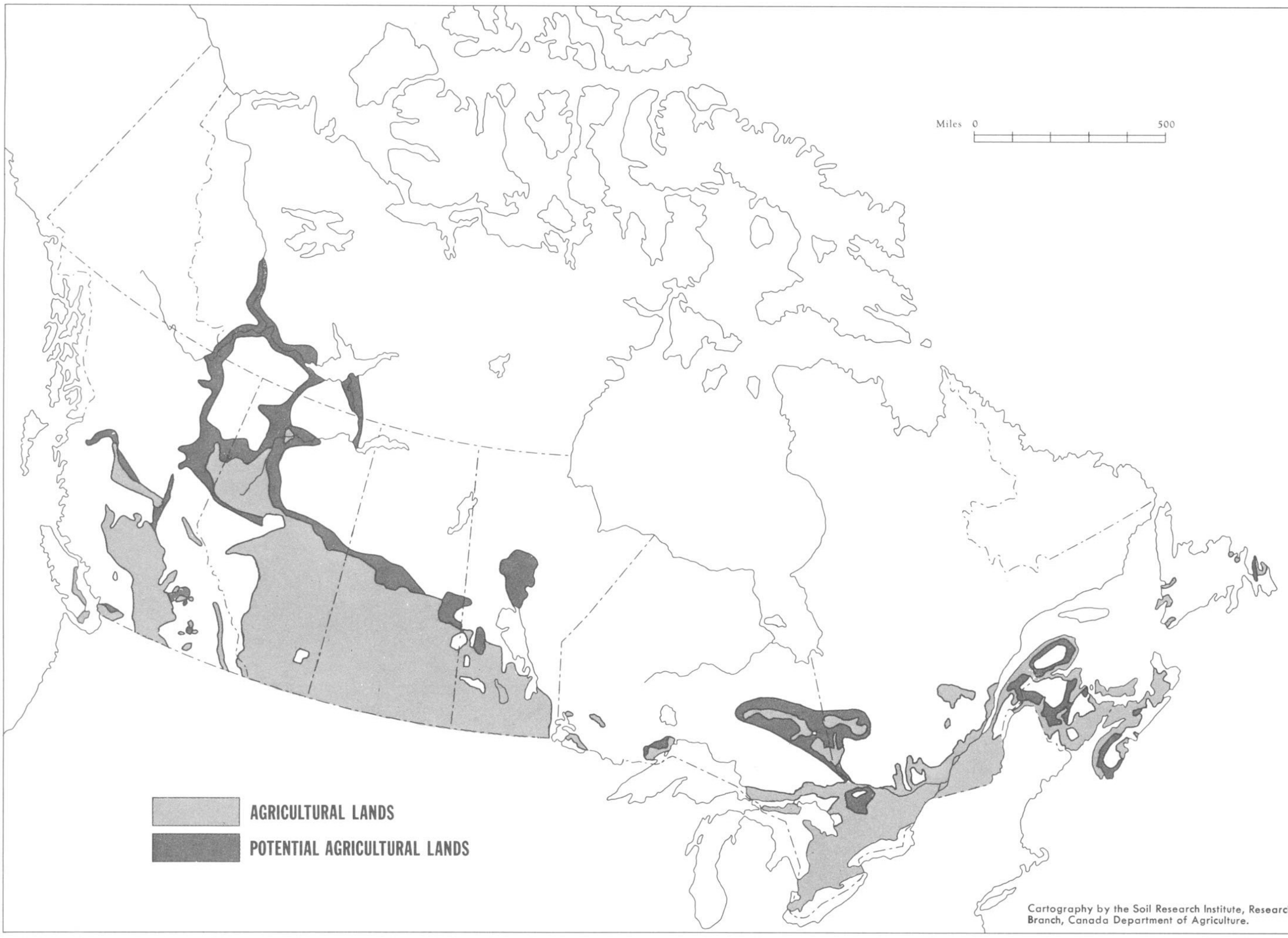

Figure 2.3. Agricultural lands in Canada.

often creates serious problems. A significant portion of the northern region of the Prairies is covered by Organic soils. Little or no agricultural development has yet occurred as the majority of these soils are saturated for most of the year with water. Limited attempts have been made to artificially drain and develop them for food production – with limited success. Soils belonging to the Regosolic order are characterized by little or no soil profile development. Some of these soils are presently farmed, particularly those which occur on recent alluvial deposits, steep slopes, and eroded knolls; the total area of these soils is approximately 12.7 Mha.

Mineralogy

A major and significant component of glacial till parent materials in the Prairie Provinces is their carbonate content. The percentages of carbonate (expressed as calcium carbonate equivalent) have been delineated by St. Arnaud (1976). The extremely high carbonate contents in south-central Manitoba reflect the outcrops of Paleozoic limestone formations which occur in that area. The westward decrease in carbonate contents reflects the increasing amounts of materials from local noncalcareous geological deposits incorporated into the till. Increased carbonate levels in the areas along the northern boundary of Alberta and in the southwestern region are associated with local calcareous bedrock materials.

Montmorillonite has generally been found to be the predominant clay mineral with illite usually a major constituent. Other clay minerals are present in varying but, in comparison, minor amounts (Ehrlich et al., 1955; Ehrlich and Rice, 1955; Christiansen, 1959; Rice et al., 1959; Forman and Rice, 1959; Warder and Dion, 1952; Pawluk, 1960; St. Arnaud and Mortland, 1963; St. Arnaud, 1976; Huang and Lee, 1969; Sudom, 1970).

It is generally considered that the composition of most glacial deposits reflects the composition of the nearby preglacial rock formations. This oversimplified picture is not generally true in the Prairie region as it is known that the glaciers carried materials for hundreds of miles, and further there have been successive periods of glaciation. However, it has been shown that the clay minerals of the lacustrine soils of southern Saskatchewan (Rice et al., 1959) and of the tills in that area (Christiansen, 1959) do not deviate significantly from that of the underlying Bearpaw shales (Forman and Rice, 1959). Similarly, the moderate kaolinite content of the glacial tills would appear to reflect the inclusion in the glacial tills of variable portions of a kaolinite-rich Whitemud geologic formation (Christiansen, 1959).

There is no strong evidence that supports significant alterations in clay minerals in Western Canadian soils either in extent, degree or amount due to pedogenic processes. Kaolinite, for example, where present is probably inherited.

Table 2.2

Area of major soil orders in the Prairies[1]

Soil order	Great Group	International U.S.	International FAO	Area of soil group (ha x 10^3) Man.	Sask.	Alta.	Total prairies
Chernozemic	Brown	Aridic Borolls	Aridic Kastanozems	—	5 625	3 240	8 865
	Dark Brown	Typic Borolls	Typic Kastanozems	—	6 812	3 640	10 452
	Black	Udic Borolls	Chernozems	5 263	6 539	4 450	16 252
	Dark Gray	Borafic Borolls	Greyzems	2 632	1 595	1 820	6 047
			TOTAL	7 895	20 571	13 150	41 616
Solonetzic		Natric	Solonetzic		1 635	4 820	6 455
Luvisolic		Alfisols	Luvisols	3 044	7 352	29 350	39 746
Podzolic		Spodosols	Podzols	—	—	—	—
Gleysolic		Aqua suborders	Gleysols + Planosols	3 753	1 247	—	5 000
Brunisolic		Inceptisols	Cambisols	11 857	8 879	4 050	24 786
Regosolic and Rocklands		Entisols	Fluvisols + Regosols	4 049	6 233	2 430	12 712
Organic		Histosols	Histosols	23 030	11 134	12 150	46 314
			TOTAL	53 628	57 051	65 950	176 629

[1]Estimates for the Prairie Provinces are from the respective soil survey groups.

In general, the principle weathering process ranging from the arid Brown soils to the heavily leached northern Podzols is an intense cation exchange reaction whereby mica and chloride alter to expanding layer silicates and in some cases vice versa.

A wide spectrum of heavy minerals has been identified in the fractions of the glacial till deposits across Western Canada. Such minerals generally constitute from 2-3 per cent of the minerals present in the deposits. The bulk of these heavy minerals would appear to have been derived from the Precambrian rocks which dominate the northern portion of the region. As a comparison the heavy mineral content of the local marine shale bedrock and the Precambrian rocks is 0.1 and 8.7 per cent respectively (Twardy et al., 1974). Data recently reported by St. Arnaud (1977) for the major horizons of an Orthic Gray Wooded profile provided background information for the spectrum of heavy minerals present. The fine sand fraction contained from 2.74 to 2.93 per cent of heavy minerals: of the 19 minerals identified, the dominant ones included diopside, epidote, garnet, hornblende, hypersthene, magnetite, tremolite, zircon, and opaques.

Limitations to productivity

The agricultural land base of the Prairie region has a number of significant physical factors that limit the region's capability to produce food, in particular cereal grains. Among the most dynamic of these is climate. Low precipitation (27-35 cm) and the very short frost-free season in northern regions (1000-1112 degree days above 5.5°C) severely limits the selection of crops which can be grown. In general, however, the climatic limitations to food production within the agriculturally developed region of the Prairies are far less severe than formerly considered; potential wheat yields based on climatic limitations have been shown to be almost twice as high as actual yields (de Jong and Rennie, 1969).

A rather wide range of landscape characteristics significantly affect the productive capacity of the Prairie soils. Topography frequently is the determining factor in separating arable from non-arable land. A further landscape limitation is drainage.

There is a wide range of specific soil properties which limit production to varying degrees. These include droughtiness, poor surface, and subsurface structure, low native fertility, and excessive salinity. The salinity problem at the present time can be termed the most serious soil factor limiting production in Saskatchewan, and central and southern Alberta. In the former province, recent studies have indicated that the area of salt affected soils has increased from approximately 0.4 Mha in the early 50's to in excess of 1.6 Mha today, or a four-fold increase (Crosson, 1976). Very careful soil management and crop sequence practices must be followed in all salinity-prone areas (approximately 90 per cent of the agriculturally developed soils in Saskatchewan fall in this category) in order to prevent further spread of salts to highly productive agricultural soil.

The productivity grouping of the soils of Western Canada

In the Canada Land Inventory Classification System of land capability for agriculture, all soils are grouped into seven classes according to the limitations noted above for agricultural use. Class I through to IV are considered arable; Class V capable of being improved for hay or pasture; Class VI of some use for grazing; and Class VII of little or no use for agriculture. The Prairie Provinces contain 70.3 per cent of the arable land classes I through to IV in Canada, or a total of 47.6 Mha. Of this total, 31.7 Mha are used for the

Table 2.3

Organic matter contents of the Chernozemic and Luvisolic soils of Saskatchewan (Ap horizons)[1]

	% OM	OM as a % of original
Chernozemic		
– Brown	3.70 ± 1.7	56
– Dark Brown	4.34 ± 1.58	56
– Black	5.48 ± 1.96	60
– Gray-Black	5.98 ± 2.46	62
Luvisolic	2.40	65

[1]Rennie et al. (1976).

production of cereal grains and oilseeds, 5 Mha is in tame hay and forage, and the remainder, primarily in class IV, is undeveloped. Land not suited for annual cropping but of value for hay and pasture totals 36 Mha, of which considerably less than half is presently being utilized to any extent at all.

Comparative production indices of 1, 0.85, 0.70, and 0.50 can in a very approximate way be used to indicate the comparative production of Classes I, II, III and IV respectively (Shields and Ferguson, 1975). These indices provide the basis for converting all arable lands in the three Prairie Provinces to Class I equivalents. On this basis, Manitoba, Saskatchewan, and Alberta have 5.3, 14.4, and 13.0 Mha of Class I equivalent land. Research data presently available suggest that with modest to high levels of management Class I land should be capable of producing on the average 2900 kg of wheat equivalents per hectare. Equating the total area of Class I equivalent lands available with this potential yield, the attainable level of production is in excess of 100 per cent greater than the average annual production that has been achieved over the past 10 years.

Crop yield and yield changes in the Prairie Provinces

An analysis of cereal grain yield trends for the past 20 years has shown a consistent and steady increase in yield with upward adjustments in the yield of wheat, oats, and barley approximating 30, 31, and 36 per cent respectively (Hedlin and Rigaux, 1976). There is no doubt but that upward adjustments in yields would have been much more dramatic had favourable markets been more consistent.

Agriculture in Western Canada has probably benefited more during the past two decades from scientific developments than at any other time since settlement in the early 1900's. In general, where fertilizer N and P are applied in accord with soil test guidelines 1 kg of N or P_2O_5 will produce a yield increase of approximately 15 kg of wheat. Nitrogen is required for economic yields of all stubble seeded lands and to a growing extent for fallow seeded crops as well. A deficiency of phosphorus limits the growth of cereal grains in most of the soils in the Prairie region. There is an estimated 1.8 Mha of soils deficient in potash (Halstead et al., 1970) and 3.4 Mha with moderate deficiencies of sulfur (Beaton, 1976).

An analysis of the major factors responsible for the upward adjustment in crop yields has shown that improved varieties have accounted for approximately 19 per cent of the change in yield during the past two decades, while fertilizer in contrast can be credited with 81 per cent (Hedlin and Rigaux, 1976).

Table 2.4

Nitrogen balance — Saskatchewan

	Nitrogen released		
	kg/ha each year	kg/ha -60 y	16.2 Mha cult. land (tons)x10^6
Release from soil O.M.	42	2520	40.8
Sold off the farm	14	840	13.6*
Leached below rooting depth	11	660	10.7*
Denitrified	10	1020	16.5*
Erosion losses	7		

*These quantities of N are equivalent to 51, 50 and 62 x the N sold in the prairies in 1975 (0.31 MT).

Uses of the soil

Agriculture in Western Canada dates back to 1870 with the transfer to the Dominion of Canada of lands held by the Hudson Bay Company under Royal Charter. Soil management practices up to the late 30's included little or no conservation of crop residues, with large areas in summerfallow to conserve moisture. The adverse climatic conditions prevailing in the mid 30's resulted in extensive loss of fertile top soil by wind erosion. While crash management practices have since that time controlled wind and also water erosion, recent research has shown that the rapid drop of soil organic matter typical of the earlier part of the 20th Century is still continuing (Table 2.3; Rennie et al., 1976). The continued disappearance of carbon from these soils appears to be closely associated with the practice of summerfallowing. During the period 1971 to 1975, for example, the per cent of cultivated land in fallow ranged from a low of 26 through 35 to 42 per cent for Manitoba, Alberta, and Saskatchewan.

The effects of tillage associated with the summerfallowing practice has resulted in up to a 50 per cent decrease in soil organic matter, a serious waste of soil nitrogen (Table 2.4), the continued deterioration of the surface tilth or structure of the soil, and in Saskatchewan in particular a rather alarming increase in soil salinity. At the same time, the practice of summerfallowing, while designed primarily to store water, has been a major reason for the low efficiency of crop use of available water (Rennie, 1976).

Agronomic guidelines for farmers throughout the Prairie region urge farmers to divorce the summerfallowing practice as a formal or integral part of their crop rotation sequence; rather summerfallowing is recommended in the same manner as fertilizer use and herbicides, namely as a necessary input in order to maintain economic yields. This approach to land use requires a significant conceptual change by farmers and in addition a radical change in their machinery component etc.

National research committees such as the Canadian Agricultural Research Council appear to be cognizant of the soil deterioration that has been reported for a wide spectrum of soils in Western Canada, and accordingly have placed soil degradation and land evaluation at the top of the ladder as far as research priority is concerned. If this priorization is reflected in a sharp increase in research funds to enable soil scientists to accurately assess the extent of soil deterioration, and to provide urgently needed guidelines to arrest this deterioration, there is a good probability that such data will encourage farmers to shift crop sequences and land use practices in the next decade or so. If such a trend does materialize, this could precipitate further problems since the key to arresting soil degradation appears to be a marked increase in continuous cropping; this, with good soil management practices, can be expected to result in a significant increase in the production of food crops. Whether world markets will be able to absorb the necessary doubling in cereal grains exported by Canada is a difficult question to answer. The alternative is to continue the marginal soil management and land use practices prevalent today. The effect that these practices have had on soils is serious and if continued for many more years could seriously jeopardize the future prosperity of agriculture in Western Canada.

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SOILS AND LAND USE – ARCTIC SOILS

C. Tarnocai[1]

Introduction

The Arctic is the area (2 759 940 km^2) which extends northward from the arctic tree line and covers approximately 30 per cent of the area of Canada (Fig. 2.4).

A modified version of Polunin's (1951) subdivision of the Arctic into Low, Mid, and High Arctic regions is shown in figure 2.4. The separation of the arctic regions is based on vegetation and, to some extent, on climate. Recently, however, this zonation has been found to have much wider implications in the degree of soil development, the distribution of patterned ground, and the depth of the active layer (Tarnocai et al., 1976; Zoltai and Woo, 1976).

Soil development

The dominant soils of the Canadian Arctic are the Cryosols (Fig. 2.5). These soils are associated with a perennially frozen layer and cryogenic processes play a major role in their formation. Cryoturbation, which is probably the most outstanding of these processes, tends to mix the soil materials. Thus, instead of classical soil horizon development, the result is a strongly disrupted (frost-churned) soil profile (Fig. 2.6). In southern arctic areas cryoturbation affects mainly fine and medium textured materials or coarse materials having sufficient silt content. In the High Arctic areas cryoturbation affects all of the above-mentioned materials and also sandy materials, notably those with high

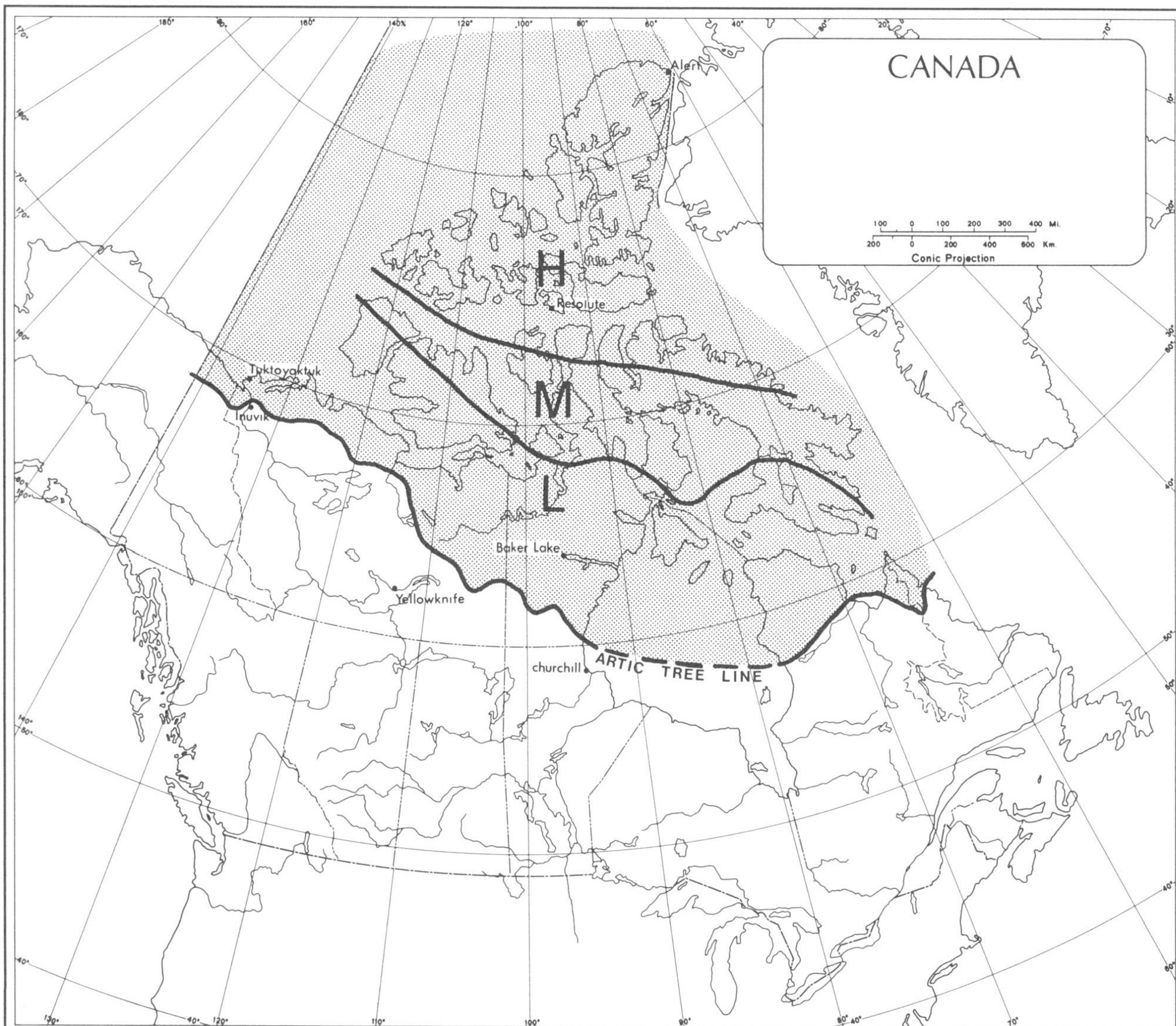

Figure 2.4. Canadian Arctic and its subdivisions into Low (L), Mid (M), and High (H) Arctic regions (a modified version of Polunin, 1951).

[1]Canada Soil Survey, Agriculture Canada, University of Manitoba, Winnipeg, Manitoba.

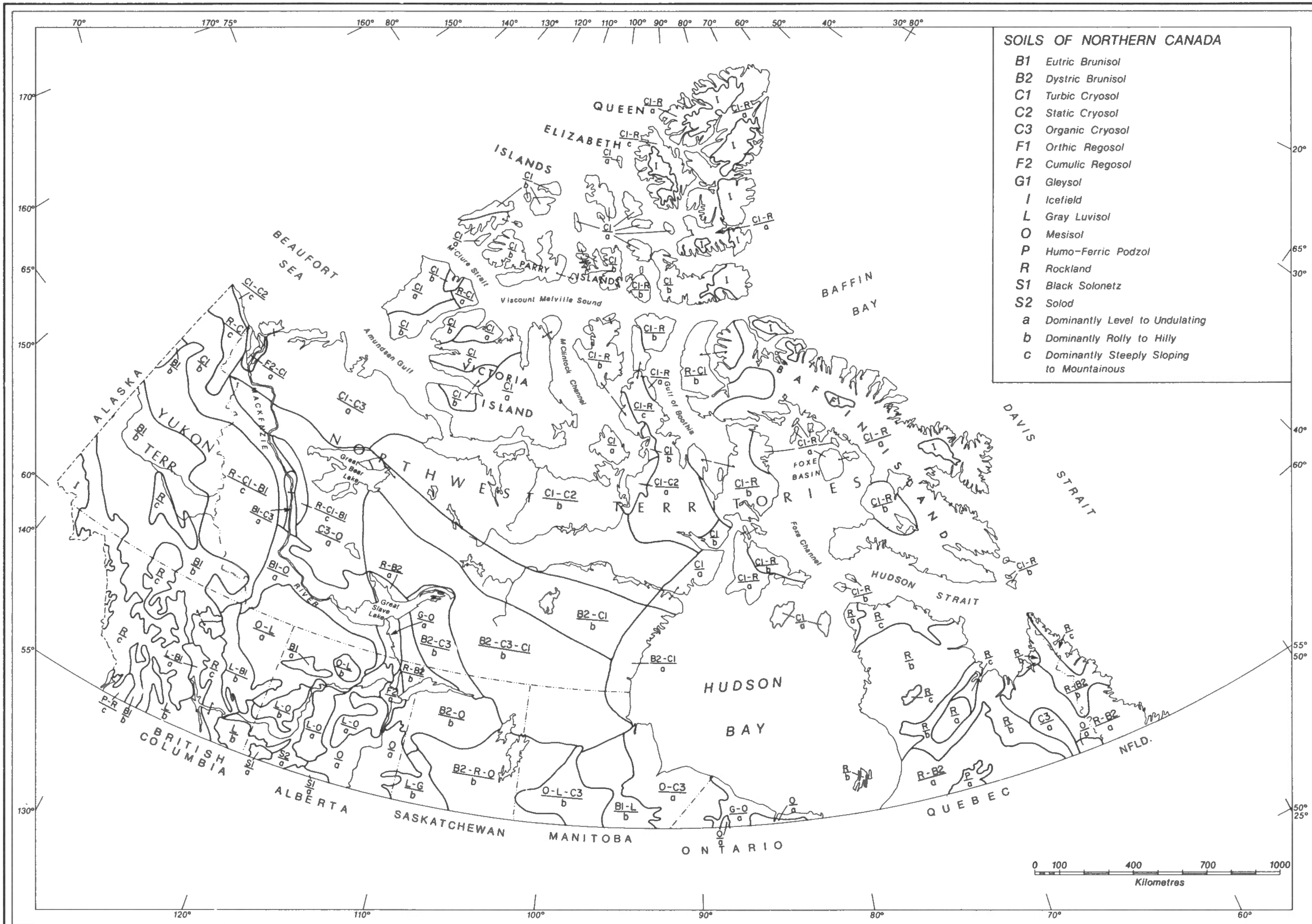

Figure 2.5. Soil map of northern Canada (areas south of 60° latitude are mainly after Clayton et al., 1977).

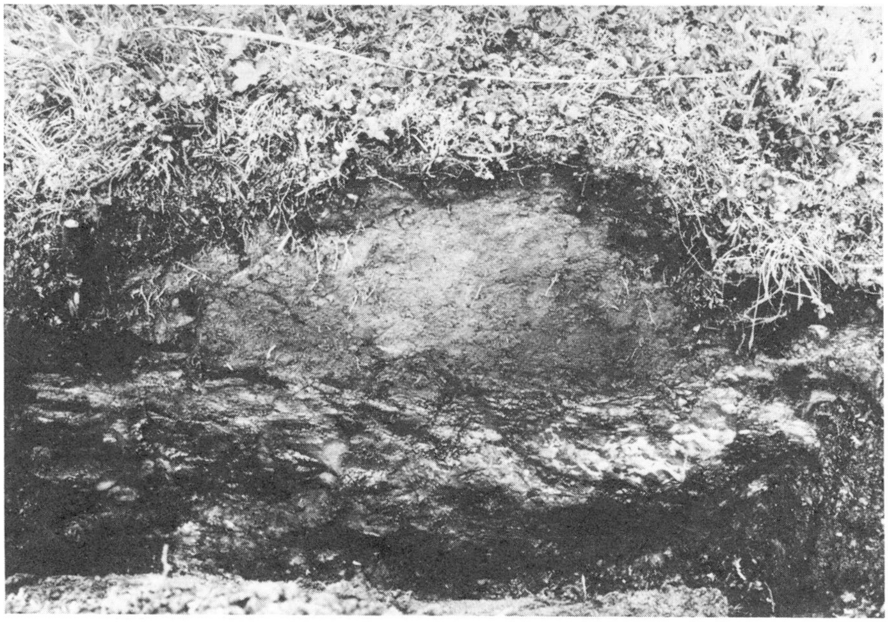

Figure 2.6A

Brunisolic Turbic Cryosol associated with an earth hummock. Note the organic-rich subsurface horizon, the intrusions of organic materials and organic smears resulting from cryoturbation and the high ice content layer at the top of the permafrost. Tuktoyaktuk Peninsula in the Low Arctic.

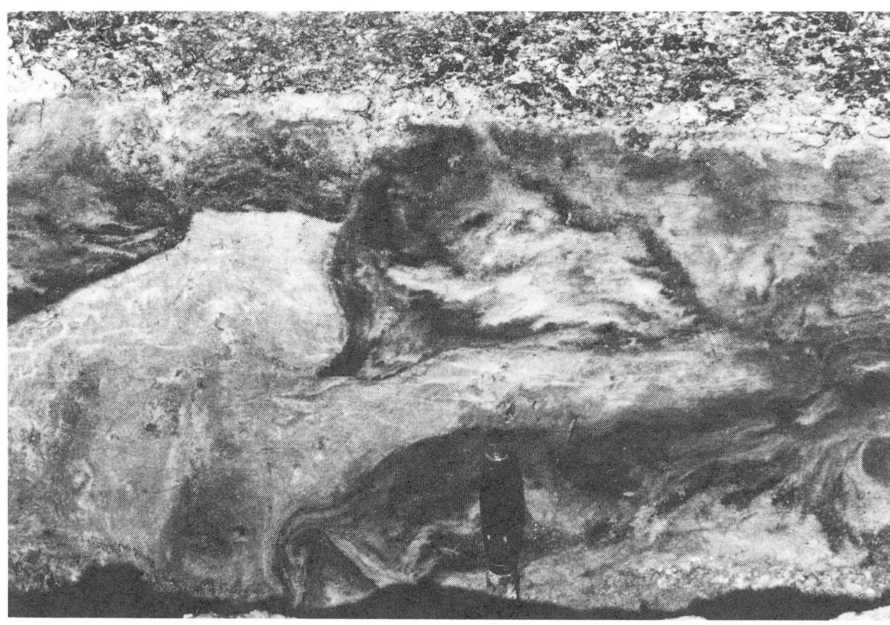

Figure 2.6B

Orthic Turbic Cryosol developed on marine sand. Note the distorted and disrupted soil horizons resulting from cryoturbation. Bathurst Island in the High Arctic.

moisture content. Cryogenic processes have a strong effect on the surface micromorphology of these soils, resulting in patterned ground development. Sorted and unsorted circles, nets and stripes, hummocky microrelief, and polygonal patterns are common characteristics of arctic soils.

The organic matter content is high, even in soils developed in the High Arctic. A large portion of the organic matter is cryoturbated from the surface and is found in the form of organic layers, intrusions, smears and very fine organic particles mixed with mineral materials. Organic matter can also slowly work into the soil by means of small polygonal cracks, which occur commonly in the Mid and High Arctic. Cryosolic soils, in general, contain a much greater amount of fulvic acid than of humic acid. This fulvic acid, being mobile, also translocates organic matter into the lower horizons.

Because soils in the Arctic are characterized by a generally high moisture content, especially in horizons near the permafrost table, gleying usually occurs, even in better drained situations. Soils associated with earth hummocks in the western Arctic show very characteristic reddish brown mottles and grey gleyed characteristics (Drew and Tedrow, 1962; Zoltai and Tarnocai, 1974). Soils of the High Arctic are very often saturated because of the shallowness of the active layer but gleying is not very common, except on fine textured materials. The lack of gleying is likely due to the fact that most of the water entering the shallow active layer from rain and snow melt is oxygen-rich. Since very little downward percolation takes place, most of the water moves laterally in the active layer. Aeration is also facilitated by a well-developed vesicular pore structure and by small polygonal cracks where air exchange can take place. Thus, this water moving through the soil system causes oxidation rather than reduction of the soil (Tarnocai, 1976).

Soils in the Arctic are associated with characteristic structural types. The development of vesicular pore structure (Bunting and Fedoroff, 1973; Zoltai and Woo, 1976; Tarnocai, 1976) is closely related to drainage and texture. When the soil is frozen, much of the soil pore system is occupied by ice lenses or crystalline ice and its melting is the course of the instability known as thixotropy. Well-developed granular structure occurs near the surface of earth hummocks associated with fine textured Cryosols (Drew and Tedrow, 1962; Zoltai and Tarnocai, 1974), but the lower horizons are massive and structureless, having a high bulk density. In addition, vertical channels, frost cracks, and banded structure are also found in these soils.

Translocation of materials by solution can take place in several ways. Eluvial, or leached, horizons are found in the southern portion of the Low Arctic and have been observed on Cameron Island in the High Arctic (McMillan, 1960; Tarnocai, 1976). In such soils organic matter is also translocated and deposited on the underside of stones in the B horizon. Translocation of iron in poorly drained sandy soils has also been noted. Translocation of salts, which form a well-developed salt crust on the surface of the soil, occurs commonly in the High Arctic (Tedrow et al., 1968; Tarnocai, 1976). A calcareous crust may be formed on the underside of rocks, both at the surface and within the soil mass.

Mass displacement of soil materials by downslope movement, or gelifluction, and by active layer flow is widespread in the Arctic (Tarnocai, 1976; Tarnocai et al., 1976; Zoltai and Woo, 1976). Downslope movement, which is common in the Mid and High Arctic, can occur on slopes as gentle as one degree. These processes not only translocate new soil materials but also mix the materials.

One of the most striking features of arctic soils is the great amount of ice occurring in the near surface permafrost in the form of segregated ice crystals, vein ice, ice lenses, ice wedges, and thick, massive, ground ice. The ice content varies and generally depends on the soil texture. These high ice content soils are very sensitive to disturbance and this ice content is one of the major controlling factors in their utilization.

The thermal characteristics of arctic soils are radically different from those of soils found in more temperate climates. Cryosols in the Arctic, being cold soils, have very little buffering capacity against a change in atmospheric temperature. This is due mainly to the shallowness of the active layer, which provides only a small amount of stored energy. The underlying permafrost acts as a heat sink and continuously removes energy from the thawed layer of the soil. Hence, the slightest decrease in air temperature (due to storms or shortening of the hours of daylight) quickly lowers the soil temperature at all depths. This cooling causes the frost table to rise long before the surface freezes (Tarnocai, 1977).

Arctic soils and land use

The population of Arctic Canada, based on the 1974 census, is 20 000. This vast land area, although supporting a small population, must be considered in the context of a low energy output ecosystem, requiring large land and water areas to support life. It is a system which can be altered drastically by minor manipulation and which, by virtue of its low energy output, is slow to recover.

Recently major changes have taken place. There is now a large energy input from the south and, in return, energy has been exported to the south. While the northern people become more dependent upon southern goods, people from the south look to northern areas for their raw materials and energy. The basic question is: How can development take place without major environmental damage?

Soils in the arctic regions not only support the biological life and man-made structures but also protect the underlying permafrost. In the south we can clear the bush, plow the soil, and burn off or remove the surface peat layer and, in most cases, the damage is confined to the loss of a little top soil. In the Arctic, as in all permafrost areas, the removal of surface peat or vegetation and the disturbance of soil materials often does lead to a drastic and rapid environmental change with possible resultant damage to man-made structures. Thus, the role of the soil both in the arctic ecosystem and in land use is much more crucial than in temperate regions.

Human activity, mainly relating to oil and gas exploration during the mid-1960's, has left scars on the arctic landscape because of improper land use. This environmental damage, which affected only small areas in the western Arctic, resulted from both a lack of knowledge concerning the best method of dealing with the arctic terrain and a lack of data relating to the arctic environment. During these operations the surface organic layer was badly scraped. The erosion thus begun by the rapid melting occurring in the exposed ice-rich permafrost caused great devastation as this permafrost degradation led to further erosion, subsidence, and flow slide development.

This serious disturbance of the terrain led those who were, for various reasons, concerned about the environment to initiate studies which showed the importance of such factors as soil moisture and ice content, the surface organic layer and the vegetation. Through studies such as these and as a result of new methods and technology together with the scheduling of the work for the winter months only, the damage to the surface soil has been reduced and thus little or no environmental degradation is now taking place.

Probably the most significant projects are the future pipeline corridors in the Mackenzie Delta and the Eastern Arctic. The pipeline actually crosses only a small area but it is likely that the area affected will extend to approximately 10 per cent of Arctic Canada — the area in which various government departments have carried out special studies. Other industrial projects are small in size and affect only local areas but many of these projects appear to be located in sensitive areas, areas critical to the survival of some form of wildlife — e.g. staging areas for geese, calving ground for caribou. Therefore, even though these projects are local in areal extent, they can alter the overall population of that particular wildlife species.

From the potential land use point of view, the enormous empty space of the Arctic, together with its lack of pollution, represents a priceless asset for the preservation of wildlife resources and for recreation and other human uses in our increasingly crowded and polluted world.

Further research needs

At the present time, less than one professional man-year is spent by Canada Soil Survey on soil studies in Arctic and Subarctic Canada, an area covering approximately 56 per cent of the land area of Canada. Other agencies (e.g. universities and industry) have carried out limited, site specific, soil studies in the Arctic relating to I.B.P. and pipeline projects.

Until now only 8 per cent, approximately, of the Arctic has been covered by broad reconnaissance and exploratory soil surveys. In addition to this, approximately 20 site specific soil studies have been conducted in scattered localities throughout the Canadian Arctic. Most of these soil inventories and soil studies have been carried out to satisfy the needs of large projects (e.g. pipeline development). They provide insufficient information, however, for smaller and more detailed projects (e.g. land use planning around settlements) and for evaluating the interaction between competing land uses. More intensive land use planning should be based on explicit rather than general soil and other resource information. A sustained, in depth, long term, inventory program is very much needed to provide both the areal and site specific data required for governments and land use managers.

Soil characterization, soil drainage and soil temperature studies are needed to provide an understanding of the nature of both mineral and organic soils. Further studies are also required to determine the mechanism of, and conditions controlling certain processes which take place in arctic soils (e.g. cryoturbation, frost heave, thixotropic behaviour and moisture movement). These studies, by providing information concerning the near surface permafrost, would supply basic data not only for land use purposes but also for a vital part of the permafrost research carried out in Canada.

Existing soil data has been used to obtain terrain sensitivity ratings based on soil materials, slope, vegetation, drainage, and ice content in order to provide the land use planner with useful information about the level of disturbance the terrain can sustain before serious damage occurs. The ratings obtained to date are only preliminary and further research is needed to determine the degree of sensitivity of Cryosolic soils to the most common types of disturbances. Further research problems that have arisen concern the development of a soil sensitivity classification and an engineering interpretation methodology for Cryosolic soils.

Although arctic communities rely largely on local food sources, the importance of arctic soils as related to food production (in the form of meat from local wildlife) has, for the most part, been ignored. With urban spread rapidly consuming large amounts of arable land in southern Canada, northern settlements must maintain this self-sufficiency on local food resources. It is also very costly to replace the local food supply by produce from the south because of the initial relatively high cost of the food as well as the high cost of the transportation and handling. Because soil is an indicator of productivity, a knowledge of its properties can be useful for determining the wildlife capability of the land. Studies to determine these soil properties and the resulting wildlife capability should be carried out co-operatively by wildlife managers, soil scientists, and ecologists.

Soil, as perhaps Canada's most important continuing natural resource, is an integral component of the arctic ecosystem. Soil scientists, therefore, should be actively involved in research into ecosystem interrelationships. For example, sound land use decisions, revegetation work, and plant (and, hence, animal) species distribution studies require a knowledge of the whole ecosystem.

A greater liaison between soil scientists, biologists, surficial geologists, and permafrost researchers is required. Multidisciplinary studies carried out in the north during the past decade prove that, in addition to greater efficiency and reduced cost, all members and disciplines benefit from the resulting exchange of ideas.

There is also an urgent need to train soil scientists, at both the graduate and undergraduate levels, in the field of arctic soils. Few countries in the world have so much polar land as Canada and yet so little attention is paid in the soil science curriculum to northern soils in general and to arctic soils in particular.

Although much has been accomplished in the past, there is still a great need for more detailed and long range studies and research carried out by well-trained scientists working alone or as part of multidisciplinary teams.

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SOILS AND LAND USE IN THE CORDILLERAN REGION

L.M. Lavkulich[1]

Introduction

The Cordillera is one of the most definitive physiographic regions of Canada. It extends for 800 km in southern British Columbia to western Alberta. In the north the region extends from the Mackenzie River in the Northwest Territories through the Yukon into Alaska. The length of the Canadian Cordillera is about 2560 km from near the Arctic Ocean to the Canadian-United States border. Elevations range from sea level to over 4300 m. The valley bottoms are highly prized for agriculture, transportation corridors, and for centres of urban growth. The plateaus, valley sides, and higher elevation valleys are utilized for forestry and serve as habitat for wildlife and watershed values. The serene alpine environments are utilized for grazing by both domestic animals and wildlife, and recreation. Scattered throughout the Cordillera are productive mines, unique waterfowl and wildlife habitats, archaeological and historic sites and several provincial and national parks.

The region is characterized by high relief steep slopes and varying local climates. This high energy environment results in a variety of landscapes formed by weathering, nivation, solifluction, congeliturbation, mass movement and pedoturbation. The Canadian Cordillera has been further complicated by the successive deposition of volcanic ash. These combinations of geology, physiography, and climate have produced a complex mosaic of soils. In fact, the Cordillera has soils represented in every order of the Canadian System of Soil Classification.

Geologic setting

As indicated above, the soils of the Cordillera reflect to a large degree the geologic history of the region. The Cordillera is made up of two geologically different mountain systems. The older western Cordillera was formed about 140 million years ago. Erosion since that time has exposed the resistant granitic dioritic rocks of the Coast Range and the metamorphic, intrusive, volcanic, and sedimentary rocks of the remainder of the western system. The resultant soils reflect the bedrock by being largely acid and coarse textured. The eastern Cordillera formed about 57 million years ago comprise the Rocky Mountains and the associated Foothills. The Rockies are composed largely of limestone and dolomite, while the Foothills are composed of younger sandstones and shales. Again the resultant soils reflect the geology by their finer texture and greater tendency to be neutral to alkaline (Nelson, 1970).

The Cordillera was affected by glaciation. Holland (1964) states that in general, ice did not cover mountain peaks above 2130 m as peaks and ridges above this elevation show the effects of intense alpine glaciation.

Westgate and Fulton (1975) have reviewed the occurrence of known volcanic ash deposits in the Canadian Cordillera. The major volcanic ash deposits include Glacier Peak (12 000 BP), Mazama (6600 BP), Mount St. Helens (500 and 3000 to 3500 BP), Mt. Rainer (2000 to 2300 BP) and Bridge River (2120 to 2670 BP). Farther north volcanic ash from Mt. Edgecumbe in southeastern Alaska dated at 9000 BP may be present in Canada. White River ash (1220 and 1900 BP) is present in the southern Yukon and Northwest Territories. The importance of volcanic ash can not be underestimated in the genesis of the soils of the Cordillera, as the tephra imparts many unique properties to the soils.

Soils of the Cordillera

As a result of the complex geology and climate, the soils of the Cordillera are extremely variable in morphology, genesis and properties. Similarily the utilization of the soil resources are varied. It is also a region where numerous problems exist with respect to an understanding of the soil resource, its nature, distribution, genesis, and utilization.

For a geographic framework, the Cordillera may be divided into three major divisions, which are, from west to east: the coastal, interior, and eastern systems. The coastal system has three district subdivisions. These are the Insular Mountains, forming the backbone of Vancouver Island and the Queen Charlotte Islands, the Coastal Trench, occupied by the Gulf of Georgia, and the rugged western section of the Mainland. The interior system is a series of plateaus, mountains, and broad undulating valleys. This system is broken into the southern, central, and northern plateaus and mountains. The eastern Cordillera is the Rocky Mountain Trench, Rocky Mountains, and Rocky Mountain Foothills.

In this large expanse less than 10 per cent of the area may be considered arable for agriculture and less than 5 per cent is suitable for the production of food crops. In the entire province of British Columbia less than 1 per cent of the land area has Class 1 agricultural capability and only 0.01 per cent is suitable for production of tree fruits. On the other hand, the Cordillera is noted for its productive forests, scenic landscapes, mining, wildlife, and watershed values.

A brief description of the soil resources within the three major geographic regions are outlined below. For a more complete description of the soils of this region the publications by Farstad and Rowles (1960) and Clayton et al. (1977) should be consulted.

Coastal System – The soils of the coastal system are predominantly Podzolics and Gleysolics, with lesser amounts of Organics, Brunisols, Luvisols, and Regosols. The major valleys and the lowlands below about 1000 m are productive forest and agricultural lands. It is here where pressures of urbanization are most strongly felt. Most of the soils have developed under forest and have been leached during the rainy season. The well drained soils require supplemental irrigation for maximum agricultural production, while the poorly drained soils require drainage. Some of the more productive soils in Canada are found in this area.

Above the lowland are the highly productive forest soils, dominated by Podzols. Some of these soils are the most productive forestry soils in Canada. Commercial tree species include Douglas fir, hemlock, spruce, cedar, amabilis fir, and grand fir. Problems related to the land use on these soils are related to watershed management, erosion and slope stability and re-forestation following logging.

Major issues related to the soils of this area are concerned with both of these activities, watersheds are affected as are wildlife habitats. The continuing demand in the area for urban growth and recreation complicates the resource utilization decisions. Information is required on the soil resources of the area with respect to the inherent quality of the soils and the effects that agricultural and forestry practices have on them.

Interior System – The interior system is by far the most complex of the Canadian Cordillera. It extends from some of

[1]Department of Soil Science, University of British Columbia, Vancouver, British Columbia.

the driest and warmest climatic areas in Canada through to areas of permafrost. Soils are extremely variable, representing every order recognized in Canada. These include Chernozems in the southern valleys to Brunisols, Luvisols, and Podzols covering large areas of the mountain sides and extensive plateau areas. In depressions are found areas of Gleysolic, Cryosolic, Organic, and Regosolic soils. In the central interior areas, Solonetzic soils can be found, while at high elevation are found alpine Brunisols, Regosols, Organics, and Cryosols. The soils reflect the complex geology and climate of this system.

Land use is equally complex. In the south, tree fruit production, intensive agriculture and recreation flourish. Moving northwards, or to higher elevations, forestry, watershed, grazing and wildlife values increase. Most of the ranching industry in the province is located in this area. This is truly an area of integrated resource management, as it is here where large metal mines are found as well as critical habitat for waterfowl, ungulates, and other wildlife. Commercial forest operations are spread throughout the area. In the far north there is limited resource development.

In such a complex area, soils research in relation to genesis, behaviour, and management is urgently needed. Studies related to hydrology, land slope stability, salinization, land degradation, reclamation, and resource allocation are paramount.

Eastern System – The soils of this system are predominately Brunisolic, Podzolic, Luvisolic, Chernozemic, and Regosolic. Snowfields, glaciers, and bare rock are prevalent at the higher elevations. The area is a striking setting to study the effects of geology and climate on soil genesis.

The dominant land uses in the area include pockets of agriculture, forestry, grazing (mainly wildlife), mining, and recreation. In contrast to other areas of the Cordillera, the soils are calcareous, reflecting the geology and history of the area. This area has probably received the least amount of attention in soils research, even though several National Parks, productive forests, large open pit mines and unique wildlife habitats are contained in the system.

With respect to the soils resource, the main problems include resource allocation (especially ranching and wildlife, forestry and recreation), slope stability, reforestation, watershed management and land deterioration.

Summary

The Cordilleran region of Canada is a complex, exciting area, where soil resource information is continually being used for multipurposes. The region has great demands for many resource management alternatives; these demands are continually changing. There are great deficiencies in our knowledge about the soils of the Cordillera, especially with respect to genesis, behaviour, soils deterioration, slope stability, and soils in relation to resource allocation.

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CANADA'S SOIL INVENTORY PROGRAM

J.H. Day[1]

An integrated Canadian soil inventory program has developed from initial surveys in several provinces some 60 years ago. The major objective of soil surveys in Canada, until about 1955, was planning for agricultural development. With the passage of time and the progress of agriculture and soil surveys into forested and nonagricultural areas in more northerly regions, the objectives have come to include the inventory of the Canadian soil resource for planning of uses as diverse as Arctic pipelines and of urban and recreation areas.

Soil surveys depend on the systematic examination of landscapes and their associated soils and nonsoils. Attributes of the landscape (for example geological surficial material, bedrock, present vegetation, slope, exposure) and attributes of the soils (for example kind and depth of soil development, depth to impermeable or other layer, kind and particle size of parent material, drainage, presumed fertility) and their aerial distribution are recorded. Samples are collected for characterization analyses or for research needs.

The soil report and maps together provide factual information on the soil resource. It also provides interpreted information and ratings of the soils for various uses. The reliability of the soil report and maps is related to the period when the work was performed, to the objective of the survey project, and to the intensity (scale) of mapping and of soil examinations made.

In southern settled areas of Canada most maps are published at scales between 1:50 000 and 1:126 720 whereas in northern areas maps of exploratory surveys are published at scales smaller than 1:125 000, usually 1:250 000. Detailed surveys are conducted usually only in urban-rural areas and are published at scales larger than 1:50 000.

The soil inventory program to 1976 has surveyed 327 733 000 ha (Table 2.5) about half on an exploratory basis mainly in the Northwest Territories. This coverage represents nearly 33 per cent of our total area. Over 200 soil survey reports have been published and nearly half as many again are in preparation for publication. In some cases unpublished information is made available on request.

[1]Soil Research Institute, Agriculture Canada, Ottawa, Ontario K1A 0C6.

Table 2.5

Area surveyed in 1976 and total area surveyed (thousands of hectares)

Survey type*		BC	Alta	Sask	Man	Ont	Que	NB	NS	PEI	Nfld	Y&NWT	Total
						Soil Survey							
New surveys													
Reconn.	1976	2 797	-	101	-	-	77	65	-	-	-	1 254	4 290
	Total	54 605	19 424	28 219	18 967	15 149	7 556	4 788	5 297	595	1 266	4 961	160 827
Detailed	1976	2	364	-	-	-	-	-	-	-	-	-	366
	Total	110	416	-	-	-	-	-	-	-	-	17	543
Exploratory	1976	-	-	-	2 709	-	-	-	-	-	728	4 843	8 280
	Total	2 630	42 429	10 926	14 993	5 284	42 977	-	-	-	4 197	42 967	166 403
Resurveys													
Reconn.	1976	193	1 228	506	63	-	-	-	84	-	-	-	2 014
	Total	4 727	17 178	20 521	109	475	339	28	610	-	-	1 214	45 201
Detailed	1976	24	84	-	65	87	11	-	38	-	-	-	309
	Total	390	1 753	2 079	1 164	806	11	-	62	595	-	-	6 850

* Reconnaissance at scale 1:50 000 to 1:126 720; detailed at scale greater than 1:50 000; exploratory at scale less than 1:125 000.

During the early period (1920-1955), when the objectives were mainly oriented toward agricultural needs, about 95 reports and maps covering about 457 000 mi^2 were published describing the nature and distribution of soils mostly in southern populated areas. Between 1955 and 1965 about 70 additional soil reports were published in more northerly areas covering about 151 000 mi^2. These reports and additional unpublished data constituted the data base on which the agriculture and forestry sectors of the internationally known Canada Land Inventory program were formulated and conducted. Land capability maps published (at scale 1:250 000 except in British Columbia where 1:125 000 is used) or in preparation total 274 and 273 for the agriculture and forestry sectors respectively. The Canada Land Inventory area covers about 19 per cent of Canada's total land area.

Since the completion of the bulk of the CLI program the scope of the Canada Soil Survey has necessarily expanded in response to demands for more detailed information in urban-rural conflict areas, and in response to environmental impact concerns such as the Mackenzie Valley and the Arctic Islands — Keewatin pipeline corridors.

A recently-adopted objective is to interpret the soil and landscape information into forms more readily used by planners of communities or of resource development. We are undertaking to make the soil maps and interpretations of soil data available earlier to users and to preclude the long delays that unfortunately still are too frequent.

The Canada Soil Survey is constituted by pedologists employed by Canada Agriculture, by provincial departments of agriculture, environment or research councils, and by university departments of soil science.

Informal agreements by joint consultation among federal, provincial, and university representatives developed over the years to share inventory programs. Project priorities and allocation of staff and resources were conducted annually to meet the provincial inventory requirements.

Soil survey groups thus constituted, operate at universities at Edmonton, Saskatoon, Winnipeg, Guelph, Quebec and Truro, or at CDA research stations at Fredericton, Charlottetown, and St. John's. In British Columbia the soil survey is dispersed at Kelowna, Vancouver, and Victoria. In recent years formal tripartite agreements have been negotiated that established institutes of pedology in Saskatoon, Alberta, Quebec, and Ontario. The objective of these institutes is to co-ordinate the provincial inventory program and research projects in support of the development of improved systems of classification and interpretation.

The Soil Research Institute of Agriculture Canada at Ottawa also conducts soil inventory projects, mainly in Northwest and Yukon Territories, and correlation of the national mapping program. A cartographic section prepares soil map manuscripts for publication and generates interpretive or single-factor maps. The institute also conducts research in soil classification and characterization by soil mineralogists, soil physicists and soil chemists, in soil pollution by soil chemists and soil microbiologists.

The co-ordination of development of soil classification and of related operational and research activities has evolved with the growth of the Canada Soil Survey Committee. This co-ordinating committee was initiated in the late 1930's to fulfill the need for communication among soil surveyors employed by various agencies. In this objective the committee, presently chaired by J.S. Clark of the Soil Research Institute, has achieved a nationally accepted soil taxonomy and terminology. Operational standards and cartographic standards are developing. The committee also serves to recognize and integrate abilities of geologists, foresters, environmentalists and engineers into the inventory and research programs, and it encourages and fosters development of contacts with users of inventory data and interpretation.

To enable the attainment of these objectives of the Canada Soil Survey Committee soil scientists are conducting research projects in soil taxonomy, soil moisture regime, relationships of mineralogy to engineering properties, relationships between vegetation boundaries and soil boundaries, characterization of alpine soils, effect of volcanic ash on soil development, composition of map units, interpretive groupings of soils for recreation and engineering uses, evaluation of landscape units for agricultural production, agricultural typonomy, computer storage of soil data, to name only a few among many projects.

The Canada Soil Survey Committee reports to the Canadian Agricultural Services co-ordinating committee (CASSC) and thereby indirectly to the Canadian Agricultural Research Co-ordinating Committee. These committees are composed of provincial deputy ministerial representatives and of Agriculture Canada administrators.

Current concerns about the supply and use of land resources for food production have produced pressures for adequate and up to date soil survey information for sound land planning improvement, and management. Although soil survey activities have been increased at the provincial and federal level surveys are not being carried out rapidly enough to meet the current demand. The Canada Soil Survey Committee is particularly concerned about the adequacy of soils information in the following areas:

Atlantic Provinces where major land improvements programs are being planned or being carried out without adequate specific information on the soil and its properties.

Ontario and Quebec have an urgent need for detailed survey for land planning and management in urban-rural pressure areas.

Prairie Provinces where updating of soil surveys is the essential foundation for agricultural management, salinity control, and water management.

The Canada Soil Survey has therefore recommended to CASCC that soil survey support be increased at the federal and provincial level to provide an adequate basis for agricultural land planning and management needs.

The committee considers that the effective and economic use of Canada's land resources for food production must be based on the quantification of the suitability and productivity of soils for various agricultural enterprises. Land evaluation requires a knowledge of soil, climatic, economic, and other factors affecting land suitability and productivity for various agricultural enterprises. An adequate program of land evaluation requires close co-operation between federal and provincial agencies, universities, and private research consultants. The committee considers it essential that the program be assured of adequate support both intra and extra mural so that the program be fully established and operative within a relatively short time frame, and therefore has recommended to CASCC that an integrated national program of evaluating land for crop production and other alternative uses be developed to extend and quantify the Canada Land Inventory for specific agricultural land planning and management for local, regional, and national needs.

Although there is widespread concern about soil degradation the actual extent and progression of the degradative process and their effect on soil productivity is simply not known with any degree of certainty. It is essential, for example, to know how much soil erosion is taking place in the cropping system used in eastern Canada, and to establish the extent and progress of soil salinization in the prairie provinces, as a basis for determining the requirement for and the nature of effective degradation control procedures. Even less is known about the extent of other degradative processes, which could cause serious and permanent losses of soil productivity. The Soil Survey committee therefore has recommended to CASCC that a program for assessing the extent and nature of soil degradation by erosion, salinization, industrial pollution, urban wastes, transportation corridors, and other activities be established to provide a basis for measures to prevent and control soil degradation.

The Canada Soil Survey committee has identified additional research needs. These include development of an improved classification of soil water regimes, improved design of soil mapping units in relation to scale and other factors, improved interpretive classification of soils, and development of improved methods for evaluating the accuracy of mapping.

THE CANADIAN SOIL INFORMATION SYSTEM (CanSIS): A TOOL FOR SOIL DATA PROCESSING

B. Kloosterman[1] and J. Dumanski[1]

The Canadian Soil Information System (CanSIS) was established in 1972. The basic objective was to develop a working tool for soil science for better characterization and quantification of soils, correlation, soil resource interpretation and parametric land evaluation.

CanSIS is a collection of co-operative data systems — national and provincial —that are linked together through agreement on organization, files, and codes. Co-ordination is provided by the national data system located in Ottawa. By agreement, all systems are compatible, complementary, and mutually supportive. Regional or provincial data systems are made up of pertinent portions of the national system (Table 2.6).

Logical structure of CanSIS

All soil information contained in CanSIS is structured in a hierarchical fashion on the basis of files, records, and modules. Four basic files, soil data, cartographic, administrative/geographic and performance/management were established at its inception. To these, the soil names files, soil description file and land degradation file have since been added.

The currently active files are described as follows:

1. Soil Names File

This is a national/provincial file listing all soil names that have been or are being used in Canada, and their appropriate subgroup classification in English and French. Presently, this file is used exclusively for soil correlation, but its content will be expanded to make it serve as a catalogue to information contained in CanSIS on a particular soil.

2. Soil Description Files

These are provincial files designed as a personalized data collection procedure for individual soil survey projects. They consist of daily sheets on which routine, observation data is collected. The intention is to provide a permanent record of site observations and to supplement data collected in the soil data file.

3. Soil Data File

This is a national/provincial file comprising records of those environmental, morphological, and analytical variables that are obtainable from a pedon sampling site. These data are arranged according to records and modules. The modules

[1]Soil Research Institute, Agriculture Canada, Ottawa, Ontario K1A 0C6.

reflect common soil survey operations and include: identification, classification, geographic location, climate, vegetation, site description, interpretations, special notes, morphological description, chemical data, physical data and mineralogy.

4. The Soil Cartographic File

The soil cartographic file is a national/provincial file consisting of a series of digitized soil maps, providing information on the geographic distribution of soils. Input into this file involves digitizing systematically drawn soil maps, while output consists of area measurements and derived interpretive maps.

5. Performance/Management Files

These are national/provincial files collating soil productivity data relative to agriculture and other land uses obtained under defined systems of management. The agricultural small plot data file is being worked on at present.

The performance/management file is fundamental to the effective operation of CanSIS. The application and utility of the system will, to a large extent, depend on the success achieved in defining concise relationships between soils and their performance as reflected by yield and management.

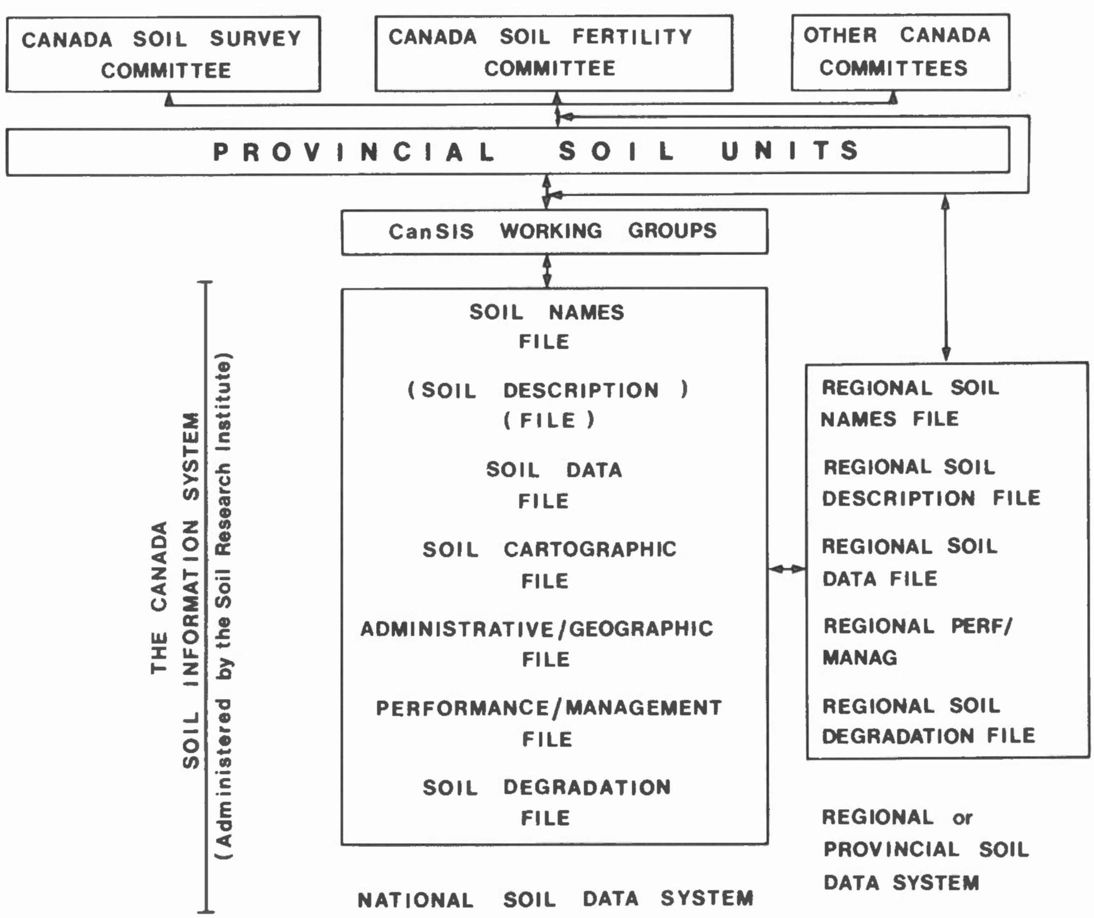
Computer roles in CanSIS

The national data system in Ottawa and other locations can be accessed remotely through the national Data Crown network, centrally located in Toronto. Computing power is provided by three IBM360/168 systems operating under MVS-OS. Provincial data systems use available IBM systems through university, government, or commercial channels. The central CanSIS facility also owns and operates a PDP11/10 minicomputer with 24K which drives a number of digitizing tables and performs related tasks.

Most of the software used in CanSIS, with the exception of standard statistical packages, were written in-house. Although designed specifically for soil science, most of the software can be applied to other earth science and geographically related data. A file management package written in IBM compatible PLI can accommodate most hierarchically structured data. The system has flexible input, editing, retrieval, and report generating capabilities. The software for the geographic data is line segment- and polygon-oriented, allowing for efficient processing and low cost retrieval of derivative map products.

Table 2.6

Schematic representation of the data gathering and co-ordination structure of the Canada Soil Information System



SOILS AND THE PRODUCTION OF FOOD

J.S. Clark[1]

Food production represents one of the more intensive uses of land. The utilization and management of soil resources for food production has been a major scientific and social concern of agriculturalists. The exploitation and settlement of the land provided the foundation for the development of Canada.

The food producing base

During its period of development Canada was regarded as a vast territory with almost unlimited agricultural potential. Indeed many current attitudes towards the use of land stems from these frontier times. Although the total land area of Canada is large, in fact extremely large, only a relatively small part of the total area is suitable for intensive agriculture. Canada has a cold northern climate and the soil mantle of much of this country is so thin or so rough that agriculture is restricted to a narrow southern belt (Fig. 2.3).

The total land area of Canada is approximately 900 million ha. The largest proportion of this total (520 million ha) is wildland made up of tundra, rock, muskeg and other land which is unsuitable for either agricultural or forest production because of climate or poor soil conditions (Fig. 2.7). Approximately 260 million ha is forest that is not suitable for agriculture because of steep topography, adverse climate, shallow soils, excessive stoniness or other unfavourable soil features. The remaining 120 million ha is considered suitable for agricultural use. Slightly less than half of the area with potential for agriculture is suitable only for grazing and much of the potential pasture land is presently forested. It is estimated that cities, roads, and other development occupies about 4 million ha. Unfortunately much of the urban and other development in Canada occurs in the best agricultural areas so that the loss of agricultural production is relatively serious.

Consequently only 77 million ha or approximately 8 per cent of the total land area of Canada is suitable for intensive agriculture. Not all of this land is of the highest quality and the land area actually used for intensive agriculture amounts to 44 million ha. (Seventy per cent of this improved land is in the prairie provinces and sixteen per cent in Ontario and Quebec.) There should therefore be a potential "reserve" of 30 million ha. This estimate is probably more realistically placed at 20-25 million ha because much of the potential remaining is marginal for field crops (capability class 4) or too fragmented and dispersed for efficient agricultural production. The total potential agricultural land area of Canada is then only about 70 million ha.

Because most of the urban and industrial development in Canada occurs in the best agricultural areas a significant proportion of the agricultural land resources of Canada are

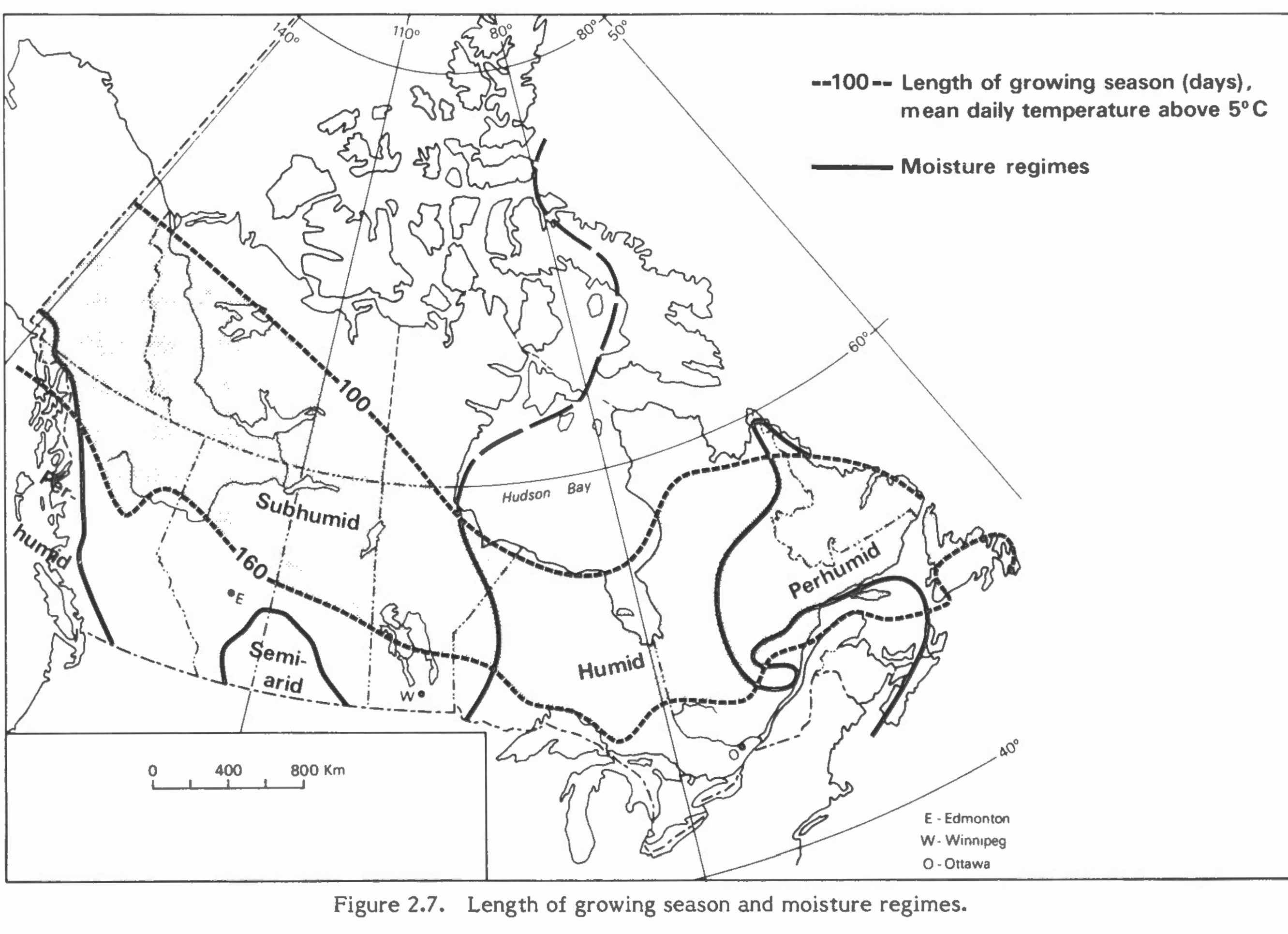


Figure 2.7. Length of growing season and moisture regimes.

[1]Soil Research Institute, Agriculture Canada, Ottawa, Ontario K1A 0C6.

Table 2.7

Soil Capability Classes in Canada* with the Canada Land Inventory Boundary

Soil Class	Capability	— Thousand hectares —							
		B.C.	Alta.	Sask.	Man.	Ont.	Que.	Atl.	Canada
1	Soils in this class have no significant limitations to use for crops.	21	813	1 072	184	2 249	14	—	4 353
2	Soils in this class have moderate limitations that restrict the range of crops or require moderate conservation practices.	236	4 041	6 446	2 556	2 360	976	611	17 227
3	Soils in this class have moderately severe limitations that restrict the range of crops or require special conservation practices.	693	6 447	10 082	2 190	3 279	1 381	2 561	27 005
4	Soils in this class have severe limitations that restrict the range of crops or require special conservation practices, or both.	1 703	9 940	4 252	2 573	2 902	2 830	2 544	26 745
5	Soils in this class have very severe limitations that restrict their capability to producing perennial forage crops, but improvement practices are feasible.	6 677	11 433	7 799	2 250	1 910	1 636	2 352	34 056
6	Soils in this class are capable of producing perennial crops only, and improvement practices are not feasible.	5 423	3 794	4 065	2 162	1 192	9	2 903	19 553
7	Soils in this class have no capability for crop use or permanent pasture.	78 770	4 770	284	1 254	13 036	21 851	9 350	129 325
0	Organic Soils (not placed in capability classes).	**	5 173	2 914	5 113	2 154	1 268	3 695	20 316

*Nowland and Shields. Additional Land For Crop Production — Canada Proc. Soil Cons. Soc. of Amer. 30th Annual Meeting, 1975.

**Estimates not available for Organic Soils in British Columbia.

used for cities, transportation, and other alienating uses. Equally serious is the removal of agricultural land from production in the urban shadow zone due to high land prices, fragmentation of farms, speculating, recreation, and hobby farming. The total productive agricultural land area in Canada is not large and indeed it is a small population and not an unlimited agricultural potential that makes Canada a net exporter of food.

Food producing capacity of Canada agriculture lands

The variable productivity of agricultural lands in Canada is well known from the results of the Canada Land Inventory Program, which are summarized in Table 2.7. The soil capability rating system recognizes the productivity of soils with respect to differences in climate (heat, rainfall, frost free period, winter temperature), soil (topography, stoniness, drainage, water holding capacity, depth), and other properties. The capability classes were established on a regional basis for British Columbia, the Prairie Provinces, Ontario and Quebec, and the Atlantic Provinces. As a result Class 1 soils in Ontario and Quebec are more productive than the same class of soil in the Atlantic provinces or the Prairie region. Research is required to allow a precise inter-regional comparison.

In any given region class 2, 3, and 4 soils are respectively about 4/5, 2/3, and 1/2 as productive as Class 1 soils. Soil capability class 5 soils and above are not suitable for intensive agriculture but can be used for grazing and other purposes. In many cases little can be done to alter the relative productivity of many soils but the productivity rating of others can be increased by drainage, irrigation and other practices provided these can be justified economically. Fertilizer and other soil management practices can be used to improve the productivity of all soils but will not significantly alter their relative capability ratings.

The capability ratings for soils are generally based on the productive capability of soils for the major field crops. What are particularly important in the Canadian situation are those unique areas such as the fruitbelt of Ontario, the Okanagan Valley, the Annapolis Valley, and the Fraser Valley. These have especially favourable climatic and soil conditions that permit the production of fruits, vegetables, and other specialty crops.

In broad terms, the highest returns are obtained from soils of high capability. For example, with current production technology, corn production in Ontario during 1974 provided economic returns only on class 1 and the higher capability class 2 soils. With current costs of production, returns were already marginal for the "less capable" class 2 soils which still can be considered as "prime" agricultural land. Substitution of lower capability soils for prime agricultural soils will mean either higher food costs for Canadians or difficulties for the agricultural industry.

Differences in soil capability must be recognized in estimates of the population potential for Canada. Land requirements for food production from other climatic areas cannot be applied without recognizing the soil and climatic conditions existing in Canada. To estimate the population potential for Canada it was assumed that the basic land requirement is 0.68 ha (1.5 a) of prime agricultural land (class 1 and 2) in Ontario and Quebec per person. This amount of high quality land would allow a diet comparable to the current Canadian caloric intake but probably with a somewhat lower consumption of meat, poultry, and other animal products depending on the overall land productivity that could be achieved and the farming system used. To recognize regional differences in soil capability ratings it was assumed that soils in the Atlantic provinces were 2/3 and those of the western provinces 1/2 as productive as soils of the same capability class in Ontario and Quebec. It is of course assumed that Canada would be self sufficient in food production. Table 2.7 was constructed with these assumptions and resulted in a population potential for Canada of approximately 50 million persons. The total figure can readily be adjusted by altering the assumptions used for its construction to allow for possible climatic change, changed dietary habits, lower levels of production, loss of agricultural land to other uses and so on. On the whole, the estimate is probably a generous one as it is based on high average yields for prime agricultural land particularly in the prairie region. Even if the more conservative potential of 40 million persons is assumed, it is clear that Canada faces no serious land problems feeding its projected population of 30 million by 2000 unless productivity levels are drastically reduced.

Increasing food production in Canada

Food production can be increased either by increasing the resource base or by increasing productivity. The most direct adjustment in food production can be made simply by expanding or reducing the cropland base. Total agricultural production in Canada could of course be expanded by exploiting the remaining "reserves" of agricultural land. The final disposition of these reserves will be mainly determined by need in relation to costs of production.

In order to anticipate productivity increases that might yet be achieved it is essential that the sources of gain responsible for past progress be fully understood. Although no quantitative study has been made of the sources of productivity gains in agriculture in Canada this has been done in the U.S. As our agricultural technology is not greatly different from theirs the gain sources are probably similar. The main sources of gains for 1940 to 1955 were:

1. Replacement of land as a source of farm power (tractors for horses) — 25%
2. Changes in value added by livestock — 25%
3. Changes in crop production per acre — 43%
4. Changes in land use — 7%

Fertilizers (i.e. soil fertility) were responsible for at least 50 per cent of the increased crop production per unit area over the entire period from 1940 to 1955 and accounted for 65 per cent of the crop productivity increases during the latter part of the analysis. The data forecasted a continuation of this trend and fertilizers have remained the chief source of gains through the 1960's and 1970's not only in the United States but in Canada as well.

Research for increased food production

In addition to fertilizers, soil management and land improvements have also contributed significantly to increased productivity. Conservation of moisture in dry areas by means of proper soil management, timely tillage, irrigation, drainage, improvement of structure, and other practices have all resulted in appreciable gains in productivity. Thus soil management in total has produced a large proportion (perhaps as much as 70 per cent) of the overall increase of crop production per unit area that modern technological agriculture has achieved over the last forty years. It is essential therefore that a strong program of soil research be maintained in Canada to secure these gains. This will be particularly critical over the next five or ten years if energy prices rise as predicted and the costs of fertilizers, tillage, irrigation and other soil management practices rise proportionately. Priority will have to be given to better nutrient management in soils, more precise methods of soil analysis, alternative sources of fertilizer nutrients, improving nitrogen fixation by legumes, adaptations of rotations and alterations of moisture conservation, tillage, drainage and other soil management practices to ensure that current levels of productivity are maintained. Intensive monoculture, summer fallow and other agricultural practices have resulted in some degradation of soils by salinization, compaction, deterioration of structure, loss of organic matter, soil erosion, heavy use of chemical fertilizers. Attention will have to be given to these problems as well if agricultural productivity is to be maintained.

The careful management of the resource base is also an essential element for the maintenance of soil productivity in Canada because the soil resources are limited and climate is unfavourable. The advantages to be gained from preserving the best lands for agricultural production are as great as the gains that have been made by the technological developments of scientific agriculture. At the present time only a fraction of the total agricultural research effort is devoted to the evaluation and management of the agricultural land base to ensure its most effective use in order to meet national food objectives and to provide for a viable stable agriculture. Indeed, less than 5 per cent of the agricultural research budget is devoted to soil management. It is a common concern of soil scientists that it will not be possible to maintain, let alone increase, agricultural productivity unless greater attention is given to the management of soil resources than is being done at present.

SOILS AND FORESTRY

H.H. Krause[1]

About 25 per cent of Canada's land area sustains forests suitable for regular harvest. These forests form the basis of an industry which, in 1969, provided 14.5 per cent of the total value added in the national economy, employed 3 per cent of the labour force and contributed 20 per cent to the total export value (Manning and Grinnell, 1971).

Major forest regions and their industrial importance

In the British Columbia Coast region there are Western red cedar (**Thuja plicata** Donn), Western hemlock (**Tsuga heterophylla** (Raf.) Sarg.), Sitka spruce (**Picea sitchensis** (Bong.) Carr.), and Douglas fir (**Pseudotsuga menziesii** (Mirb.) Franco). Forests of the Columbia region on the east side of the central plateau of British Columbia have similar species composition of the coast forest, but are generally somewhat slower in growth. The subalpine forest region within the Cordilleran area is characterized by Engelmann spruce (**Picea engelmanii** Parry), alpine fir (**Abies lasiocarpa** (Hook.) Nutt.), and lodgepole pine (**Pinus contorta** Dougl.). Such stands are generally productive except on rocklands.

In the three forest regions mentioned above are a major portion of Canada's timber reserve. Although they do not represent the entire area of British Columbia, they sustain the forest industry of that province which contributed about 70 per cent of the lumber and 44 per cent of the wood pulp produced in Canada during 1966 (Manning and Grinnell, 1971).

The boreal forest region extends from Newfoundland west to the Rocky Mountains and northwestward to the Alaskan border. The principal species are black spruce (**Picea mariana** (Mill.) B.S.P.) and white spruce (**Picea glauca** (Moench) Voss). Less common but characteristic of the region are tamarack (**Larix laricina** (Du Roi) K. Koch), balsam fir (**Abies balsamea** (L.) Mill.) and jack pine (**Pinus banksiana** Lamb.). The predominantly coniferous stands usually have an admixture of broadleaf species, white birch (**Betula papyrifera** Marsh.) and trembling aspen (**Populus tremuloides** Michx.).

The boreal forest of the interior plains contains appreciable timber reserves, which are largely underutilized still today. At the annual rate of cutting between 1964 and 1968, it would have taken 1263, 352 and 648 years to harvest once the entire inventoried forests of Manitoba, Saskatchewan and Alberta (Manning and Grinnell, 1971).

The boreal forest contributes a major share of raw wood to the Ontario forest industry which, in a provincial comparison, ranks third in the country. In Quebec, the boreal forest sustains the demands of a heavily concentrated pulp and paper industry and provides for a primary forest production which was second only to that of British Columbia in the late sixties.

The Great Lakes – St. Lawrence forest region forms the transition between the boreal forest to the north and deciduous forest to the south. Characteristic species are white and red pine (**Pinus strobus** (L.) and **P. resinosa** Ait.), eastern hemlock (**Tsuga canadensis** (L.) Carr.), white spruce, yellow birch (**Betula alleghaniensis** Britton), sugar maple (**Acer Saccharum** Marsh.), red maple (**A. rubrum** L.), and beech (**Fagus grandifolia** Ehrh.). These forests generally show higher productivity than the boreal forest, but priority is given to agriculture and other forms of land use. Forest industries are therefore not concentrated in this region.

In the Acadian forest of the Maritime Provinces, the species composition resembles that of the Great Lakes – St. Lawrence forest region, except for the wide occurrence of red spruce (**Picea rubens** Sarg.). Mixed coniferous stands of balsam fir, red spruce, and black spruce cover extensive areas on level and gently sloping land; mixed hardwoods are predominant in hilly terrain.

The timber resources of the Acadian forest have been utilized by man over more than 200 years. Cutting has intensified during the last few decades by a growing pulp and paper industry. As a result, standing timber volumes and yields per unit area are generally low despite favourable soil and climatic conditions for forest growth. Between 1964-68, average harvest yields were approximately 74 m^3/ha in New Brunswick as compared to 194 m^3/ha in British Columbia (Manning and Grinnell, 1971).

Forest productivity and soils

Forest productivity is a function of climate, soil and sand characteristics. Climate is the dominant factor. Its effect is revealed in the variable nature and productivity of Canada's forest regions. Within an area of little climatic variation, differences in species composition and biomass production are largely accounted for by differences in soil.

Soil features playing a key role in forest growth are drainage, water retention and storage, porosity and consistence. Depending on these and other factors that determine rooting depth, the mineral composition of the root-exploited stratum and the efficiency of nutrient cycling, different forest types create their own levels of soil fertility which ultimately determine tree growth.

A few selected reports from Canadian studies would tend to support this generalized view of the function of soil in forest growth. Jamison (1965) found that natural jack pine growth in Saskatchewan was well correlated with moisture regime, pore pattern and cation exchange capacity of soils. He suggested that cation exchange capacity may serve as a general indicator of nutrient content. Duffie (1965) reported that white spruce growth in Alberta was most strongly influenced by moisture regime and to a lesser degree by type of parent material. Soil moisture was also found to be the most important factor for black spruce and balsam fir growth in Newfoundland (Page, 1976). Whereas growth was often limited by water shortage in the boreal forest of the interior plains, maximum growth occurred, as a rule, on pervious sandy soils under the perhumid climate of Newfoundland. Parameters reflecting nutrient content in soil were also correlated with conifer growth in Newfoundland, but not as closely as soil water status.

In contrast to the descriptive studies employing statistical inference, experimentation with fertilizers has shown that forest growth is limited more often than not by nutrient shortage. Summarizing the results of fertilization experiments in northern coniferous forests, Armson et al. (1975) reported that adult conifer growth in Canada is commonly limited by nitrogen shortage, and that plantation growth is often retarded by potassium deficiency on coarse-textured soils. These results together with those from many other countries have dispelled the long-held view that soil fertility is less important to forest growth than other forms of vegetation.

[1]Department of Forest Resources, University of New Brunswick, Fredericton, New Brunswick.

Soil survey and ecological site classification in forestry

In most provinces, only limited portions of the existing forest land have been covered by regular soil survey. The information contained in soil survey reports and maps has found little application in forestry. A probable reason for the infrequent use of soil maps by foresters is the fact that the surveys were carried out at low levels of intensity and the maps were usually produced at small scales of 1:63 360 or 1:126 720. These maps lack resolution showing large portions of the surveyed area as undifferentiated complexes or incorrectly as one series. Most survey reports did not contain an adequate interpretation of soil information for forestry or entirely lacked a reference to forestry. With these limitations, maps were of little use to foresters in the field or in large-scale planning at the district or provincial levels.

Stone (1975) pointed out that the need for soil information increased with the intensity of land use and input of management skills. Until recently, forest practices in Canada consisted predominantly of the harvesting of natural forests and their protection against fire and insect pests. Harvesting was carried out on a sustained yield basis so that a certain age class pattern would develop when clearcutting was employed and continuity of wood supply was assured. Regeneration of forests after cutting was expected to occur naturally. Silviculture was practiced to a very limited extent in some provinces and not at all in others. At this level of forest management, good soil maps could have been useful in road location, but few other operations would have required detailed soil information.

Rather than promoting soil surveys in forestry, various institutions set out to develop different methods for the evaluation of forest lands. For example, in portions of Quebec, forests were typed, rated and named after site-specific ground cover plants (Lafond, 1964). A predominantly physiographic approach to land evaluation for forestry was taken in Ontario (Hills, 1953). The eco-unit, a given combination of forest stand, soil and climate, was recognized as the subject of forest management, but the principal unit of land classification was the physiographic site which resulted from the interaction of ecoclimate, soil moisture, and nutrient regime. Soil moisture regimes were derived from texture and consistence, and nutrient regimes from the mineralogical composition of the soil parent material. Surface conditions relating to processes of soil formation were disregarded as criteria for site evaluation.

Since insufficient nutrient supply has been shown to be a common growth limiting factor and since fertility and nutrient cycling depend strongly on processes in the solum, the omission of soil surface features as criteria of classification must be regarded as a shortcoming of this system.

In British Columbia, Krajina (1969) and his students developed a system of forest classification based on a combination of physiographic, edaphic and biotic factors. The province has been subdivided into biogeoclimatic zones and about 140 biogeocoenoses (ecosystems) have been projected. Krajina's ecology of forest trees has found application in forest management by government and industry of British Columbia.

A more recent ecological approach to land evaluation is the biophysical land classification of Canada. It attempts to integrate physiography, soil, and vegetation. The basic unit is the land type which is determined by the landform, soil and chrono-sequence of vegetation. Similar to the method of Hills, soils are characterized according to texture, drainage, and geologic origin of the parent material. A recent example is the biophysical survey of Kejimkujik National Park (Gimbarzevsky, 1975).

The ecological methods of land classification have taught foresters the general functioning and distribution of natural forests. There is little doubt that the approach is valid and essential where forest management is predominantly a manipulation of the natural tree cover.

Intensified land use and the growing need for soil information in forestry

According to compilations by Weetman (1977), Provincial governments and industries expended approximately 60 million dollars on silviculture in Canada during 1974. In the same year about 910 000 ha of forest land had been cut throughout the country. The above expenditure was not limited to immediate activities of reforestation but also included cost of seed procurement, planting stock production, tree improvement work, and spacing of naturally regenerated young growth. Under these circumstances, the expended amount would not have been sufficient to restore more than a small fraction of the cut area to satisfactory forests. Nevertheless, the 1974 silvicultural expenditure marks an important change in Canadian forestry.

At present, it is generally the aim to reforest those areas which will not regenerate naturally. However, artificially established forests are generally superior to natural forest growth as far as volume yield and wood quality is concerned. If Canadian forestry is to follow developments in other countries, it can be expected that increasingly larger proportions of raw wood will originate from high-yield, man-made forest.

High-yield forests are created with a limited number of economically rewarding species, from seeds of selected provenance of genetically improved stock. Such stands are usually harvested in shortened rotation and utilized to the fullest extent. Tree species and soil must be matched and sites need to be prepared by an appropriate method for stand establishment. If necessary to reach the management goal, periodic adjustment of soil fertility levels may be made.

This type of forestry involves soil management, and not just forest management in the classical sense. Soil management, in turn, requires basic soil information and knowledge of how trees and soil interact under different types of silvicultural treatment.

Characterization and classification of soils at the Family and Series levels according to the latest edition of The Canadian System of Soil Classification, would seem to generate the information required under conditions of intensified land use in forestry. Certain criteria, as for instance, soil moisture regimes, may require further attention. Slope, an important factor in forest growth, is dealt with directly by recognition of soil phases and indirectly when characterizing soil horizons. To make this information available to practicing foresters, detailed surveys of high intensity and maps of both large and intermediate scales are required.

Soil maps with the Series as mapping unit and with a scale of 1:20 000 or larger could serve as a basis for the establishment of land units and definition of management goals. The large-scale maps would unquestionably facilitate planning of silvicultural and tree-harvesting operations by the field forester. Maps drawn at scales of 1:50 000 or 1:100 000 and with the soil association as mapping unit may be useful in regional planning provided that a rating of the soils for forestry is available.

Maps as specified above have been prepared for Waterloo County, Ontario (Presant and Wicklund, 1971). Unfortunately, the report does not include an interpretation of the soil survey information for forestry.

To avoid duplication of cost and effort, it is recommendable that survey and mapping of forest lands be carried out by soil survey staff of the various provincial and federal institutions in close co-operation with forestry personnel. Examples of such co-operation are the more recent soil survey reports of Manitoba (Smith et al., 1975) in which sections on forestry were prepared by members of the Canadian Forestry Service. Ideally, soil survey and mapping should be the responsibility of a national organization which is not identifiable with one particular form of land use, but is independent and adequately staffed to meet the requirements of all user groups.

Soil research for forestry

The international literature contains ample information on soil-forest growth relationships. However, intensification of land use for forestry has created a need for new information requiring applied and basic research. For example, the efficiency of site preparation for stand establishment by a given method will obviously vary with soil conditions. An objective base from which to evaluate the interaction of soil, type of surface disturbance, and growth of the new stand is presently not available.

The present tendency for shortening rotation age and the introduction of complete tree harvesting result in increased nutrient loss from the land. In this connection, the possibility of soil exhaustion has become a question of considerable concern. To estimate nutrient loss in tree harvesting, the accumulation of macro and trace elements in forest stands has been determined in many countries, including Canada. Valuable reference values have been obtained, but this approach, reminiscent of the substitution principle in soil-fertility maintenance during early periods in agriculture, is inadequate to establish guidelines for soil management under high-yield forestry. A minor change in soil pH, for instance, may produce a greater effect on the pool of available phosphorus than the removal of phosphorus in tree harvesting. Essential to effective soil management under forestry is an understanding of those reactions that affect nutrient cycling, one of the most important processes in the soil-forest system.

It was pointed out earlier that adult conifer growth is commonly limited by nitrogen shortage. For some time, it was assumed that such shortages could be alleviated routinely by fertilizer use. It seems now that high fertilizer cost and principles of energy conservation and environmental control may constrain forest fertilization in many locations. Under these circumstances, research to maximize the efficiency of indigenous soil nitrogen, and studies aiming to induce or increase biological nitrogen fixation during certain stages of stand development should be given serious consideration. Finally, attention is being drawn to the possibility of loss of potential soil productivity after replacement of indigenous forest types by monoculture plantations. In New Brunswick, for instance, large portions of hardwood forest are being replaced by black spruce. With this change, a radically different forest floor develops which undoubtedly will affect, adversely, solum and nutrient cycling. The question is whether the rate of change is such that it needs to be considered in long-range projections of forest management goals.

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SOILS FOR WASTE RECYCLING

L.R. Webber[1]

Introduction

Historically, the use of soils for waste recycling is as old as the problem of waste disposal itself. Perhaps, the first irrigation system designed primarily for sewage disposal began in 1559 in Prussia and operated for more than 300 years. In England, a Royal Commission on Sewage Disposal (1859) recommended the application of town sewage on land as a means of avoiding river pollution. In more recent times, irrigation of crops with sewage effluent has been advocated in order to utilize the fertilizing potential of the waste. Since the 1890s the Board of Works Farm, Werribee, Australia has used up to 10 935 hectares of land, 32 km west of Melbourne to handle the sewage from almost two million people. In 1974 the operation provided pasture for 22 000 cattle and 40 000 sheep most of which were marketed locally and subject to state health inspections.

Why recycling through soil

Land application of organic wastes and wastewaters containing organics is a form of advanced waste treatment, including nutrient removal and the inactivation of disease-causing bacteria, viruses and Protozoa. The practice is an alternative to costly physical-chemical and ultra-treatment processes which are designed to achieve a high quality effluent. The recycling of wastes through soils has been supported by the public for such reasons as:

1. a recognition of severe damage to surface water supplies due to the discharge of liquid wastes into streams;
2. a means of recharging aquifers, particularly in areas where the depth to an aquifer is increasing or the source of supply is unreliable;
3. a trend by water quality authorities to require zero discharge of contaminants to surface water supplies; and
4. an economical means for the ultimate disposal of certain wastes by industry or municipal authorities.

While much remains to be learned about the ultimate fate of some wastes during land application, it is apparent that many of the contaminants in waste are beneficial to soils and crops. When the nutrient requirement of a crop is met primarily from added wastes, there is a minimal hazard to soil or water.

The ultimate objective in using soils for waste recycling should be to dispose of and utilize wastes on crop-producing land without imposing an excessive burden on the capacity of the soil or the crop to assimilate the nutrients in the waste or the byproducts from waste degradation. When using land as a receptor of wastes, the objective must be to utilize wastes and not impair the quality of any aspect of the environment – soil, water and air.

The ultimate fate of biodegradable material when added to soil is determined largely by local climatic parameters and soil conditions. Temperature is an environmental factor affecting the microbial degradation of soil-applied wastes. The rate of degradation normally increases as ambient temperature increases but under field conditions soil is known to undergo diurnal and seasonal fluctuations. Many of the effects of climate on chemical processes in soil relate to organic matter, its accumulation, degradation and the establishment of an equilibrium value. Organic matter tends to accumulate in soils as the mean annual temperature decreases and as soil drainage is impaired.

The physical condition of a soil often determines the suitability of a site for the surface application of wastes and subsequent biodegradation. The physical properties of major concern include: soil texture, infiltration rate, permeability, drainage, aeration, erosion and runoff.

The effects of soil physical conditions and their limitations on soils for accepting nontoxic biodegradable wastes are summarized in Table 2.8.

When organic wastes or wastewaters containing organics are added to a soil several processes are involved in the transfer of ions or compounds from the applied waste to the soil. The waste or some portion of it may pass through soil virtually unchanged. For example, the capacity of soil to retain the chloride ion is so weak that it is often used as a tracer ion in water movement studies. The nitrogen in some wastes may be lost as gaseous ammonia by volatilization or by denitrification of nitrate-nitrogen to gaseous nitrogen or nitrous oxides. Organic compounds are degraded to carbon dioxide under aerobic conditions. The uptake of ions and compounds by vegetation from wastes is a desirable process when the substances absorbed by the plant are nutritional. However, toxic substances may also enter the food chain by this means. Finally, the added ion or compound may be immobilized in soil in a form that is virtually insoluble. Soluble phosphates are immobilized in most soils by calcium, iron and aluminum compounds. Immobilization is desirable when the added wastes contain toxic compounds, such as heavy metals.

Kinds of wastes and limitations to uses

The kinds of organic wastes or waste waters containing organics that are recycled through soils include:

1. Livestock and poultry manures
2. Shredded solid waste in combination with sewage sludge
3. Anaerobically digested sewage sludge
4. Wastewaters from food processing operations, industry, tanneries and sewage treatment plants.

To recommend loading rates for a given waste, it is necessary to have an analysis of the waste or know its general composition, to know the site and soil characteristics and the probable management program.

It has been estimated that 75 per cent or more of the organic material in manures will undergo microbial decomposition during the first year when incorporated in a well drained soil. Mineralization processes release numerous plant-available nutrients, such as nitrogen, phosphorus, potassium and many micronutrients. Excessive applications of manures or sludges could result in movement of the soluble nutrients to the groundwater, particularly nitrate-nitrogen.

Farmers are urged to employ manure management practices that ensure the optimum utilization of the nutrient content for crop production. There is a growing concern about shortages and rising costs of fossil fuel and the overall affect on agriculture. Attention has been drawn to the energy equivalent in chemical fertilizers and the energy

[1]Department of Land Resource Science, University of Guelph, Guelph, Ontario.

Table 2.8

Soil limitations for accepting nontoxic biodegradable liquid waste (adapted from Stewart and Webber, 1976)

Item	Degree of Soil Limitation		
	Slight	Moderate	Severe
Infiltration	rapid to moderately rapid 1.5 cm/hr	moderately slow 0.5 to 1.5 cm/h	slow to very 0.5 cm/h
Permeability of the most restrictive sub-horizon to 150 cm	moderately rapid 1.5 to 15 cm/hr	rapid to moderately slow 15 to 50 and 0.5 to 1.5 cm/h	very rapid 50 cm/h very slow 0.5 cm/h
Soil drainage	well to moderately well drained	excessively and poorly drained	excessively poorly and very poorly drained
Runoff	none to very slow	moderate	rapid

savings when fertilizers are replaced by livestock manures. The energy input for producing 0.4 hectares (1.0 acre) of corn has been estimated at 1.8 million kilocalories; 52.9 per cent of this energy input is related to chemical fertilization. If manure is used to replace fertilizers the energy saved is about 240 litres of gasoline per hectare.

More than half of the nitrogen in manures may be lost to crop utilization by improper storage and faulty application methods. A major research need in animal and poultry manure utilization on crop-producing land is to determine ways and means of conserving the nitrogen fraction. Research programs designed to investigate on-the-farm storage structures and mechanical means of incorporating or injecting manures are needed in a nitrogen conservation approach.

Numerous reports have detailed the beneficial effects from the incorporation of composted urban wastes (solid waste and sewage sludge) into crop-producing soil. Research data using non-composted solid waste and sludge as a soil amendment are limited. At Guelph, Ontario unsorted, shredded, domestic garbage and anaerobically digested sewage sludge were incorporated with a loam soil (King et al., 1974). In addition to disposing and utilizing urban wastes, the principal advantages were significant improvements in soil physical properties and the production of reasonably good yields of corn grain.

The use of digested sludges on crop-producing land is beneficial in that the waste is a low-analysis fertilizer containing virtually all nutrients essential for plant growth. In addition to its fertilizing properties, the organic matter in sludges has a beneficial effect through its action on soil structure and other physical properties. The major problems in using sludges on crop-producing land include a public acceptance of the practice, and hazards associated with ground and surface water pollution, contamination of the food chain by heavy metals and health hazards by pathogenic organisms.

Utilization of digested sludges on crop-producing land appears feasible to municipalities as an economical means of disposal and to farmers as a way of reducing the energy input by using the fertilizing value of the sludges. Research funds are required to avoid land contamination by heavy metals, to determine the level of metal phytotoxicity and to prevent animal and human toxicity from the ingestion of metal contaminated agricultural produce.

Large volumes of waste water are released by industrial operations processing agricultural products and by municipal sewage treatment plants. The waste waters normally undergo some form of primary treatment, such as sedimentation, screening and clarification followed by biological oxidation. The industrial effluents are often spread on land by overhead spray irrigation, infiltration-percolation or by overland flow. Land application has been found to give a high degree of waste water treatment including nutrient removal and bacterial inactivation or destruction. Generally, land disposal of these waste waters is more economical than treatment by municipal sewage treatment plants.

Heavy metal hazards

Land application of digested sludges containing heavy metals could induce toxicity effects on plants and endanger the food chain as there is a tendency for the metals to remain in the surface soil or the rooting zone. Once established, removing or overcoming metal toxicity in soil is most difficult. Most research reports indicate that the metal concentration in plants increases as the level of soil metals is increased. The response of plants to metals added to a soil varies with the plant or crop and several soil properties.

Considering the chemistry of heavy metals and other toxic elements in sewage sludges and the uptake of the metals by plants, CAST (1976) divided the elements into two categories of hazard (Table 2.9).

Most provincial, municipal and state authorities have developed guidelines for the use of digested sewage sludges on crop-producing land. Generally, guidelines recommend rates of application based on nitrogen requirement of the crop to be grown. In some instances, special provisions and constraints are imposed if the content of certain heavy metals in sludges is particularly high. When using or recommending the use of treated sludges on agricultural land, one should consult the local authorities and become familiar with local regulations.

Disease hazards

The disposal of waste waters on land and the subsequent re-use of the water after passing through or over soil and the consumption of certain crops and vegetables by humans introduce hazards in the transmission of organisms that may cause a disease or other type of infection in a consumer. It is important to note that the occurrences of these diseases or infections in Canada are particularly infrequent due largely to improved sanitary conditions, water control and the use of

Table 2.9

A subdivision of elements into hazards of toxicity to plants and animals (adapted from CAST, 1976)

Relatively little hazard	Potentially serious hazard
Mn, Fe, Al	Cd
Cr	Cu, Mo
As	Ni, Zn
Se, An	
Pb, Hg	

vaccines. However, a person may contact a viral infection by ingesting food or water and not develop the characteristics of the disease but at the same time he may be an effective carrier and transmit the disease to others who in turn develop acute symptoms of the disease. It has been demonstrated that disease-causing organisms do survive in water, foods and soils for varying lengths of time and can infect a consumer by direct contact, consuming contaminated food or water and probably other means of transmission.

Summary and research needs

Agriculturalists have regarded livestock and poultry manures as resources not wastes; they have emphasized the utilization of these resources in crop production. Application rates of animal manures on soils should not exceed the nitrogen requirement of a reasonable crop yield. It is the responsibility of operators of high-density confinement units and feedlots to apply manures to land, either owned or used, in such a manner and time that environmental problems are not created.

The principal motive in recycling wastes through soils is economic; it is generally less costly for municipalities and some industries to dispose of wastes by land application. When the nutrient requirement of a crop is met primarily from added wastes, there is a minimal hazard to soil, water or air.

There is little evidence to show that the incidence of diseases in humans or animals is related to the spreading of treated sludges on land. Raw untreated sludges or septic tank cleanings should not be applied to crop-producing land. Special precautions are essential when using sludge-amended soils for vegetable production and for livestock grazing.

In Canada, agricultural land is not a renewable resource; it is finite in area, depth, and in many characteristics that determine its crop-producing potential. The use of soil resources as a medium for recycling wastes requires further research if the operation is to be beneficial to agriculture and the waste producers. In using soils for waste recycling, it is essential that the soil itself is not contaminated, that foodstuffs for humans and animals are of acceptable quality and that other segments of the environment are not impaired.

It is recommended that Environment Canada and provincial governments increase their research funding to:

(1) define those soil factors and properties that determine the availability to plants of metals; the ability of plants to absorb metals appears to depend on factors other than metal solubility in water.

(2) encourage and support plant breeders to investigate a possible discriminatory function by vegetation with respect to metal uptake and once absorbed the screening or blocking effect which tends to produce varying metal concentrations in various parts of the plant.

(3) investigate the feasibility of introducing compounds into industrial waste waters for the purpose of immobilizing known toxic metals.

Municipal governments should be encouraged and supported to monitor old and currently used disposal sites. Once agricultural land has been contaminated with toxic compounds, renovation costs are virtually prohibitive.

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SOIL MATERIAL IN INDUSTRY

G.R. Guillet[1]

Soil materials are the feed stocks for a number of diverse industries in Canada. In addition to such widely distributed materials as topsoil, clay, peat, sand, and gravel, local surficial occurrences of marl, kaolin and refractory clays, bentonite, diatomite, silica sand, phosphate, and sodium sulphate may have economic value.

In the world of minerals, no other material is consumed in as large a quantity as sand and gravel. Indeed, the increasing materialism of Western Society is reflected in the consumption of these materials. For example, consumption in the Toronto area in 1950 was 2.1 tons per person; in 1974 it was 7.4, a capita increase of 350 per cent in 24 years. Construction on multilane highways, suburban shopping plazas with large adjoining parking areas of asphalt and concrete, and increased use of concrete in high-rise residential and office complexes are the reasons for the dramatic escalation in consumption of these essential, low priced, commodities.

While once the basis for all brick and tile manufacturing, surface clay has been replaced by shale in many instances. It is still used extensively however, in the making of drainage tile in rural agricultural regions. While glacial clays of the low-quality illite-type predominate in Eastern Canada, a variety of higher quality clays occur at or near the surface on the Western plains. Here, kaolin-type clays are used as fillers in paper and in manufacture of many types of refractory and ceramic products. Bentonite, a montmorillonite clay possessing superior properties of absorption and plasticity, finds application as a sealing agent and binder. Drilling mud and oil refining are the largest of a great variety of uses.

Peat moss is probably best known in Canada for its horticultural value, as a soil conditioner in home and greenhouse gardening. Its high porosity and power of selective absorption give it a wide range of other potential uses, such as absorbing oil spills, absorbing impurities in water treatment systems, and as a carrier for fertilizers. Who knows but that its historic value as a low-grade fuel in Europe may again become significant in an energy-deficient world?

Marl occurs as precipitated calcium carbonate in many emerald-coloured lakes inhabited by the blue-green algae that causes its deposition. Extensively used for making Portland cement around the turn of the century, marl is only important now in areas lacking suitable deposits of limestone. Other potential uses include many filler applications where finely ground limestone flour is required.

Sodium sulphate is widely distributed in both the soil and groundwater of the western plains. It is excavated from dry shallow lake beds on which the salt has been precipitated during arid conditions. Its principal use is in the manufacture of kraft paper and newspaper where it adds strength.

Phosphate is an important soil material in many parts of the world, but has yet to be found in near surface commercial deposits in Canada. It is of course an essential ingredient in fertilizer.

Silica sand of high purity is the principal ingredient in glass. Suitable deposits are scarce, particularly in the heavily industrialized areas of Canada, and much of our supply is imported from the United States. Silica sand has many other industrial uses, including filtration which it shares with another siliceous soil material, diatomite. Deposits of diatomite consist of microscopic skeletal remains of certain minute organisms called diatoms. Diatoms exist today in many Canadian lakes, and low grade deposits are accumulating with other bog debris. These have yet to be of commercial importance in Canada.

Most soil materials of industrial value are typically low-priced, high-bulk commodities dependent on local markets. Proximity to market is, in many cases, the single most important economic factor determining the development and utilization of a particular deposit.

In recent years there has been a growing awareness of the universal importance of sand and gravel as a basic construction material. In particular, concern is being felt for the dwindling supply of these materials in major urban areas, a problem related not so much to physical depletion as to social reaction against surface mining. In recent decades immense quantities of valuable undeveloped gravel resources have been lost to future industrial use through urban sprawl and restrictive land-use legislation.

Clearly, a major effort must be made towards carrying out resource inventories as prerequisites to land-use controls. Most provinces in Canada today have recognized this, and have mineral aggregate inventories in progress or planned over much of their territories. There has been a tendancy however to overlook other surficial resources, perhaps because they are not used in the large volumes as the common construction aggregates, and do not make the same large contribution to the national economy. Generally they are not as widespread as sand and gravel, but for little extra effort they could easily be included with the aggregate inventories. Only by first knowing the locations, quantities, qualities, and probable markets for all surficial materials of potential industrial use can we plan effectively for the future extraction of the best deposits with minimal disturbance to residential and recreational areas.

It is important to realize also that a lower environmental standard may have to be accepted in certain major resource areas. No amount of cosmetic surgery can enhance the appearance of a surface mining operation to the point where it becomes an aesthetic asset to the community. But, it should be emphasized too, that resource extraction is only a temporary use of the land, and that modern rehabilitation practice can progressively return mined-out lands for other uses. Many of our most famous urban parks exist today because they were sand, gravel, or clay pits during the early developing years of our cities, not because planners then foresaw the need for open space.

[1]Gartner, Lee Associates Ltd., Willowdale, Ontario.

PERMAFROST SCIENCE AND ENGINEERING IN CANADA

R.J.E. Brown[1]

Permafrost — Origin and distribution

One half of Canada lies in the permafrost region ranking this country second only to the Soviet Union in the area of terrain affected by this phenomenon. The term "permafrost", or "perennially frozen ground", refers to the thermal condition of earth materials — soil and rock — in which their temperature remains below 0°C continuously for at least one year. The origin of permafrost is commonly attributed to cold climate and it probably appeared during the Pleistocene. During subsequent climatic fluctuations, corresponding changes have occurred in its extent and thickness. Prediction of the occurrence and distribution of permafrost is difficult because of the complex interaction of various factors including air temperature, relief, vegetation, drainage, snow cover, fire, glacial ice cover, soil and rock type.

The permafrost region consists of two principal zones — discontinuous in the south and continuous to the north (Fig. 2.8). Within the discontinuous zone, areas of permafrost exist, together with unfrozen areas; the thickness ranges from a few metres at the southern limit to about 100 m in the more northerly areas. In the continuous zone, permafrost occurs everywhere under the ground surface and extends to depths of 1000 m in the High Arctic. The same zonation is also found vertically at high elevations in the Western Cordillera, designated as alpine permafrost.

Permafrost characteristics

layer which freezes in winter and thaws in summer. Its thickness varies regionally from a metre or more in the south to only a few centimetres in the Far North and is dependent on the same climatic and terrain factors that affect the permafrost.

A broad relationship exists between mean annual air temperature and mean annual ground temperature (Fig. 2.8). Observations have indicated that the mean annual air temperature is about 1 to 5°C lower than the mean annual ground temperature depending on local conditions; the overall average difference is about 3°C.

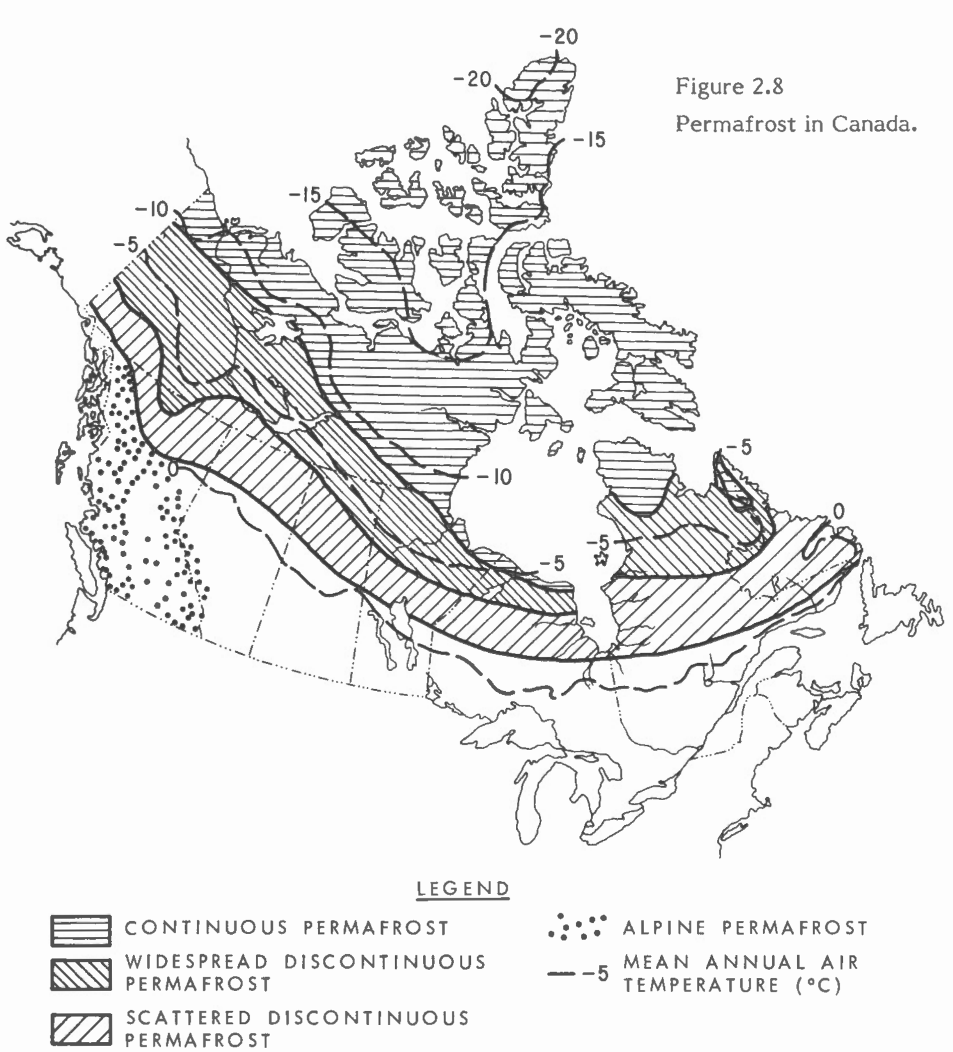

Figure 2.8
Permafrost in Canada.

Soils in the permafrost region may contain large quantities of ice which can occur in various ways ranging from coatings or films on individual soil particles and minute hairline layers to large inclusions up to several metres thick. Fine grained soils, especially silts, generally contain the largest volumes of ice, but considerable quantities may occur in coarse grained soils and even bedrock.

Engineering considerations

Although frozen soil provided excellent bearing for a structure, it may, when thawed, lose its strength to such an extent that it will not support even light loads. Substantial settlement can occur when frozen foundation materials thaw; differential movements usually result in serious damage or even complete failure of a structure. The detrimental effect of frost action in the active layer, has also to be considered. To ensure satisfactory structural performance, special steps must be taken, for example, reduce the depth of frost penetration or to replace such soil with material in which ice accumulation will be minimal.

[1]Division of Building Research, National Research Council of Canada, Ottawa, Ontario K1A 0R6.

Three features of permafrost are significant in engineering construction:

(1) Permafrost is particularly sensitive to thermal changes. Any natural or man-made change, however slight, in the environmental conditions will greatly affect the delicate natural thermal equilibrium.

(2) Permafrost is relatively impermeable to moisture. Drainage is vital, therefore, because all movement of water occurs above the permafrost; in northern areas, surface water is conspicuous despite the generally low precipitation. If natural drainage is impeded, or proper drainage structures are not provided, construction operations can be seriously complicated by intensified frost action during the winter and accelerated thawing during the summer.

(3) The ice content of frozen ground is a most important consideration. Most construction problems arise with fine grained materials and organic materials such as peat, which usually have extremely high ice contents and are susceptible to frost action. As long as the water remains frozen in such soils, the ice binds the individual particles together to produce a material with considerable strength; when thawed, however, these soils can change to a soft slurry with little or no strength.

Design and construction

The results of site investigations will indicate the approach to be taken in the design of foundations and the construction techniques to be used. Selection of suitable foundation designs is normally based on one of the following four approaches.

(1) Permafrost conditions can be neglected when structures are sited on well drained, coarse grained soils or bedrock. These materials usually contain little or no ice in the frozen condition and changes in the ground temperature regime will have little influence on their properties. Thus conventional design and construction methods are possible.

(2) The frozen condition can be preserved and utilized to support a structure. In the continuous permafrost zone, particularly when fine grained soils with high ice content are encountered, every effort must be made to preserve permafrost. This is usually accomplished by either ventilation or insulation construction techniques. The former is commonly used with heated buildings, the latter with embankments for roads, railways and airstrips.

(3) When foundation soils contain excessive amount of ice and it is not possible to preserve the frozen condition it may be convenient to thaw it and then consolidate it prior to construction. In some cases, it may be advantageous to remove and replace this material with compacted, well drained, non-frost-susceptible material.

(4) At some locations, foundation design must take into account anticipated settlement. This is particularly true in the southern fringe of the permafrost region (but also in the continuous zone) where considerable consolidation of the foundation material is to be expected and thawing of the ground is inevitable during the life of the structure.

Research needs

Although formalized programs on permafrost research began 30 years ago in Canada, there are still many unanswered questions about the fundamental and applied aspects of this phenomenon and the number of man years involved in this work is small. Research needs, ranging from the development of mapping techniques to rational design criteria for pipeline construction, are listed below:

a. Site investigations and physical properties

- remote sensing and geophysical methods to map the distribution (extent and thickness) of permafrost.
- methods to obtain and record precise measurements, in the field throughout the year, of ground temperatures and other thermal properties of permafrost.
- methods to determine other in situ physico-mechanical properties of frozen soils.
- improved understanding of freezing and thawing processes in perennially frozen soils.

b. Engineering design and operating criteria

- design criteria for building foundations and municipal services; embankments for roads, railways and airstrips.
- design criteria for warm-oil and chilled-gas pipelines.
- exploration and production techniques in mining and petroleum operations.
- building codes and land use regulations for permafrost regions.

SOIL ENGINEERING IN CANADA

Edward Penner[1]

Major engineering problem soils

There are major soil engineering problems associated with some of the more extensive geological formations in Canada. The problems are uniquely characteristic of the deposit as a whole but the harsh Canadian climate adds a further dimension to the engineering design difficulties encountered.

Canada has at least four extensive regions (Associate Committee on Geotechnical Research, ACGR, 1969) that fall into this category. These are (1) the sensitive postglacial clays deposited into the Champlain Sea (Crawford, 1968; Karrow, 1961), which occupied the now heavily industrialized area drained by the St. Lawrence River and its tributaries; (2) the over-consolidated Upper Cretaceous shales of the Great Plains area in which the major diagenic process in their formation has been the overburden pressure; (3) the highly plastic glacial deposits of the Prairies on which four of the largest urban centres are located; and (4) the varved clays of glacial Lake Barlow-Ojibway of northern Ontario and Quebec.

Other soils with engineering problems include the loessal soils (Hardy, 1950) of Kamloops area, British Columbia; the wet, open-structured, low density tills of Ungava-Labrador region (Eden, 1976) that liquefy when disturbed during construction and the black, calcareous, pyritiferous Ordovician shales that increase in volume due to biochemical weathering observed recently in Ottawa (Penner et al., 1973).

[1]Division of Building Research, National Research Council of Canada, Ottawa, Ontario K1A 0R6.

Engineering problems in the Canadian permafrost regions are unparalled in magnitude and degree of complexity (Linell and Johnston, 1973; ACGR, 1969). The perennially frozen ground condition underlies roughly one half of Canada's land mass. The terrain of Canada's North is commonly muskeg (about 12% of Canada's land mass) and has its own well-known engineering problems. Difficulties with the development of ground surface transportation (roads and railways) is a serious impediment to resource development in the North. Travel over organic terrain is usually only possible with specially designed vehicles.

1. Post-glacial clays of the Champlain Sea

The property that distinguishes this postglacial deposit from other soils is its high sensitivity (ratio of undisturbed to remoulded strength) which in the extreme condition causes the material to liquify when remoulded. The loose "card house" structure, the loss of salt by leaching, and the high natural moisture content – often higher than the liquid limit – account for its high sensitivity and large compressibility. Numerous landslide scars, which are pear-shaped craters mostly of the retrogressive flowslide type, characteristically dot the river banks and terraces of the region. Recognition of slope instability, is fraught with difficulty. Flowslides are costly in the loss of human lives and property. Recent advances, however, are thought to have improved slide predictability (Mitchell and Markel, 1974) but this remains to be proved.

Trees using excessive water, particularly during unusually dry summers, cause soil shrinkage which can never be recovered because soil structure collapse is not reversible. For new areas, trees that are inherently small or those that do not transpire excessively should be used for new plantings.

2. Clay shales of the Great Plains

Shales of the Great Plains have significant amounts of montmorillonite-type clays as well as other clay-sized particles. Ice recession and extensive erosion has unloaded these materials and with the reduced overburden, and the physical and chemical weathering processes that dissolve cementing agents, has resulted in stress releases and expansion. The ensuing pressures cause soil slumping along river banks in addition to slope and foundation instability (Hardy, 1957).

3. Glacial lake clays of Western Canada

The volume of the lacustrine clays is very moisture dependent because of their mineralogy. Hence the environmental factors that cause moisture change, control swelling and shrinking. Much of the damage that has been reported involves, for example, small structures, private dwellings, and schools, but dams and spillway structures have also been damaged.

In basement excavation for domestic dwellings more weight may be removed from the site than is replaced by the structure. These stress reductions permit some rebound and are thought to be a part of the swelling problem. For shallow-founded structures success depends on keeping moisture and stress conditions in the "before constructed" state.

For deep foundations, where moisture changes are small, volume changes are small also. Thermal changes around structures (e.g., heat losses from basements) induce thermally activated diffusion of moisture. Unsaturated soils have a propensity for such movement (Hamilton, 1965). Moisture changes mean clay volume changes and the racking and distortion of structures.

4. Varved clays of northern Ontario and Quebec

The identifying characteristics of varved clays (Antevs, 1951) are the alternating layers of silty clay, silt and clay. The layers vary in thickness depending on conditions during sedimentation. The variability of the laminar structure is an added dimension upon which anisotropy is superimposed. Some varved clays also liquify easily when disturbed. Characteristically, alternate layers are different in particle size, mineralogical composition, structure, and permeability. Despite such complexities reasonable agreement has been found between bearing capacity calculated from in situ vane strengths and the average bearing capacity applied by the structure (Eden and Bozozuk, 1962). Careful sampling and analysis for design purposes have been used with success. Greater attention is usually given to factors of safety where hazards to lives and property are involved.

Engineering properties and soil classification

Many soil engineers make good use of available pedological and geological soil survey data before undertaking any major soil exploration study. Pedological survey maps have been used to good advantage in Ontario for highway engineering since 1945 (Rutka, 1961). Soil survey and geological maps have also been used extensively to locate much needed granular deposits for construction purposes. Frequently, however, the information available from both geological and pedological survey sources has been less than satisfactory for engineering purposes.

There are numerous papers in the literature that describe how pedological surveys can be interpreted for maximum effectiveness in soil engineering (e.g. Felt, 1950; Aitchison and Grant, 1968; Bodman, 1949).

In the past the pedologist has given precedence to classical pedological factors, such as morphological features, and the physical and chemical aspects of soil fertility as related to plant growth. On the other hand, the geologist needs basic information about parent materials. Some recent examples where both geological and pedological surveys have served the broader need of earth science are given by Presant and Wickland (1971), Christiansen (1970), and Prest and Hode Keyser (1962). The approach has proved to be so useful to soil engineering that it would be unfortunate if future soil surveys were not planned for multidiscipline use.

Field identification and classification for engineering purposes

The engineering behaviour of soils is dependent on certain physical properties that are readily identified in the field. It is logical, therefore, that these should form the basis for the field engineering classification of soil.

The field identification and classification of soil for engineering purposes would constitute the major desirable addition to the current standard pedological and surficial geological surveys. It would be useful to include other types of information, such as depth of overburden (depth to bedrock), depth of the water table and its seasonal variation, the ground surface drainage and seepage conditions. The importance and the type of additional information required would vary with location and conditions and should be selected by consultation between interested parties.

It is hoped that the much-needed co-operation, discussion and communication between the three geoscience disciplines, pedology, geology and soil engineering will ensue and that those charged with the organization of pedological and geological surveys will find the additional engineering requirements can be included in their field programs. On the other hand, those agencies responsible for the engineering aspect of soils will have to assist with the planning of survey programs and provide the necessary additional support.

Research needs

The committee charged with the Background Study for the Science Council of Canada, 1971 Special Study No. 13, Earth Sciences Serving the Nation, made the recommendations listed below regarding research needs in geotechnical field. The author believes these still apply in 1977. A further recommendation was that in future geotechnical R and D the emphasis on research should be those aspects pertaining to resource development, transportation and urban and regional development especially in the Canadian North.

Resource development:

- slope stability studies;
- economic methods of land restoration;
- strength/deformation characteristics of earth materials;
- guides of practice for earth material excavation;
- rapid permafrost exploration methods;
- groundwater movement and storage.

Transportation:

- inventory of granular material resources;
- beneficiation of earth materials for construction;
- development of technology for construction in permafrost areas;
- minimization of frost action in subgrades;
- terrain/vehicle trafficability in muskeg and soft ground.

Urban and regional planning and development:

- geological studies and mapping in urban areas;
- development of earth science data storage and retrieval systems;
- increased public awareness of the economic value of earth science data and methods in the abatement of natural hazards;
- development of national methods of earthquake risk evaluation;
- hydrodynamic and geochemical implications of surface and subsurface disposal of wastes.

Note: The items underlined are considered by the author to be priority items at this time.

An important conclusion reached by the same 1969 study group was that R and D support for the geotechnical field was too low. The specific recommendation was that by 1985 the level of annual R and D support should have increased by a factor of four to $15 million and this in part should come directly from industry through tax-incentive programs.

Analysis of the NRC research grants to the universities in the geotechnical field shows that support rose dramatically from a modest $40 000 in 1960 to $600 000 in 1969. The demand for research funds decreased steadily during the next 5 years until only $500 000 was granted in 1974. The total funds for all the Earth Sciences under which most geotechnical research falls, had in these five years increased by about $1 million. It is to be noted that the NRC Associate Committee on Geotechnical Research had recommended in their 1969 brief to the Science Council that immediate attention be given to the encouragement and development of training of scientific and technological personnel in the fields of muskeg, permafrost, snow, ice and rock. This would seem to be an obvious response to the decreasing demand for research funds in all fields of geotechnique but to a lesser extent in soil mechanics.

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SOILS IN GEOCHEMICAL PROSPECTING

G.J.S. Govett[1]

Measurement of the trace element content of residual soils is used in many parts of the world as an exploration technique to detect economic mineral deposits in the underlying bedrock. This technique of soil geochemistry (or pedogeochemistry as it is sometimes called) has been successful even where the residual soil is as much as 50 m thick. The usefulness of geochemical soil surveys for mineral exploration in Canada is circumscribed by the fact that about 97 per cent of the land surface was beneath ice during the Quaternary. As a consequence, about 90 per cent of Canada is blanketed by glacial debris; this is the parent material of Canadian soils. In many areas of Alpine-type glaciation (and also in areas of continental-type glaciation) where the thickness of glacial material is not too great and is locally derived, anomalous element contents may still be detected in surface soils close to a buried mineral deposit – although the anomaly may be displaced in the direction of ice movement.

Where the glacial material is of exotic origin – particularly where it is glacial outwash or varved clay – conventional geochemical responses are not forthcoming. In addition to this fairly obvious problem Tilsley (1977) has drawn attention to the widespread occurrences of relic and active placosols; material above the placon is depleted or totally devoid of detectable base metals so that a mineral deposit as little as 1 to 1.5 m beneath the surface cannot be detected (Tilsley, 1975). On the positive side, it has been found that in areas of permafrost – long thought to be chemically inactive – weathering does in fact occur and is probably particularly active around exothermally oxidizing sulphide bodies. Realization of this has led to the successful application of exploration soil geochemical surveys in permafrost areas (Cameron, 1975).

Despite the problems of glacial overburden, soil geochemistry has been used in Canada and has been relatively successful in the Appalachian and Cordilleran regions. However, as a generalization, conventional geochemical responses to mineralized bedrock in surface soils derived from exotic or very thick glacial debris is faint or nondetectable. Exploration geochemists have tackled the problem in essentially two ways: by ignoring topsoil horizons and analyzing samples of till (especially deep, basal till); and by attempting to isolate and measure geochemical responses in surface soils that are specifically related to underlying mineralization. The latter approach is obviously preferable, from an economic and operational point of view, to having to dig or drill for deep till samples. It demands, however, a far better understanding of the processes of element migration from bedrock sources and fixation in soils than is presently available.

The general considerations for the development of suitable exploration geochemical techniques to be used on surface soils are applicable to both residual and transported soils and have been well stated and illustrated by Bradshaw et al. (1974). These considerations are: recognition of differences in distribution of elements in a vertical soil profile between background and mineralized situations; recognition of groundwater and internal drainage effects; and recognition of differences in bonding of elements as a function of their history of migration and fixation. Bradshaw et al. (1974) lay particular stress on the efficacy of different extraction techniques (e.g. measurement of EDTA-soluble or cold, dilute HCl-soluble elements) on soil samples to preferentially extract that fraction of an element that has migrated in solution in response to the presence of mineralization.

These, and other similar approaches, have failed to provide a technique that gives a response in surface soils overlying impermeable varved clay, nor have they succeeded in providing unequivocal guides to interpretation of geochemical responses in surface soils derived from glacial debris in more favourable circumstances. A theoretical study of the problem by Govett (1973, 1975) in Canada and by Bølviken and Logn (1975) in Norway suggested that element dispersion into soil from a conducting orebody may be influenced by electrochemical reactions. Field tests indicated that the electrochemical effect could be most readily detected by movement of the ubiquitous and mobile H^+ in surface soils (Govett, 1976); subsequent work (Chork and Govett, 1977) on B-horizon soils in a variety of situations, including those where an underlying impermeable varved clay is present, has indicated that not only does H^+, but also organic carbon, tend to have a characteristic distribution pattern over deeply buried mineralization; this pattern is interpreted as a response to variations in current density around a conducting sulphide body.

The distribution of trace elements in soils is a complex function of parent material, local climatic and geomorphological conditions, and also organic reactions. It is obvious that unless these processes are fully and completely understood by the exploration geochemist, it is not possible to predict how underlying bedrock will be manifest in the overlying soil horizons. Thus, it may not be possible to determine what elements to measure, what analytical techniques to use, or what response to expect that would be best suited to detect buried mineralization in any particular situation. As far as the exploration geochemist is concerned, the pressing need is for information on the processes of trace element migration and fixation in soils; much of this

[1]Department of Geology, University of New Brunswick, Fredericton, New Brunswick.

fundamental information for normal, nonmineralized conditions is probably already known and available to the soil scientist. Insofar as the soil scientist is primarily interested in normal, background conditions and the exploration geochemist is interested in departures from equilibrium caused by mineralization, there is obviously enormous scope, indeed a necessity, for close interdisciplinary study.

Research needs

Joint soil science and exploration geochemical research would be most fruitful and economic if both facets were pursued in the same institution; this obviously limits the possibilities to those institutions where there is a strong capability in both disciplines. A useful approach would be for soil scientists to work with a group of exploration geochemists in the Geological Survey of Canada for a five-year period to specifically investigate the physical, chemical, and organic controls of element dispersion in soils from a mineral exploration viewpoint. Additional funds should be assigned, again for a five-year period, for the support of a number of regional investigations in universities willing and capable of undertaking interdisciplinary studies. A realistic cost for a five-year project of this type (exclusive of the principle investigators' salaries) would be about one million dollars. Although the objective of the research would be to develop a reliable exploration soil geochemical technique to use in the glaciated terrain of Canada, it is obvious that the data generated would have wide-ranging applications in problems of agriculture, forestry, human health, and the environment.

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SOILS IN ARCHAEOLOGY

N.W. Rutter[1]

During the past ten or fifteen years archaeologists have increasingly used soils as an aid to solving archaeological problems. As archaeologists are concerned with all aspects of man's evolution, it is natural that they should turn to ancient soils or paleosols to elucidate more fully the environments that man was subjected to through time. As a consequence, archaeologists are relying on paleosols, both buried and on ancient surfaces, found within, and in the area of archaeological sites. In addition, paleosols are utilized as time lines in stratigraphic correlation, to determine local terrain conditions, to obtain ^{14}C, and for extracting opal phytoliths for vegetation studies.

Two factors that have contributed significantly to the greater use of paleosols in Canada are the advent of interdisciplinary investigations and independent university archaeology departments as opposed to a division or a group within another department. A major impetus for the first factor was the conference held in Edmonton in 1969 entitled "Pedology and Quaternary Research" sponsored by the Associate Committee on Quaternary Research, National Research Council of Canada. The Conference, and later the proceedings, alerted many workers to the potential value of soil studies in their research. This, coupled with the growing awareness of the value of interdisciplinary studies by various groups of earth scientists on a variety of problems acted as catalysts for archaeologists to learn more about soils and include soil scientists in their field investigations. It would be safe to say that in Canada today most archaeologists in the field are on the lookout for paleosols and continue to increase their successes in identifying "real" paleosols. Whether or not a soil is properly sampled and identified is another story and will be dealt with later.

The second factor, that the independence of university archaeology departments results in a greater use of paleosols by archaeologists, could be debated. However, archaeologists use and rely on methods and techniques employed in many facets of earth science. In archaeology departments, there generally is more freedom for students to elect more courses applicable to solving technical and field problems – such as a course in soil science or geology. When archaeology is a subject in another department, most commonly anthropology, the students have less chance to elect earth science courses because of requirements necessary for a degree in that department. Further, it is usually easier for archaeology departments to staff their departments with specialists in other facets of archaeology or in some other contributing science than in say anthropology departments, where these specialists may have lower priorities. One university that

[1]Department of Geology, University of Alberta, Edmonton, Alberta T6G 2E3.

comes to mind is Calgary, where the archaeology department not only offers a number of interdisciplinary courses but brings in experts in various fields to teach these courses. For years they have offered courses in soil classification, invertebrate paleontology, Quaternary geology and airphoto interpretation.

At the present time then, the archaeological community is aware of the value of paleosols and is pursuing their study. One important practical problem facing many archaeologists is distinguishing between sediment stratification, subsurface weathering and paleosol horizons in the field. This may seem routine to a soil scientist but to an archaeologist with perhaps only one course in soil science, and a limited amount of field experience, it may represent a real challenge. The more prudent archaeologist will call in an expert. Others, feeling confident with their one or two course background and their association with soil scientists, choose to do their own identification, classification and interpretation, commonly with disastrous results. In other words, a little knowledge may be a bad thing. As an extreme case, one recalls the archaeologist who identified a buried Brown Chernozem from the presence of Ah, Bm and Cca horizons. Later the horizons were properly identified by a soil scientist as a detritus peat bed, loess, and a volcanic ash layer respectively. This is not to imply that archaeologists are incapable of working with soils – many are becoming competent and a few know the business better than many soil scientists.

Another problem is the proper sampling of the soil horizons. Once the archaeologist knows he has a soil, it must be sampled for later laboratory work. If he is unable to obtain the services of a soil scientist in the field, he has no choice but to sample this soil himself. Commonly, the archaeologist is at a loss in sampling procedures to insure proper identification and interpretation. Proper sampling techniques may be the weakest link today in the archaeologists "soil education".

It is apparent that soil scientists are playing an important role in archaeology but have an opportunity to play a much greater role. Needless to say archaeologists should and do welcome the participation of soil scientists. To encourage this further soil scientists in universities should offer formal soil courses geared to archaeologists. As archaeologists are mainly interested in the climatic and ecological implication of paleosols and their recognition, the course should be strong in pedogenesis and classification, and laboratory and field techniques. Another formal course that would be desirable, but may be harder to implement, is one dealing with the use of paleosols in reconstructing past events. This would require a staff member whose research interest is in paleosols working with the archaeological staff.

Perhaps more important than formal courses, is the active participation of soil scientists in all phases of an archaeological project. This would include field investigations, sampling and laboratory work and interpretation of the data. Only with this sort of assistance will we ensure high quality results. If soil scientists show little interest in co-operating, archaeologists will be forced to carry out the investigations themselves. We all know that in this day and age it is difficult enough to master one science to say nothing of two.

PALAEOSOLS IN CANADA

John F. Dormaar[1]

Palaeopedology, the study of soils that have formed in landscapes of the past, is often caught between two disciplines. Pedologists (Yaalon, 1971) are usually concerned with relict or residual features that indicate a change in the environmental conditions during the development of the soil. In contrast, geologists use palaeosols as stratigraphic or relative-time markers. Also, palaeosols assist in interpreting the climatic conditions and fluctuations of the glacial and interglacial ages by providing qualitative information in the reconstruction of Quaternary environments. To be useful as a stratigraphic unit, however, a palaeosol must have lateral continuity. Christiansen (1965) used dates obtained from soils, wood, and charcoal to delineate positions of ice fronts in Saskatchewan. Quaternary research studies can thus provide much useful background information for the study of palaeosols.

Palaeosols can be divided into relict soils and buried soils (Ruellan, 1971). Relict soils possess certain characteristics that are the outcome of pedological environments that differ from the present. In this paper, palaeosols are always considered to be the buried variety.

Palaeosols are studied by the same methods as are used to study present-day soils. For example, a reddish brown B horizon may have belonged to a Chernozemic, a Brunisolic, or a Gleysolic soil; and analysis for an extractable Fe would be required to determine which origin is correct.

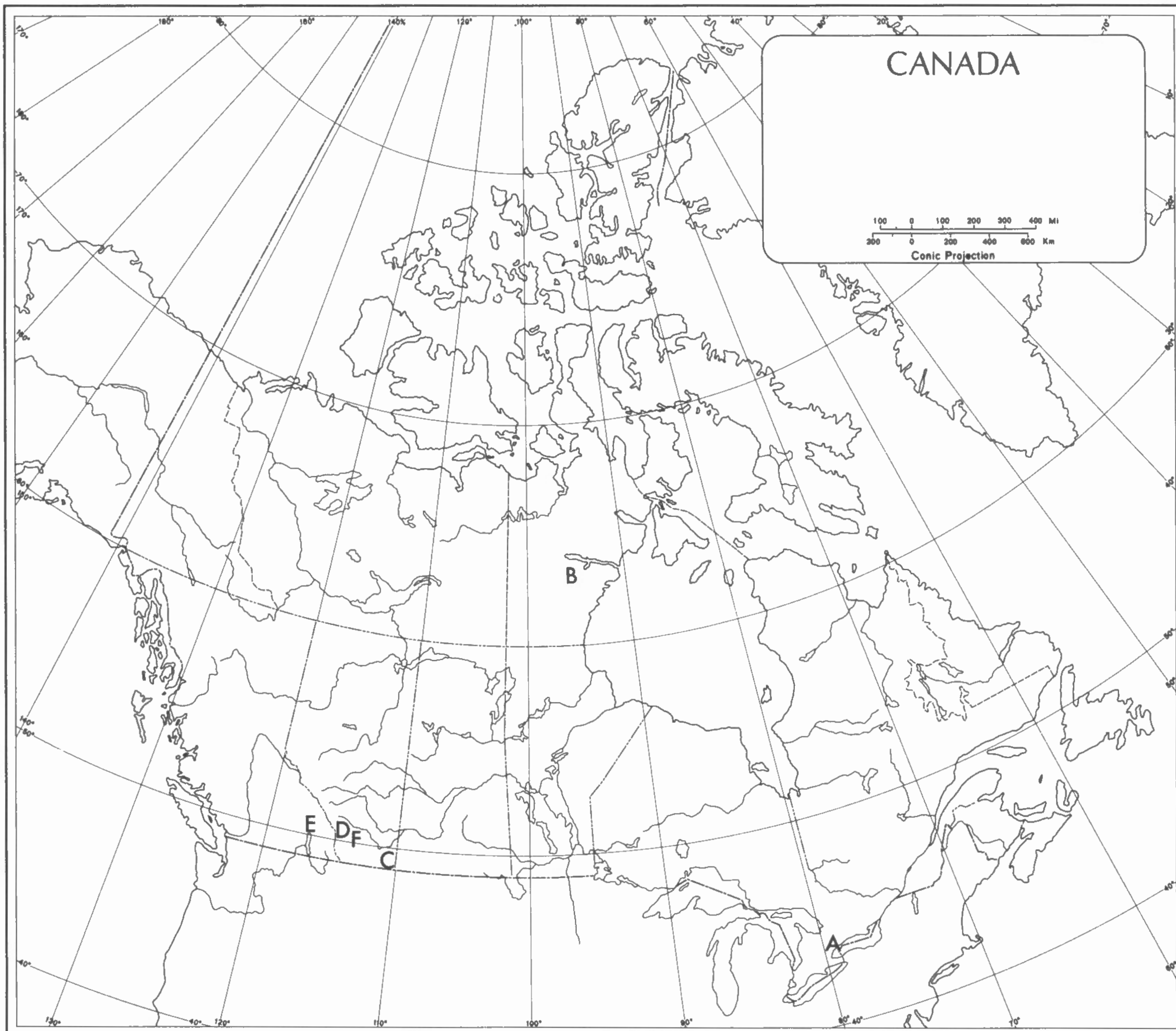
Degradation of organic matter does not cease after burial; yet, no fresh C is added. Many post-burial events may change the properties of the soil. It is, therefore, necessary to establish what are the fundamental and stable properties of soils. The examination of certain micromorphological features has often been useful in this context.

The use of fossil soils in the reconstruction of Quaternary environments is thus difficult because of the complex factors that comprise the soil forming processes (Yaalon, 1971). Therefore, examples will be given of several specific studies where palaeosols have aided the interpretation of events in Canada.

The excavation for the Rapid Transit Subway of Toronto, Ontario (Fig. 2.9A), revealed almost every Pleistocene formation to be seen in the area (Watt, 1954). It was suggested that a soil profile, leached to a depth of 1 m and preserved under the lowest Wisconsinan till, was formed in Sangamonian Interglacial time (Don Formation) on an uplands with stratified beds overlying the Illinoian till. If so, this would indicate that the highland above Lake Iroquois shoreline (ca. 11 800 to 12 500 y B.P.) existed before the Wisconsinan glaciation.

Knowledge of the interaction between soil/vegetative associations and air mass characteristics allows for a reconstruction of the geographic stability of the forest/tundra boundary (Fig. 2.9B) from information recorded within the morphology of palaeosols that have formed during the postglacial period in north-central Canada (Sorenson and Knox, 1974). Palaeosols in this area indicated that the position of the forest/tundra border has varied from its present position at least six times during the late Holocene, from 280 km north of the present forest border to 50 km south. Major northward migrations of the forest occurred after 2900, 1800, and 800 years B.P. Southward movements of the forest border were recorded at about 3500, 2600, and 1600 years B.P. The palaeosols suggested that palaeoclimates were not much different than today's climate in the area. It was further suggested that the frequency of cold, dry

[1]Soil Science Section, Agriculture Canada Research Station, Lethbridge, Alberta.



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A. Toronto, Ontario
B. Mackenzie and Keewatin, Northwest Territories
C. Cypress Hills, Alberta
D. Front Range of the Rocky Mountains, Alberta
E. Kootenay Lake area, British Columbia
F. Southwestern corner of the Prairies

Figure 2.9. Palaeosol sites in Canada. Location of the areas discussed in the text.

conditions in summer was a critical factor in limiting the northward migration of forest.

After the last glaciation, there was a period of erosion and deposition of colluvium and alluvium in the Cypress Hills (Fig. 2.9C) in the southeastern corner of Alberta (Jungerius, 1969). This was succeeded by a long period of erosional stability and soil formation. Radiocarbon dates for this period range from 4300 to 3600 years B.P. Comparison of a buried soil and the modern soil at the same site shows that climatic conditions during most of this period were somewhat more humid than they are today. Towards the end of this period of landscape stability, aridity increased. A Gray Luvisol was developing into a Chernozemic soil before it was buried beneath slope wash. Most humus was of the anmoor type, which is formed under relatively humid conditions, but in the final stages before the soil was buried only humus of moder type was produced. The present climate favors the return to forest.

Salvage excavations at an archaeological site located in the Front Range of the Rocky Mountains in southwestern Alberta (Fig. 2.9D) revealed the presence of a series of living floors, radiocarbon dated at ca. 6060, 6720, and 8000 years B.P., in association with the Ah horizons of a series of buried soil profiles (Reeves and Dormaar, 1972). Analysis of the buried soils indicates that they formed under vegetative cover and climate that differed from that at the site today. The earliest soil, a Degraded Alpine Eutric Brunisol, inferred to have developed under subalpine to alpine vegetation and a cold wet climate, suggested depression of the timberline in the order of 600 m. These climatic characteristics were considered to reflect those of the last valley glaciation. The two later buried soils, Orthic Regosols, developed under grassland vegetation reflective of a drier warmer climate, indicating the lower tree line shifted upwards a minimum of 30 m. A return to 'normal' climatic conditions was correlated with the onset of the Neoglacial dated ca. 4700 years B.P. in the southern Alberta Rockies.

Olympia Interglaciation deposits are exposed in a borrow pit north of Kootenay Lake, British Columbia (Fig. 2.9E). The section consists of an upper sequence of deposits and a lower sequence. These sequences were separated by an unconformity. Below the unconformity, an A, B, C palaeosol had developed on deposits of the lower sequence. A radiocarbon age of 41 900 years was obtained from roots embedded in the A horizon. Radiocarbon dates from outside the immediate study area indicates that the ice, which deposited the till in the upper sequence, did not advance over the area until after 20 000 years B.P. and had retreated from the Purcell Trench before 10 000 years B.P. (Fulton, 1968). The palaeosol was used to explain the regional chronology.

Canada in the Quaternary cannot be described on the basis of palaeopedology alone. Co-operation with disciplines such as palaeobotany, stratigraphy of Quaternary deposits, and archaeology will be necessary. Many studies are fragmentary in terms of the continental record. However, efforts are being made to provide a card index from the information collected by various disciplines. It has been possible, for example, to establish a chronological sequence of Late Quaternary environmental changes in most of the major geographical regions of Canada (Terasmae, 1974). Prest (1969) prepared a general pattern of retreat of the Wisconsinan ice sheets in Canada. Ritchie (1976) assembled a comprehensive account of the late Quaternary vegetational history of the western interior of Canada.

A synthesis of the Quaternary of the Prairies is being prepared under the auspices of the Associate Committee on Quaternary Research of the National Research Council of Canada. There is an interesting set of events in the southwestern corner of the Prairies (Fig. 2.9F) that should be included in this synthesis.

A distinct Ah horizon, often 25 cm thick, underneath a layer of tephra (Mazama, deposited ca. 6600 years B.P.) is present at numerous locations. Its radiocarbon age is around 6800 years B.P. The Mazama tephra are usually found in waterlaid deposits. Between 8000 and sometimes after 6600 years ago there must have been a period of instability and movement of much material because there is often a deposit of up to 3 m over the tephra layer. Yet, the present river levels are up to 70 m below the present prairie level. It has been suggested that the last valley glaciation in the mountains just west of the area terminated either about 8000 years (Reeves and Dormaar, 1972) or 6200 years B.P. (Stalker, 1969). The widespread Ah horizon may thus be related to the cooler conditions and an early version of the boreal forest as described by Ritchie (1976) and Terasmae (1974) present at that time. The Atlantic climatic episode dating ca. 8000 to 5000 years B.P. followed the retreat of this last valley glaciation. Reeves (1973) noted that periods of alluviation in the Upper Saskatchewan Basin occurred at ca. 8000 and 5000 years B.P. at the beginning and close of the Atlantic climatic episode. These are separated by a major erosional interval in which the streams degraded their floodplain. The alluviation at the end of this episode deeply buried the emergent floodplain again.

Research needs

The identification and characterization of palaeosols may provide useful information for some other earth science disciplines. It would appear that most pressing needs are:

1. establishment of criteria for the recognition of palaeosols;
2. analytical techniques appropriate;
3. appropriate analytical techniques to determine the particular properties of these soils;
4. evaluation of inferences which may be drawn from the results of laboratory and field analyses;
5. maintenance of contact with other earth and environmental scientists to ensure a recognition of the value of research in palaeosols for their particular discipline.

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SOIL SCIENCE EDUCATION IN CANADA

R.J. St. Arnaud[1]

The following dissertation attempts to evaluate the present status of soil science education at the university level in Canada. It is based largely upon personal experience, supplemented by available information of university programs as well as by responses to questionnaires sent out specifically for this study. It provides but an initial appraisal of the subject which it is hoped will promote more thought on Canada's needs in this area of knowledge.

Soil science falls within the broad field of the earth sciences. As such, it is closely related to, yet apart from, other disciplines such as geology, geography, ecology and soil mechanics. Traditionally in Canada, soil science has been closely related to agriculture, although the basic knowledge in this field is essential to several disciplines. The affiliation between soil science and agriculture has arisen largely as a result of circumstance. In the early days of this country's development the need for detailed information as to the nature, distribution and capabilities of our land resources was first felt and responded to by agriculturalists.

Marked differences in the levels of instruction are evident in the teaching of soil science at Canadian universities. The subject is generally taught in considerable depth within agricultural faculties, but is either ignored or dealt with in a cursory manner by most other faculties, except in cases where trained soil scientists have been taken on staff. Even then the situation is not always entirely satisfactory because such specialists often feel isolated from the mainstream of pedological activities. The Canadian Society of Soil Science has promoted continuous contact amongst soil scientists working in various disciplines. It has also attracted membership from workers who do not have, but feel a distinct need for, a soils-oriented background. A closer look at the teaching of soil science in Canada will focus on existing programs and the adequacy of these in meeting society's needs.

Soil science taught within agricultural colleges

At the seven universities offering programs leading to degrees in Agriculture (British Columbia, Alberta, Saskatchewan, Manitoba, Guelph, Laval and McGill (Macdonald College)), soil science is taught by soil specialists, and strong soil science departments have been traditional. There are several reasons for this.

1. Agriculture has always been, and continues to be a major user of soils information; its needs have been and are presently being met by pedologically-oriented departments.
2. The traditional acceptance by agricultural faculties of the concept that teaching, research and extension are mutually essential has always kept soil specialists in close contact to soils-related problems.
3. Soil survey units, staffed by professional pedologists, have been located at agricultural universities, usually as a part of, or closely allied to, the Soil Science Departments. A formal recognition of this long-standing association is reflected in the recent establishment of formal institutes of Pedology in at least three provinces.
4. The system of classification of soils in Canada, essential for the application and dissemination of soils information, has been developed by the Canada Soil Survey Committee which consists of pedologists representing university soil science departments and both provincial and federal soil survey units across Canada. This has provided a close link between the soil taxonomists, the mappers, the researchers and the teachers of soil science at these universities.
5. A major portion of the soil science research conducted in Canada is done within agricultural faculties even though a significant part of this is basic research and applies, not only to agriculture, but also to other disciplines.

Examination of the soil science courses taught about 13 years ago indicate that in all agricultural faculties the following basic undergraduate classes were a standard part of teaching programs: (1) Introductory Soils, (2) Soil Chemistry, (3) Soil Physics, (4) Soil Microbiology, and (5) Soil Genesis and Classification. Since then, most soil science departments have expanded their course listings to permit specialization in various aspects of the field and to promote application of the technology to modern problems. A present day listing of soil science courses now available to agricultural students and to those of other faculties located on the same campus include the following:

A. *Undergraduate Classes.*

1. Introductory Soils (for Agriculture students)
2. Soil in Man's Environment (for non-Agriculture options)
3. Geography of Soils
4. Soils in Natural Resource Management
5. Forest Soils
6. Agroecosystems
7. Microbial Ecology
8. Soil Biology
9. Soil Chemistry
10. Soil Physics
11. Biometeorology
12. Soil Classification
13. Use of Soil Survey Information
14. Methods of Soil Analyses
15. Surveying Methods (Field class)
16. Photo Interpretation
17. Soil and Water Conservation
18. Soil Fertility
19. Soils for Agricultural Use
20. Irrigation and Drainage
21. Resource Management
22. Land and Water Use in Tropical Countires
23. Problems in Land Resources
24. Soil biochemistry
25. Soil in Planned Environments
26. Special Problems in Soils

B. *Graduate Classes.*

1. Soil Classification and Genesis
2. Soil Geography
3. Clay Mineralogy
4. Current Research in Pedology

[1]Department of Soil Science, University of Saskatchewan, Saskatoon, Saskatchewan.

5. Soil Physics
6. Advanced Soil Microbiology
7. Chemistry of Soil Organic Matter
8. Physical Chemistry of Soils
9. Advanced Soil-Plant Relationships
10. Soil Fertility and Fertilizer Use
11. Principles of Scientific Research
12. Instrumental Techniques
13. Special Topics

While not all of the above courses are available at all of the agricultural colleges, it can be said that the number of courses taught has increased significantly during the last decade or so. This increase reflects the attempts of agricultural faculties to realign their courses to meet present-day demands. In some cases, departments have changed their names from Soil Science to others such as Renewable Resources (Macdonald College) or Land Resource Science (Guelph) to indicate the broader scope of their activities, particularly in aspects of land use and of the environment. At the postgraduate level, similar changes in the number and scope of classes offered are also evident. In certain areas which have not been covered adequately in other disciplines (e.g. clay mineralogy, soil microbiology) soil scientists have taken the lead in both research and teaching.

By the early 1950s university enrolments across Canada returned to normal following the high attendance of the postwar period. Since then, the number of students graduating from Colleges of Agriculture has gradually increased. The trend at the author's university (Fig. 2.10a) is considered typical of the situation across Canada. It is noted that about 12 per cent of the graduates are specialists in Soil Science (Fig. 2.10b) although the plotted data is suggestive of a cyclic trend demonstrated by decreases in this proportion from 1951 to 1965, an upswing in the 1966-67 period, and a decrease since then. The number of graduate and

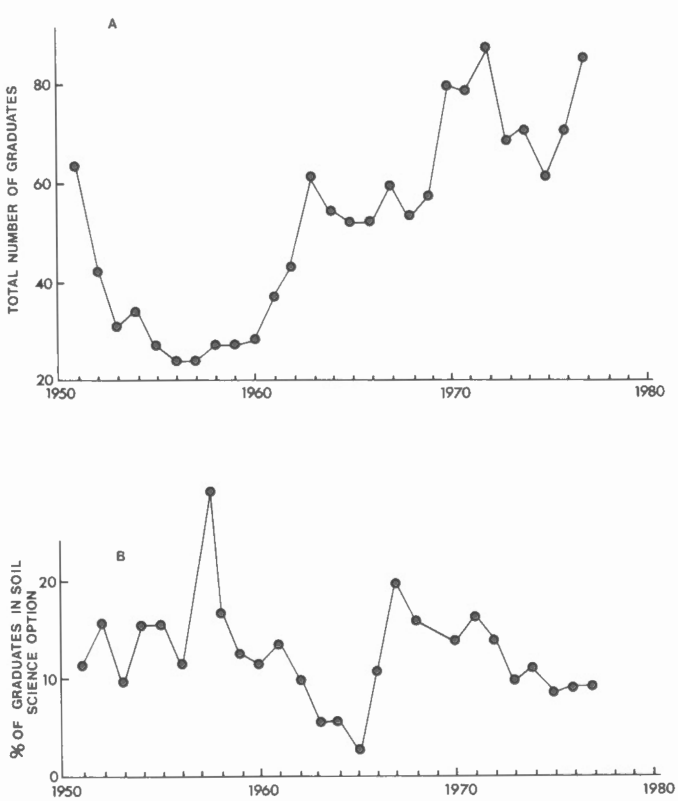

Figure 2.10. Graduates in agriculture.

postgraduate degrees awarded to soil specialists at Canadian universities during 1975 and 1976 are provided in Table 2.10. Present enrolments of soil specialists in graduate schools are lower than usual and reflect the decreased demand for graduates by both government and industry over the last few years.

Soil science taught in nonagricultural colleges

At universities which do not have a College of Agriculture as part of their structure, various departments such as Geography, Geology, or Earth Sciences incorporate some aspects of soil science in their courses, even though they do not generally give courses in Soil Science per se. A questionnaire sent to 25 nonagricultural universities in Canada brought 18 responses; of these only three departments (Geography) taught courses dealing specifically with soils. These departments had qualified pedologists to teach such courses. All the others offered no specific soils courses, even though many of them offered options in land use, resource management, environmental studies or other land related study areas. Emphasis is given to the geographical, sociological and economic aspects. Responses from ten of these departments deplored the lack of soil science teaching within their faculties or universities. Several suggested that soil science should not be restricted to agricultural colleges but would have just as significant a role to play in other faculties. All were agreed that a basic knowledge of soils is essential to land use and environmental studies. While such views should be somewhat gratifying to soil scientists, it is nevertheless disconcerting that on some campuses in Canada where the courses are available (through College of Agriculture faculties) only minimal use is made of them by other colleges offering land and resource management options.

There may be several reasons why students in colleges other than colleges of Agriculture do not take advantage of soils courses as electives in programs related to land or environment. In many cases they do not have the necessary basic science background classes (biology, chemistry, physics) which are prerequisites. Lack of appreciation of the usefulness of such courses to their field of specialization may be another reason. Most often, however, it is likely related to the fact that the choice of elective classes is limited, or restricted by the nature of the compulsory courses required in the programs. Even though some of the nonagricultural classes within these programs may include some phases of soil science, very often they lack the required depth for a full understanding of the subject and its significance to the fields in question.

Present status of soil science

In recent years, Soil Science has become increasingly sophisticated. In developing as a science in its own right, it has extended the boundaries of chemistry, physics, biology and geology. Through application of modern technology it has delved into the unknown areas of the soil system and led the way in developing an understanding of its many facets. Through remote sensing it has enhanced the capabilities of carrying out soil and land inventories in both settled and remote areas. By development and application of isotope methodology it has thrown light on organic matter turnover rates and the cycling of nutrients within the soil-plant system. It has brought forth an understanding of the factors affecting soil degradation and conservation, of the soil properties affecting plant growth and of the complex physico-chemical reactions related to the organic and inorganic fractions of the soil. While these advances in knowledge are being incorporated into existing and new soils courses, such courses are, in essence, available mostly to soils specialists and are not benefiting those in other disciplines who could usefully apply the knowledge to their own advantage. The

Table 2.10

Specialists in Soil Science graduating from Canadian universities in 1975 and 1976*

Institution	Bachelors		Masters		Ph.D.	
	1975	1976	1975	1976	1975	1976
British Columbia	9	4	4	4	2	6
Alberta	7	7	1	2	1	0
Saskatchewan	4	5	2	6	0	1
Manitoba	2	3	3	1	0	1
Guelph	3	1	7	4	1	3
Macdonald College	3	4	2	2	0	0
Laval	2	9	2	0	0	0
TOTALS:	30	33	21	19	4	11

*Data supplied by individual departments.

blame, in part at least, must be accepted by soil scientists who have led the way in soil research and in its application to agriculture, but have failed to promote the full application of their knowledge to other fields.

Future needs

More and more, society is demanding that governments and research agencies look closely at the uses of land and the state of our environment. There is a need for policy makers who are capable of dealing with these issues in a rational and informed manner. Yet many graduates from universities who will be dealing with these matters in administrative or advisory capacities will have little appreciation of the milieu in its physical entirety unless significant changes are made in their training. While they need not become soil scientists in the strict sense, they must at least have a clear understanding of the soil system with a full appreciation of the soil-vegetation-landscape-climate interrelationships.

There are several avenues open to providing nonagriculturalists with an improved appreciation of the soil-environment system. One is to infuse more soil science information into existing courses. This is being done to some extent already, without too much success. Another alternative is to increase the number of soil science courses within existing options. This would require an in-depth reappraisal of options and associated course requirements. In some cases, addition of staff with a soil science background would be required; this could be difficult in view of the present financial limitations faced by most universities. This approach would have definite possibilities on campuses where colleges of Agriculture are already present. Even so, rivalry between disciplines or colleges often makes the full implementation of interdisciplinary teaching programs difficult. It is time that university faculties recognize their responsibilities to society and make every effort to develop the truly interdisciplinary programs required.

Another development in many universities involves the trend for biology, chemistry, geography and other Arts and Science graduates to pursue advanced studies (leading to M.Sc. or Ph.D. degrees) within soil science departments. This trend has partly developed as a result of the lack of job opportunities for graduates in some Arts and Science options, but also from a desire of such graduates to find an application for their previous training, or to meet a deficiency in their training in land — or environment — related fields. Students pursuing this route are required to take background soil science classes, but the former requirement that they also take the fundamental agriculture classes (crop science, animal science, horticulture, agricultural economics, etc.) is now being waived in most universities.

Basic courses in soil science will continue to be a requirement for agriculture students, regardless of their area of specialization. An observed reintroduction or renewed interest in agronomy options within agricultural colleges will produce specialists in the soils-crops-economics area. In addition, there will still be need of graduates specializing in various phases of soil science.

Responses to the questionnaire, referred to previously, indicated a number of concerns from university teachers requiring soil science information for their classes. Many deplored the lack of a textbook dealing with Canadian soils. Also, those who were concerned enough to try to keep abreast of the system of soil classification for Canada were frustrated by the continual changes being made to it and the usual "out-of-print" response received from the publishers. Presumably a revision of the classification system presently in press will be available without modification for several years. A recent (1977) publication, 'Soils of Canada', prepared jointly by the Canada Soil Survey Committee and the Soil Research Institute of the Canada Department of Agriculture, presents an account of the important factors in the formation, distribution, and utilization of the various soils of Canada. Even though portions of these reports and maps are already out of date in some respects, they will provide specialists in other fields with a significant source of soils information previously unavailable to them.

A requirement voiced by non-pedologists was the need for a 'global' approach to soil science teaching in nonagricultural faculties. Inferred in this is the need to provide an overview of the different soils of the world in relation to their properties, their associated environments and the problems related to their utilization for food and fibre production. Also implied in the global approach is the application of soil science to all disciplines where it has significance. Too often, even within agricultural faculties, soil science teachers deal with the details of specific aspects of soils, relate these to local or direct application in agriculture and neglect the broader extrapolations of the information. With the movement of university graduates to all parts of the world, and, in particular, to developing countries where generally little is known of the soils of the areas, such extrapolations are all-important.

The teaching of soil science in Canada today should not be restricted to the university level. There is need to improve the content and promote a greater input of subject material on soils in science courses both at the elementary and secondary school levels. There is also need to make the general public more conscious of our soil resources, their utilization and their conservation. In this regard, one relatively unexploited avenue is the inclusion of soil science courses in continuing education programs. As indicated previously, while soil specialists have maintained high standards in their teaching, they have failed to promote the fullest use of their knowledge. They can no longer sit back while land use and environmental programs lacking adequate soil science input are developed and perpetuated. They must take the initiative in promoting both research and teaching in areas inadequately served by soil science even if this means invading the traditional realms of other disciplines.

For the most part, soil science graduates in Canada have always been able to find employment in their general area of proficiency, particularly if they have had postgraduate training. While few new positions are foreseen for the immediate future due to the present economic situation, many senior positions at provincial, federal and university institutions will become vacant through retirement over the next decade. Unless more soil specialists are encouraged to pursue graduate studies, there will be a deficiency of qualified people to fill these positions or those vacated by persons moving into them.

CANADA'S SOIL RESOURCES AND THE FUTURE

R.L. Halstead[1]

"What would the earth be like if there were no soil?". A question often raised by J.H. Ellis, Professor of Soil Science at the University of Manitoba (The Land for Thine Inheritance; 1947. Manitoba Department of Agriculture). "If there were no soil there would be no life for all living forms depend directly or indirectly for subsistence on the plants of the fields, forests, lakes and streams, and the growth of those plants depend in turn on the productivity of the soil and the nature of the climate". The three components – soil, climate and vegetation – together constitute "the land". Historically, man's survival and his cultural development have been linked inevitably with the land and its use, and the productivity of the soil always has been a key factor in that development and survival. It is the basis for field crop and livestock production, gardens and orchards, forestry and lumbering, game and wild-life, and therefore provides a way of life to many. In addition the land provides rest, relaxation and recreation to countless others. Thus, there is little question that the proper management and utilization of the soil resource must be one of the nation's most important problems. What then is the future with regard to the soil resource in Canada, and what are the important issues and challenges facing Canadian soil scientists in the future?

Other authors in this issue have provided information and described various aspects of soils in Canada from the beginning to the present time – systems of classification and inventory; data acquisition, storage and use; soil productivity and capability; other soil dependent industries and activities; and education of the soil scientist in Canada.

On a global basis, food and fibre production and demand continue to be major concerns. At the present time food production usually exceeds demand, but the geographic distribution of production and demand magnifies the distribution problem and makes a solution difficult with present social and economic constraints. With the earth's population continuing to grow is there a solution to this global problem of production and demand? There are many in the world today who believe that every country is capable of providing for itself given its own resources of land and people. During the 20th century, additional food was obtained by opening new lands for development and this is still continuing in many developing countries. In Canada, however, we are at the point where our most productive lands have been opened up. At the same time, urbanization is making inroads into areas where our most productive soils are located. If agricultural productivity had remained at the levels of the early 1900s, it would be impossible to provide for the 4 billion people now living in the world, or for Canada to produce for the export market. In Canada, as elsewhere, the major variables in food and fibre production are: arable land, weather and technology. The soil scientist is involved in activities relating to all three of these variables.

In Canada, the picture with respect to arable land is similar to that of the world. Only about 13 per cent (130 million ha) of our land area is suitable for agriculture because of our geology and climate. Of this, only 70 to 80 million hectares are suitable for intensive agriculture with some 50 million hectares suitable only for grazing. Of the land suitable for more intensive agriculture, only 40 million hectares are now utilized, leaving some 30 to 40 million hectares of reserve land for agriculture expansion. Much of this reserve is of lower capability than that farmed at present, and will require careful prior evaluation for effective development. Thus,one of the important tasks for soil scientists, be they pedologists, physicists, chemists, microbiologists or soil fertility experts, is that of providing information and advice for decisions on the future utilization of the soil resource. Since soils do not change their relative productivity rating regardless of the level of management, it is important that society have mechanisms and procedures for retaining the highest capability soils for production of food and fibre. Therefore, from a soil resource point of view, the development of a land evaluation program in which soil productivity data, soil physical data, climatic data and economic data are integrated to provide an information base for making land use decisions, is a responsibility of all soil scientists in the country, and is of utmost importance to the nation.

The soil scientist always has played, and will continue to play, a major role in the development and application of soil-related technology for production purposes. Inherent in the development of a production technology is that of protection of the soil. The soil scientist applies his expertise in disciplines such as physics, organic and inorganic chemistry, microbiology, soil fertility, agronomy, hydrology, engineering, etc. to develop soil management systems most suitable for particular soils and climates.

Future development in soil management will be associated with the growing concern over diminishing energy reserves in the western world. There are reasons to believe that minimum and zero tillage techniques for use in continuous cropping and summerfallowing programs can significantly reduce the energy requirements and minimize the depletion of organic matter in the soil. This is an area of research which will receive expanded attention in the future.

A major breakthrough in soil fertility which will drastically alter future crop production is unlikely to occur. It is more likely that gains up to the limit imposed by climate will occur slowly as a result of continuous updating and integration of management information. Soil fertility is however, likely to become even more important in the future than it has been in the past since intensive crop production places heavy demands on nutrient supplies in soil. Both major and minor nutrients will have to be supplied in fertilizers or through crop rotations. Consequently, there will be increasing needs for a wide range of research to determine nutrient requirements for improved crop varieties, detect deficiencies, and develop effective fertilization practices. The research will be similar to that currently in progress and will include comparisons of nutrient sources; methods, rates and times of application; studies of residual value; and interaction effects with physical properties, soil water

[1]Research Coordination, Agriculture Canada, Ottawa, Ontario K1A 0C6.

supply, and pesticides. Mounting fertilizer costs, pressures for energy conservation, and continuing environmental concerns are now placing, and will continue to place, heavy demands on soil scientists to improve fertilizer efficiency, and to substitute and utilize animal, crop, and urban wastes to supply needed nutrients for efficient production.

Research and technology development relating to irrigation, drainage, salinity, and reclamation of problem soils are also the responsibility of the soil scientist. This will require the active participation of the many scientific disciplines resident in the "soil resource" fraternity.

It is difficult to assess the resources (man-years and dollars) now directed to soil resource research since there are many institutions directly or indirectly involved in this area of work. From an agricultural point of view there are approximately 100 researchers involved in soil resource research – survey, classification, interpretation and evaluation. These are about equally divided between the provincial agencies (including universities) and Agriculture Canada. A similar number of scientists (approximately 100) are involved in areas of research relating to the production and protection aspects of the resource. Approximately 60 are with Agriculture Canada. In Agriculture Canada, the soil resource program (exclusive of production aspects) involves about 60 man-years with an expenditure of about 4.6 million dollars. This includes some funds to carry out research under contract. As indicated earlier, the total effort on soil resource research in Canada is difficult to estimate since many ministries – Agriculture, Environment, Resources, Northern Affairs, Forestry at both the federal and provincial level have soil resource responsibilities, and many university departments carry out soil resource related studies.

In summary, it would appear that the areas of need with respect to land resource information are as follows:

1. *Land use decisions and policies*
   It is necessary to define the economic and production capability implications of agricultural land use changes and losses of agricultural land to other uses.

2. *Estimation of production capability*
   The production capability of land units for a variety of crops, including forestry, under varying physical and economic constraints.

3. *Estimation of land and water resource requirements for food and fibre production*
   Policies with respect to exports, population, self-reliance in terms of food production, nutritional levels, etc. all have a bearing on our land resource requirements, and soil resource scientists will be involved in the development of these policies.

4. *Resource protection*
   The degree of degradation of Canadian soils and protection of the environment are continuing responsibilities of soil scientists. Environmental protection begins with good land use planning.

5. *Soil research*
   There will be a continuing need for soil scientists trained in all disciplines if vital contributions toward solving the problems of food production, water use and availability, and the protection of the environment are to be made.

   Areas of effort will include:

   a) More efficient use of water and nutrients by crops.
   b) Soil structure, compaction and drainage.
   c) Behavior and interaction of water, salts, fertilizers and pesticides in soil.
   d) Prevention of soil erosion by wind and water.
   e) Waste disposal on land.

There is little question that the attitude of Canadians towards their land resource base has changed dramatically in the last few years. Most of us have thought of Canada as a limitless land with few restrictions to production, but recent events such as the energy crisis, disappearance of world food reserves, climate changes, drought, and population increases have made us aware of our resource limitations – particularly soil. Future food and fibre supplies depend not only on simple formulas like applying more fertilizer or opening new lands but on long term development and proper utilization of our soil resources.

SOIL PHYSICS IN CANADA

G.C. Topp[1]

Soil physics research in Canada has evolved from simply making physical observations to studying physical processes in the soil. Such physical processes include movement and retention of water (soil solution), soil structure processes, soil temperature and heat flow, soil-plant-atmosphere interactions, soil aeration and gas transfer, and soil erosion. Some of these facets of soil physics are receiving no attention while others such as soil structure processes receive very little.

Growth of soil physics in the United States began about 40 years ago due to concern for water supply for plant growth in semiarid and irrigated regions. Good progress in developing theories for water (and soil solution) movement and storage has occurred. Significant contribution to these theoretical developments have taken place in other countries having semiarid climates, such as Canada, Israel, and Australia. Such Canadian contributions have been facilitated by the necessity of Canadian soil physicists to receive their training in the United States, or elsewhere, until as recently as 15 years ago.

With this North American emphasis on the theory of water transport phenomena, other facets of soil physics have received little attention. During this decade there are more field applications of theory to problems such as water supply to plants, soil-water studies in hydrology, the transport of chemical constituents in soil.

Type and level of activity

Currently, in Canada as elsewhere in the world, the major emphasis in soil physics relates to water supply in soil. In the western plains the work is directed to using more efficiently the limited water available for crop growth. In eastern Canada drainage of excess water, especially in spring, is the main preoccupation. Mountain slope hydrology and stability receive attention in British Columbia. Some research effort is being devoted to soil-plant-atmosphere interactions, the interrelationships between water and heat flow in frozen and freezing soils, soil structure, and the movement of chemicals (pollutants and fertilizer) in the soil solutions.

In 1977, about 22 scientist man-years were involved in soil physics in Canada, including both teaching and research activities. About seven of these work in Agriculture Canada research stations and eight are in agricultural facilities of universities. Of the remaining seven, three are in nonagricultural departments of universities, two are in government environment departments, and two are with private consulting firms. There are four schools of engineering which have water resource programs involving research similar to that of soil physicists. It is difficult to identify and quantify this input, however it is estimated to be equivalent to three scientist man-years. There is seldom more than one soil physicist per institution; the resulting isolation is particularly evident in the Atlantic region of Canada, where only one soil physicist is working. The four soil physicists at the University of Guelph are the largest team. It is generally acknowledged that, except for the team at Guelph, there is nowhere an adequate concentration of soil physics talent to develop a well rounded research program. Whether there are problems in Canada that would warrant such a specific program has not been considered or debated to my knowledge. The current approach is for soil physicists to be members of multidisciplinary teams.

Problems ahead

As one looks into the future, it is easy to identify problems which would be better understood and solved if additional soil physicists form part of the research teams. In agriculture the supply of water for optimum plant growth under arid and semiarid conditions, and the growing instances of soil degradation (salinity), will need increased research attention in the Prairies. In eastern Canada rainfall generally exceeds potential evapotranspiration. Hence, soil drainage, and the influence of soil structure on drainage needs, will require increased research, as documented by Beke and Hilchey in this report. A significant energy expenditure in agriculture is for soil cultivation. The reduction in energy requirements for soil cultivation will require both soil physical and engineering expertise. Soil resource inventory information and its classification has been largely based on chemical and mineral properties of the soil. Nevertheless, most uses of soil are affected by physical properties and processes, e.g. irrigation, drainage, septic tank use, waste disposal on land, etc. Consequently, much more soil physical information must be included in soil resource inventories, if these are to remain valuable aids in soil management. Research is required to identify what physical properties should be measured and to develop methods for their measurement.

At the 1975 Canadian Hydrology Symposium the identified future problems in subsurface hydrology were closely related to soil physics (Lennox and Parsons, 1975). For example, the influences of frost action on water movement in soil (Kay and Groenevelt, 1975), the need for more field measurements in the unsaturated soil zone (Topp and Cameron, 1975), and the transport of chemicals to and within groundwater systems (Gillham et al., 1975).

High priority environmental problems related to soil physics include: first, the soil physical problems associated with installations in the arctic, e.g. frost-heave on pipelines, soil strength changes associated with increased melt, etc.; second, safe disposal of wastes on land requiring more quantitative information on transport, storage and release of chemical constituents added to soil in this way; and third, the implications to slope stability from the changing hydrologic regime, by forestry and construction operations.

Research needs

It appears then, from the importance and uniqueness of these soil physical problems for Canadian conditions, that a 50 per cent increase in number of soil physicists over the next five years is a realistic aim. Of the eleven needed, one is urgently required at the University of Alberta to carry out both teaching and research. Four research soil physicists should join the soil inventory program of Agriculture Canada to work in conjunction with the soil survey units. An additional two should be working in crop production problems in agriculture. Many of the problems identified above, as related to soil physics, are environmental in character. It is therefore recommended that four or more soil physicists be added to Environment Canada research programs and to university departments dealing with environmental problems.

[1]Soil Research Institute, Agriculture Canada, Ottawa, Ontario K1A 0C6.

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SOIL CHEMISTRY RESEARCH IN CANADA

R.L. Halstead[1]

Soil chemistry research in Canada is carried out in support of programs on soil classification, soil management, and soil protection. Soil chemistry research involves scientists trained in the broad areas of organic, inorganic and physical chemistry, as well as bio- and geochemistry. Since the programs in soil classification, soil mineralogy, soil testing, and soil biology and biochemistry are discussed elsewhere in this publication, this presentation will be restricted to ongoing soil chemistry research directed primarily to soil management and protection.

Soil chemistry research oriented towards management and protection comprises phases such as soil fertility, including plant nutrients and use of manures, fertilizers, amendments and wastes; salinity; soil-pesticide interactions; toxic metals in soils and plants; environmental concerns, such as production without attendant contamination of surface and ground waters by nutrients and toxic elements; reclamation of soils following strip-mining, pipeline construction, etc.; and atmospheric pollution of soils and crops.

The programs vary in accordance with priorities arising from differences in soil, climate and cropping systems across the country, and involve experiments on the availability of soil and added nutrients (such as N, P, K, Ca, Mg, S, B, Mo, Se, Cu, Zn), as measured by yields in field and pot experiments, by concentrations in the plants, and by chemical extraction of the soils. These are carried out across the country in accordance with regional conditions. Where soil acidity is a problem, there are experiments on liming to ascertain the effects on yield, the availability of nutrients, the toxic concentrations of Al and Mn, and in organic soils the effect of liming on decomposition as related to subsidence of the bog. Other work relates to the use of animal wastes and sewage sludge as valuable sources of nutrients and organic matter for soil improvement without contaminating water or food crops. To establish nutrient requirements for different crops under different soil conditions, many experiments involve rates, sources, time and manner of placement of added nutrients in relation to different soil properties including soil moisture and temperature.

With recent interest towards conserving N fertilizer because of cost and risk of enriching the watertable or nearby waters, increasing attention is being given to monitoring quality of water from agricultural fields and watersheds, N fixation by legumes, N transformations in soils (mineralization, NH_4 fixation, nitrification and denitrification) and of developing mathematical models to represent the N cycle for a given soil-cropping system. To characterize soil components and to elucidate chemical reactions and biological processes in different soils, some effort is devoted to the chemistry of soil organic matter, microbiological activity and the mineralogy of the mineral soil components.

The number of professionals allocated to this research within the Research Branch of Agriculture Canada is about 50 man-years. There are about 30 man-years in the category of soil fertility specialists with competence in field and greenhouse experimentation and general soil chemistry, and about 20 man-years in more specific areas of soil chemistry involving organic, inorganic, physical and biochemistry expertise. There are a limited number of man-years in the Food Production and Marketing Branch of Agriculture Canada involved in research for regulating and licensing fertilizers, pesticides and other soil additives and amendments. Man-year involvement in soil chemistry research outside of Agriculture Canada is more difficult to assess, but in general, it is estimated that there are about 50 researchers engaged in the various aspects of soil chemistry research. Of these, approximately 30 man-years are at universities, 15 are in provincial departments or agencies, and 5 to 10 are with commercial organizations. The number of scientists carrying out related research in other federal departments has not been estimated.

In summary, soil chemistry research has implications in all aspects of soil research — classification, production and protection. Soil chemistry, in its broadest sense, is an essential element in soil testing, soil biology, soil mineralogy, soil genesis, and soil management. There is a continuing need for soil chemistry research to ensure the proper development, management and utilization of the soil resource for food and fibre production. Major emphasis will be on more efficient use of nutrients by crops, on the behaviour and interaction of water, salts, fertilizers and pesticides in soils, and on environmental concerns relative to wastes, toxic elements, reclamation, and loss of nutrients.

[1]Research Coordination, Agriculture Canada, Ottawa, Ontario K1A 0C6.

SOIL BIOLOGY AND BIOCHEMISTRY IN CANADA

E.A. Paul[1]

Soil biology and biochemistry encompasses a group of disciplines which study soil organisms and characterize soil organic constituents and biochemical processes. Soil is characteristically an active system of living organisms, organic matter, and inorganic constituents. This close interaction stabilizes a great diversity of types and numbers of soil animals and the microorganisms.

The study of soil biology ranges from the isolation and classification of the fauna and flora to the study of the physiology of soil organisms. It also includes: characterization of the soil organic constituents, determination of the metabolic products of microbial activity, measurement of the degradation of pesticides and pollutants, and the interactions of microorganisms, higher plants and animals.

In the universities, approximately half of the soil biological research and teaching is conducted in colleges of agriculture. The other half is in departments such as biology and microbiology. Soil microbiology has always had a strong nonagricultural component. Staff members within soil science departments tended to stress the reactions of organisms and the cycling of nutrients whereas staff members in other areas have stressed the classification of microbial populations and determination of the physiological processes of the organisms involved.

Research conducted at the universities has been primarily supported by University and National Research Council grants. The recent expansion into areas such as ecosystem studies, pollution investigations, and the effect of industrial processes such as mines and pipelines on soil populations and their activities has involved Environment Canada and industrial organizations.

Government research, centred in Ottawa, has stressed the interaction of plants and microorganisms, microbial taxonomy, and measurement of nutrient transformation. The larger regional agricultural research stations usually have one to two soil microbiologists, whereas the smaller stations may conduct research on microbially mediated reactions but very often do not have the staff for detailed investigations of the organism or processes involved. The recent interest in nitrogen fixation has led the National Research Council laboratories to initiate an intensive investigation of this field in their own laboratories. It has also caused workers in the field of biochemistry, genetics and microbiology to enter a field normally restricted to soil biologists.

There are about 30 university personnel known to be interested in microbial ecology, nitrogen fixation and soil microbiology in faculties of arts and science, agriculture and forestry. An equal number of scientists are associated with government research organizations in Agriculture, Forestry, Environment and National Research Council. One or two individuals work for commercial firms or consulting firms.

The interest in ecosystem processes and in the interactions of soil microorganisms with soil animals and plants has led to an expansion in research in these areas. Also, the classical agricultural fields involving nitrogen transformations continue to require a great deal of research from a practical viewpoint. The availability of tracer techniques and adequate instrumentation should now make more progress in identifying the specific biological and chemical reactions involved in the soil system possible. The findings are attracting the interest of the geochemists. The recent interest in N_2O and CO_2 atmospheric levels relative to ozone levels and long term climatic effects has directed questions to the soil microbiologist relative to the effect of biological transformations on CO_2 and N_2O evolution from soil and water. The biologist has been able to give answers concerning the microbiology and biochemistry of the system with some estimate of the rates of transformations in nature. However, further work is required before these estimates can be transposed to a global basis.

Plant microbial associations such as nitrogen fixation and mycorrhizal phosphorus uptake can utilize the photosynthate of growing plants to replace much of the fossil fuel energy now used for the production and transportation of fertilizer. The microorganisms associated with plants are known and present work is determining many of the basic relationships. Extra manpower and funding is however required to adapt a broad range of plants to the symbiotic relationship on a major scale.

In summary, it can be said that the field of soil biology and biochemistry is well established and active with a number of Canadian scientists having good international reputations. Most of the research has been conducted on an individual basis. Continuing strong advances in the fields of microbial-plant associations and in the geocycling of nutrients may however be dependent on well funded groups involving a number of disciplines. This would require special planning and funding not now available to Canadian scientists.

[1]Department of Soil Science, University of Saskatchewan, Saskatoon, Saskatchewan.

CLAY MINERALOGY IN SOIL SCIENCE

G.J. Ross[1]

Because most mineralogical investigations of soils in Canada, as well as elsewhere, have been limited to studies on the clay fraction (less than 2 micron), this discussion deals mainly with studies on the mineralogy of the clay fraction of soils. Furthermore, studies on surface and charge characteristics of the clay fraction are considered to belong also to the domain of clay mineralogy as are studies on the disordered, noncrystalline inorganic components of the clay fraction.

There are about eight scientists in Canada whose major research activity concerns the study of the clay mineralogy of soils. Half of this number are in government service and the remainder are employed by universities. Five are situated in the eastern provinces and three in the western provinces.

Historically, much of the work on the clay mineralogy of Canadian soils has been done in relation to soil genesis and classification and useful knowledge has been obtained on the distribution and alteration of clay minerals in Canadian soils. Recently, a large number of new data on the clay mineralogy of soils across Canada has been obtained from analyses of soils on field tours organized for the International Society of Soil Science 1978 Congress.

Research has also been done on the importance of soil clay minerals in release and fixation of plant nutrient elements, such as K, and on the reactions of clay minerals with aluminum and with components of organic matter in soils. A number of studies have been done on the nature, formation, and solubility of hydrous oxides of aluminum and iron and on carbonate minerals in soils.

In response to a need for more information on soil physical properties, there is at present an increasing emphasis on research concerned with clarifying the influence of clay mineralogical properties on physical properties including soil structure and formation of impermeable soil layers, retention and viscosity of water, permeability to water and air, swelling and shrinking, and strength and plasticity.

Due to a re-emphasis on sound management of native soil fertility and to the use of soils for disposal of polluting materials, there is also a renewed interest in the influence of clay mineralogy on soil chemical properties, especially in the capacity of clay minerals to complex, adsorb, desorb and release nutrient as well as toxic elements.

Clay mineralogy may influence (or be influenced by) soil genesis and consequently mineralogical data are of primary importance in studies on soil genesis and classification; for example, detailed clay mineralogical data may clarify the role of clay mineralogy in the nature and formation of impermeable soil horizons.

The requirement for more and better mineralogical data in physical, chemical and pedological investigations has increased the awareness of the need for a more accurate identification and quantification of the various clay minerals in soils, and recent work has made important progress towards this goal (Kodama et al., 1977).

Several problems in basic soil clay mineralogy await unequivocal solutions. For example, there is insufficient knowledge of the structural changes of soil minerals as they weather in soils, such as the weathering of mica or chlorite to vermiculite or to montmorillonite. Neither are the interactions of clay minerals with organic matter and the nature and reactions of clay mineral-organic complexes well understood. One of the more difficult but very important problems relates to the quantification, nature, and reactions of poorly ordered and disordered or amorphous inorganic clay mineral components. Recent clay mineral analyses have indicated the presence of relatively large amounts of these components in many Canadian soils.

In summary, the following areas in clay mineralogy need strong support.

1. More research is needed on the identification and quantification of clay minerals in soils to improve the accuracy and reliability of clay mineral data. These efforts should be applied not only to the well-ordered mineral components but also to the poorly ordered and disordered ones. Special attention should be given to the surface and charge characteristics of the disordered inorganic components and their importance in soils as compared with the better ordered components. This research has high priority because the effectiveness of most physical, chemical, and pedological investigations is strongly dependent on reliable clay mineralogical data.
2. The influence of amount and kind of clay minerals and of their associated structural, surface, and charge properties on soil physical properties and behaviour should be more extensively investigated. Mineralogical input should be effective in studies on soil erosion, slope stability, soil structure, soil salinity and drainage.
3. Clay mineralogical investigations, with emphasis on surface and charge properties, should find fruitful application in soil fertility and pollution studies.
4. More effective clay mineralogical contributions can be made to studies on soil genesis, classification and land use by a closer co-operation of scientists in these fields with clay mineralogists. This applies particularly to detailed soil survey studies as done in areas slated for urban development. In these and other studies clay mineralogical data should be considered not merely as additional information but should be integrated and related with other soils information. Examples are the relationship of clay mineral composition with swelling and shrinking and the relationship of amounts of hydrous iron and aluminum oxides with pH dependent charge.
5. Some research on the more basic aspects of clay mineralogy, mentioned previously, should be continued to avoid stagnation of the discipline and to safeguard the progress of fruitful application of new results and concepts to other disciplines in soil science.

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[1] Soil Research Institute, Agriculture Canada, Ottawa, Ontario K1A 0C6.

SOIL SCIENCE AND LAND RECLAMATION, WESTERN CANADA

D.W. Anderson[1]

Recent increases in surface mining for coal and oil sands, coupled with a strengthening concern for the environment and the loss of agricultural land, has resulted in considerable interest and activity regarding the reclamation of drastically disturbed lands. Soil scientists have an increasing involvement in this relatively new field. This involvement has been in pre-mining assessment of environmental impact, in the development of legislation, in agronomic research, and in planning and carrying out the reclamation.

Detailed soil surveys are usually a part of pre-mining environmental assessment. These are of particular importance where legislation, as in Alberta, stipulates that land must be restored to a level of productivity equal to or greater than the original land. Detailed soil surveys and analyses coupled with characterization of the geological section is of considerable value in planning reclamation. This information enables reclamation specialists to determine the most suitable reclamation alternative, identify materials unsuitable for, or toxic to, plants, and develop mining procedures which can obviate problems by in-process burial of unsuitable substrates (Shaneman, 1977; Mickleborough, 1977). Materials suitable for topsoil can be identified and stockpiled for topgrading levelled spoils.

Soil scientists trained in soil management and agronomy have researched the problems of establishing vegetative cover on unstable, usually infertile, commonly saline or sodic soil materials in generally unfavorable climatic environments. Research results from the United States Department of Agriculture at Mandan, North Dakota have resulted in methods to overcome the problems of revegetating infertile mine spoils with high sodium contents in a semiarid climate (Wali and Sandoval, 1975). Establishment of vegetation in coarse textured or rubbly mine wastes under subalpine conditions has been documented as well (Macyk and Steward, 1977). The reclamation research for the Alberta oil sands development includes physical, chemical and biological assessments of the soil materials and environments, and methods of dealing with the anticipated problems (Anonymous, 1977).

Soil biologists have had considerable involvement in reclamation research. An example is the study, in model systems, of soil biological activity and changes over time as affected by the nature of the overburden material, the amendments added, and the plant species grown (Pers. comm., D. Parkinson, Univ. Calgary).

The mineralogy of the materials can be of considerable importance. Work in the Great Plains has shown that high sodium contents are particularly serious where the materials contain montmorillonitic clays (Wali and Sandoval, 1975). The sodium-montmorillonitic clay combination results in strong, cemented crusts on soils, that hinder plant root growth and seedling emergence as well as severely reducing rainfall infiltration, thus adding to problems of droughtiness and erosion.

Of particular interest is the role of the soil ecologists. Many of these scientists question the somewhat piecemeal approach to solving reclamation problems, particularly those using the techniques of modern agriculture, such as the annual additions of chemical fertilizers and the use of introduced species which may not adapt to the wide range of physical and nutrient environments of many reclamation sites. They recommend comprehensive studies of the biogeochemical systems that reclamation presents, and the development of reclamation alternatives which will be permanent, self-sustaining and in balance with the edaphic conditions of the site (Curry, 1975; Mains, 1977). The rates of organic matter and nitrogen additions, the leaching of soluble salts and the early stages of carbonate weathering of naturally vegetated spoils under semiarid climate were reported by Anderson (1977).

Smith (1977) recommends an integrated research effort in reclamation, involving a number of disciplines as well as industry, government and university personnel. Soil scientists are, and will continue to be, active in this research area.

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[1]Saskatchewan Institute of Pedology, University of Saskatchewan, Saskatoon, Saskatchewan.

CHEMICAL SOIL TESTING FOR AGRICULTURE

T.E. Bates[1]

Chemical soil tests are used across Canada as a means of determining the fertilizer and lime requirements for field, horticultural and greenhouse crops. To some extent these are supplemented or replaced with plant analysis. These two indices when accompanied by soil survey and climatic information provide essentially the only scientific and rational means of deciding on fertilizer needs.

Accurate fertilizer recommendations based on soil tests can lead to better crops by providing the correct amounts and balance of nutrients for crop production. In the areas where fertilizer has been used for many years soil tests frequently show that little phosphate and potash are required, thus reducing the farmer's costs and increasing profits accordingly. In Ontario it is quite common for the use of soil tests to result in a $10/acre saving in fertilizer cost over what the farmer would have used without a soil test.

Soil testing laboratories in Canada invariably test for phosphorus, potassium and pH with magnesium and calcium also determined in many laboratories. Nitrogen, sulphur, sodium and salinity tests are also available in some laboratories, chiefly in the prairie provinces. Nitrogen tests in particular are used routinely in the three prairie provinces but are generally unsuccessful in the more humid areas.

Approximately 50 000 to 60 000 soil samples are tested each year by the Ontario Ministry of Agriculture and Food's laboratory with the number of farmers using the service totalling 12 000 per year. Perhaps an additional 10 000 samples from Ontario are tested in private laboratories.

Farmers use of soil testing is increasing gradually over the years with increasing demand for testing of additional nutrients such as boron, copper, manganese and zinc.

There is increasing awareness that chemical soil tests providing accurate fertilizer recommendations can be used to prevent pollution of surface and groundwaters with nutrients. In Ontario proposed regulations on the spreading of sewage sludge stipulate that sludge may not be applied to soils with phosphorus soil tests above a specified limit. There is pressure from the Ministry of Environment to apply similar criteria to nitrate fertilizers. Soil testing will obviously become increasingly important as its usefulness as a tool to monitor soil nutrients and protect water quality becomes more generally recognized. Soil tests for such nonnutrient metals as cadmium, nickel, lead and mercury are being used to some extent in Ontario and may soon become a part of routine testing.

The total content of a nutrient or metal in the soil is rarely a good measure of the amount available to plants. Research is therefore required to select an extractant or extraction procedure which will remove a fraction of the nutrient from the soil which is related to plant availability. Since the chemical forms of a nutrient which are available to plants differ among soils, different extractants may be required for different regions or for widely different soils in one region. After an extractant has been selected large numbers of field plot experiments are required to determine the response of any one crop to fertilizer at various soil test levels. Thus soil testing requires a continuing research input. The greater the use of soil testing the more important it becomes to have accurate interpretations of the results.

In Ontario, soil test development work has been largely done by the University of Guelph while soil test field calibration has been shared by the University, the Provincial Colleges of Agricultural Technology and Agriculture Canada. More research is needed to meet the increasing demands placed on this area of soil science.

Editor's note: Chemical soil testing for agricultural purposes is carried out both in private and government laboratories in many provinces in Canada. The service described above was selected as it is typical of the options offered in most provinces. There are private, government and university soil testing facilities for forestry, waste disposal, ceramics, engineering, geochemistry, archaeology etc.

[1]Director, Ontario Soil Testing Laboratory, University of Guelph, Guelph, Ontario.

SECTION F: DEFINITIONS OF PARTICULAR SCIENTIFIC TERMS APPEARING IN THE SOIL SCIENCE REPORT

ablation — the combined processes by which a glacier wastes.

ablation till — a surface deposit of loose, permeable, somewhat stratified, sandy and stony till overlying denser.

B.P. — before present. Number of years measured back from 1950.

brunisol — an order of soils whose profiles comprise dark surface horizons, and yellow brown subsurface horizons which gradually become more olive with depth.

cations — positively charged ions which take part in the soil forming process and are essential for plant nutrition.

chernozem — soils of the grassland regions which have dark coloured surface over light coloured subsurface horizons with high base saturation.

colluvial, colluvium — a heterogeneous mixture of material that as a result of gravitational action has moved down a slope and settled at its base.

congeliturbation — frost action in soil including heaving, solifluction, sludging etc.

cryosolic — mineral or organic soils that have perennially frozen material within 1 m of the surface in some part of the soil body.

cryoturbation — frost action, including frost heaving.

d.b.h. — diameter breast height. Timber mensuration term to indicate the diameter of a tree at the height of an average person's breast.

dystric brunisol — these are brunisol soils with shallow surface horizons with well decomposed organic matter.

edaphic — pertaining to the soil, especially with respect to its influence on organisms.

eluvial, eluviation — the transportation of soil material in suspension or in solution within the soil by the downward or lateral movement of water.

ericaceous — belonging to the group of plants known as Ericaceae.

eutrophic — the state of lakes and water bodies when they have little oxygen in bottom waters and much nutrient matter.

fibrisol — a great group of organic soils that are saturated for most of the year with much weakly decomposed organic matter in the profile.

fragic (Fragipan) — a subsurface horizon of high bulk density and consistence which is firm and brittle when moist and hard when dry. It is low in organic matter, mottled and slowly or very slowly permeable to water.

gley, gleysation — a soil forming process operating under poor drainage conditions giving rise to gray colours with reddish flecks called mottles.

gleysolic, gleysol — an order of soils developed under wet conditions and permanent or periodic reduction with gray or mottled gray subsurface horizons.

horizon, soil — a layer of soil or soil material approximately parallel to the land surface. It differs from its adjacent genetically related horizons in such properties as colour, texture, mineralogical composition etc.

Some designations are:

A. a mineral horizon formed at or near the surface.
B. a mineral horizon which is enriched by the deposition or precipitation of material from the overlying A horizon.
C. a mineral horizon comparatively unaffected by the pedogenic processes.

Some lower cases suffixes:

ca- horizon of secondary carbonate enrichment
e- horizon characterized by removal of clay, iron, aluminum or organic matter
g- a horizon characterized by gray colours or prominant mottling
t- an horizon enriched with silicate clay.

illuvial, illuviation — the process of depositing soil material removed from one horizon in another. An illuvial horizon is one in which material has been carried from an overlying layer and precipitated.

lacustrine — produced by, belonging to, or formed and growing in lakes.

luvisol, luvisolic — an order of soils that have eluvial (Ae) horizons and illuvial horizons (Bt) in which silicate clay is the main accumulation product. Usually developed in a forest or forest-grassland transition in a moderate to cool climate.

nivation — frost action and mass wasting under a snow cover.

opal phytolith — siliceous skeleton after grass remains.

ortstein, ortstein horizons — an indurated layer in the B horizon of podzol soils in which the cementing agent consists of illuviated sesquioxides and organic matter.

pedogenic, pedological, pedogenesis — the mode of origin of the soil, especially the process or soil-forming factors responsible for development of characteristic horizons. The division of soil science dealing with soil genesis.

pedon — a vertical section through the soil considered as a basic unit of volume of a specific soil.

pedoturbation — the shifting of the disposition of parts of the soil profile by such natural agents as freeze-thaw, expansion-contraction and organisms.

perhumid — more than normally humid climate. Exceptionally high rainfall area.

placic — pertaining to a thin black to dark reddish pan or horizon and presumably cemented by iron. Placosols are soils with such horizons.

podzol, podzolic — a strongly leached soil with yellow and brown subsurface horizons in which organic matter, aluminum, and iron have accumulated. Commonly, there is a pale gray sandy horizon immediately under the surface litter horizon.

regosolic, regosol — an order of soils having no horizon development or with A and B horizons too poorly developed to be included in other orders.

solifluction — a type of creep occurring where the ground freezes to a considerable depth and as it thaws during the warm seasons the upper thawed material creeps downhill over the frozen material.

solonetz, solonetzic — a great group of soils developed under grass in semiarid to subhumid climates. They have surface horizons which break abruptly into hard compact prismatic or columnar B horizons. The C horizon is usually saline or calcareous.

solum — the upper parts of a soil in which the parent material has been modified by soil forming processes. Normally the A and B horizons.

thixotropic — clay soils which may abruptly change from a stable, durable material to a liquid-like material.

CANADIAN GEOSCIENCE COUNCIL 1977 ANNUAL REPORT

REPORT OF THE PRESIDENT

The externally directed efforts of the Council, started in 1975, gained momentum in 1977. Armed with our 1976 Report on the Status of the Geosciences in Canada, meetings were held with the National Research Council, the Ministry of State for Science and Technology, the Departments of Trade and Commerce, Fisheries and Environment, and Indian and Northern Affairs. The Council continued to gain recognition as an important spokesman for the Earth Sciences in Canada. This was done with the active co-operation of our member societies and did not trespass on their own specific roles.

Our Ad Hoc Committee to the Geological Survey of Canada lost its ad hoc nature and is now formally known as the CGC Visiting Committee to the Survey. This committee has made great progress, much to the satisfaction of both the Council and the Geological Survey. Its first comprehensive analysis will be published in our 1978 Annual Report. The activities of this rather unique committee have aroused much interest in other government branches and departments. Several meetings have been held with the Department of the Environment to discuss ways and means whereby the Council could advise on the earth science component of their activities.

The National Research Council materially increased its grants for earth science research in this year of general cutbacks. We have been reliably informed that our submissions played an important part in this reassignment of priorities.

The Government of Ontario has recently announced the creation of the Ontario Geoscience Research Fund. The Fund will foster a program of mission-oriented research at Ontario universities and the Council takes great pleasure in endorsing this initiative. While the Council was not active in the discussions leading to the creation of this fund several of our member societies and associated committees were involved; and it is an indication of the position the Council has achieved that it has been asked to nominate candidates from industry for membership of the Funds' Administration Committee.

The policy of holding Council meetings in conjunction with those of our member societies across the country continued this year with sessions in Vancouver and Halifax. This serves the double purpose of acquainting local society members with the existence and function of the Council as well as providing Council members with invaluable insight concerning activities, people, and problems they would not normally encounter. In addition to its regular meeting in Vancouver, the Geoscience Council sponsored a Forum at the GAC/MAC/CGU meeting wherein speakers from five Federal Departments reviewed their Earth Science activities and fielded questions from a concerned audience. In Halifax our contact with the geoscientists took a more relaxed format. Our joint beer and bull session, with a minimum of speeches, was a memorable evening with the Atlantic Geoscience Society.

The Public Forum concept appears to be a useful one for Council and it will be continued in 1978 with an afternoon at the fall GAC/MAC/GSA Toronto meeting devoted to the subject of "Nuclear Reactor Waste Disposal".

This year saw the birth of Geoscience Council Special Paper No. 1. The paper grew from a specific request from the Science Council of Canada to our group for an analysis of mineral and hydrocarbon resource assessment. The papers were presented at a joint meeting of the CGC executive and the Science Council in St. John's, Newfoundland. Discussion at the meeting, and the subsequent dinner, convinced us that these papers should be printed and widely distributed. While we do not claim to have provided the last word on the subject we feel these papers will make a rational contribution to an overheated debate. While in St. John's the executive enjoyed an informal luncheon with members of the local GAC Section hosted by the Geology Department at Memorial University.

The first session of what should be a continuing dialogue with the American Geological Institute was held in Washington in June. The President, Secretary-Treasurer, and Foreign Secretary met with the AGI executive. A representative from Mexico had been invited but was unable to attend. The discussion ranged at great length over our mutual activities and problems. Particularly impressive, and probably of direct use to Canadian educators, were the educational publications of AGI. This frank, informal interchange of ideas and concerns goes a long way towards putting our problems in proper perspective. It was the mutual feeling at the end of the meeting that these joint sessions should take place at least once a year.

Our Foreign Secretary had a busy year which saw the terms of reference for that office, and the Standing Committee, formally approved by the Council. Further details of this committee's activities can be found in the pages following.

The decision of Treasury Board to rapidly effect the contracting out of the publishing of NRC's Journals of Research drew critical comment from Council and many of our members. While acknowledging that such a move could eventually be desirable, it was forcefully pointed out in letters to Ministers, and officials concerned, that the high quality of these publications could easily suffer if this move was done without very careful study and preparation. NRC had commissioned the Royal Society of Canada to make a study of the subject and it appeared that this contracting out was to take place before the study had been completed. A recent communication from NRC now reports that any move in this direction will await the presentation of the final Royal Society report.

Our Education Committee this year sponsored two Edgeo programs for junior high and high school teachers. The Committee has now been augmented with the appointment of Vice Chairmen for Eastern and Western Canada. Since local contact is an important factor in promoting these workshops we are looking forward to increased activity in this area. We are indebted to the Canadian Geological Foundation for providing the funds for this endeavour.

In June the President represented the Council at a joint meeting of the Science Council of Canada and the Association of Canadian Universities and Colleges to discuss the implications of the age structure of university teachers and researchers. While this may seem a rather esoteric subject, there is a pronounced age bump in this group brought about by the period of rapid expansion in the universities across the country. The net effect of this bulge is that for the next few years the overall age of the faculties will increase, as will the salary budget. Since the number of students is expected to fall so will the operating grants. As you may see, a rather serious problem is in the making. Further to this situation there is the additional problem of fewer and fewer positions for young graduates in our faculties. In twenty years or so when the bulge starts retiring the demographers tell us that enrollment will start increasing and a marked shortage of teachers and researchers is anticipated. Besides the numerical problems there is also some doubt if university research will continue to be effective as the body of researchers gets older. No one gathering could be expected to provide solutions for such a complex situation, however the problem has been well stated and effort is now being focused on it.

At the Mines Ministers Conference this year our President elect met with the Subcommittee of Provincial Geologists who plan to retain their status as Observers at meetings of Council. At this meeting, our member society, the GAC, presented a brief to the Ministers. An abbreviated version is published elsewhere in this report. It is probable that the Council itself will be asked to present a brief at the next Conference.

The Council Subcommittee on Funding Earth Science Research in Canada has prepared a position paper entitled "Earth Sciences and Natural Resources, The Next Decade". This paper was drawn largely from a document prepared by the Committee of Chairmen of Earth Science Departments (an Associate Member of our Council) in conjunction with members of the Department of Energy, Mines and Resources. The paper, accepted by Council at our October meeting, is published in this report. This document makes a number of significant comments and recommendations which we plan to present to the Minister of Energy, Mines and Resources in the near future.

A standing committee was created this year to provide representation to the Parliamentary Scientific Lobby. Individual interviews with some 98 M.P.'s were arranged with generally excellent rapport established. Further details can be found in a report from the committee which follows in this section. Still in the discussion stage is the formation of two other committees, one to examine Canada's Marine Geoscience effort and the other to report to Council on the subject of Nuclear Waste Disposal.

Exploration '77, an update in mining geophysics and geochemistry, was a very successful sequel to the 1967 Niagara Falls conference. Sponsored by the Geoscience Council, members from several of our constituent societies laboured mightily to create another milestone in Canadian exploration geoscience. It is expected that the publication of these papers through the courtesy of the Geological Survey of Canada will provide us with an important reference text.

Our 1978 report on the Soil Sciences in Canada is another important reference document. To many of us unfamiliar with this field the report has been a real eye opener and we feel sure that it will have impact on science policy makers as well as the scientific community. The Geoscience Council is proud to have played a part in creating this report and is grateful to the Editor and contributors for their considerable efforts. Plans for our next reports include a study of Earth Science education and research in Canadian universities, an appraisal of the status of Canadian Marine Geoscience, a look at the role of geoscience in nuclear waste disposal and a report from the CGC's Visiting Committee to the Geological Survey. The university study is about to get under way and Council hopes that its results will prove of great benefit to both the public and the universities. Preliminary reaction from many Earth Science faculty members has been positive. If an atmosphere of mutual trust can be achieved similar to that established between the Geological Survey and our Visiting Committee then the project will be assured of great success.

The establishment of the Geoscience Council's credibility and the growth of its activities have led councillors and others to ponder its future course of action. In general, Council members are concerned that we not become (or appear to be) solely a pressure group for Geoscience. They feel that we should show that we can establish priorities for the country within our own disciplines, as well as objectively state the geoscience case within the whole framework of Canadian science. Council has to be prepared to present the facts, and comment if necessary, on matters of national importance relating to the geosciences. While these statements have a motherhood tinge about them, the specifics that emerged from our debates most certainly did not. Whether or not a volunteer council such as ours can effectively do all the things we know need doing is a question that will soon have to be faced. The possibility of having a full time executive director and permanent headquarters will have to be explored, along with the financing required. Even without a full time staff, as our activities (i.e. committees) expand, our need for a broader financial base becomes more apparent. I suspect that before these problems can be resolved the relevance of the Geoscience Council will have to be well established in the minds of the individual members of our societies. We have been somewhat remiss in this regard -- as have some of our member societies. In its short life the Council has set itself and accomplished some important tasks. It would be unfortunate if our role were to be diminished because we neglected to fully inform our constituents of our activities on their behalf and to continually involve them in these activities.

P.J. Savage
President
December 1977

REPORT OF THE SECRETARY-TREASURER

There were eleven Member Societies in the Council in 1977. Table 3.1 lists the Member Societies along with their objectives and activities. Invitations to all Council meetings are extended to the following organizations as Associate Members or Observers:

- Earth Science Division of the Royal Society of Canada
- Committee of Chairmen of Canadian University Departments of Earth Sciences
- Committee of Provincial Geologists
- Geological Survey of Canada (EMR)
- Earth Physics Branch (EMR)

Funds for the Council activities are obtained from three sources; a sustaining grant and contract from Energy, Mines and Resources, fees paid by Member Societies, and grants 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 the Editorial Committee activities. The Council pays membership fees to SCITEC, the Association of Geoscientists for International Development, and the Youth Science Foundation.

The Council held three meetings during 1977; the 24th in Vancouver, in May; the 25th in Halifax in October; and the 26th in Ottawa in December. After the last session a special meeting was held with senior officials of Energy, Mines and Resources. Included in a wide ranging agenda was the presentation of the report on the Status of Geosciences for 1977. Executive meetings were also held with the Science Council of Canada, and the American Geological Institute.

The membership of the Council in 1977 included:

President — P.J. Savage
Vice President — D.W. Strangway
Past-President — E.R.W. Neale
Secretary-Treasurer — D.L. Barss
Executive Member — G.W. Mannard
Executive Director — E.C. Appleyard

Member Society Representatives

Association of Exploration Geochemists
— W.F. Bondar
Canadian Exploration Geophysical Society
— E.O. Andersen, K.A. Morgan
Canadian Geophysical Union
— D.W. Strangway
Canadian Geotechnical Society
— O.L. White, A.W. Clifton
Canadian Institute of Mining and Metallurgy
— G.W. Mannard, L.J. Cabri
Canadian Society of Exploration Geophysicists
— W.D. Evans, J.H. Harding
Canadian Society of Petroleum Geologists
— R.H. Erickson, D.L. Barss
Canadian Society of Soil Science
— G.K. Rutherford, L. Lavkulich
Canadian Well Logging Society
— W.D.M. Smith, J.A. Ellis
Geological Association of Canada
— R.W. Macqueen, D.W. Strangway
Mineralogical Association of Canada
— R.S. Lambert

D.L. Barss
Secretary-Treasurer
December 1977

REPORT OF THE FOREIGN SECRETARY

Historical Background

In early 1976, the Geological Survey of Canada divested itself of the role of the National Committee for Geology and transferred this to the Canadian Geoscience Council. This responsibility was formally accepted by the Canadian Geoscience Council at its meeting in Ottawa on March 5th, 1976. As a result of this action the Canadian Geoscience Council established the position of Foreign Secretary and requested that a Standing Committee on International Scientific Relations be established. Tentative terms of reference were drawn up in 1976 by the Foreign Secretary (W.W. Hutchison) and submitted to the first meeting of the Standing Committee in February 1977. Following discussion of the terms of reference, a final set was drawn up and submitted to the Canadian Geoscience Council meeting held in Vancouver on April 28th, 1977. The full terms of reference appear as Appendix 8 of the minutes of that meeting; the following is extracted from these terms of reference.

Purpose of the Standing Committee on International Scientific Relations

The Canadian Geoscience Council is the adhering body to the International Union of Geological Sciences and the International Geological Congress. Accordingly, the purpose of the Standing Committee is to provide authoritative advice and guidance on a continuing basis to the Canadian Geoscience Council and to provide a forum for discussion of Canadian participation in the international geoscience organizations.

Specifically the Standing Committee shall:

1. Advise the Canadian Geoscience Council, in its capacity as the Canadian National Committee for Geology, on its relations with international nongovernmental geoscience organizations or with Canadian National Committees of international geoscience organizations
2. Act as a clearing house for reporting activities of Canadian National Committees of international non-governmental geoscience organizations in order to avoid possible duplication of effort and to identify gaps
3. Propose responses by the Canadian Geoscience Council to new international initiatives
4. Ensure that the Canadian Geoscience Council is adequately represented in discussion of Canada's participation in nongovernmental international programs on meetings wholly, or in part, dealing with geoscience for which the Council has a responsibility
5. Ensure that Canada is appropriately represented on international programs, projects, or meetings for which the Canadian Geoscience Council has national responsibility.

Annual Meeting of the Standing Committee

At the annual meeting of the Standing Committee held in Ottawa on February 25th, 1977 the following topics were discussed in addition to those dealing with the terms of reference, namely: a report by the Canadian National Committee of the Inter-Union Commission on Geodynamics (presented by Prof. Ray Price), a report on behalf of the Canadian National Committee for the International Geological Correlation Program (presented by Prof. Ken North) and a report on representation of the Canadian National Committee for the International Society for Soil Mechanics and Foundation Engineering ISSMFE (presented by W.J. Eden). Also, K. Whitham, an observer at the meeting, gave a brief report as Chairman of the Canadian National Committee for the International Union of Geodesy and Geophysics. W.W. Hutchison summarized the major items of interest arising from the Executive Committee meeting of the International Union of Geological Sciences held in Vienna, February 1977.

Discussion by the Standing Committee centred chiefly on the future of the International Geological Correlation Program, national representation to the ISSMFE, the ICSU resolution addressed to the IUGS concerning withdrawal of membership of Taiwan as the official representative of China and the subsequent admission of the Peoples Republic of China as the official representative of China, and finally the withdrawal of IUGS support for the Gondwana Symposium held in Calcutta in January 1977.

Meeting with the American Geological Institute

An exploratory meeting of representatives of the Executive of the American Geological Institute (AGI) and the Canadian Geoscience Council (CGC) took place on June 17th, 1977 at the offices of the American Geological Institute in Falls Church, Virginia. The Council was represented by its President, P.J. Savage, its Secretary-Treasurer, D.L. Barss and its Foreign Secretary, W.W. Hutchison.

The major differences between the AGI and the CGC are that the CGC, in addition to being an umbrella organization for a number of national earth science societies, also carries the responsibility of the National Committee for Geology in Canada. AGI is a much larger organization than CGC with an adequate full-time secretariat. It publishes a major journal (Geotimes) with an unique international reputation, and is generally well-equipped to play a major co-ordinating role between member societies. Within the United States a separate committee assumes the role of National Committee for Geology.

The meeting was a useful, exploratory endeavour which flushed out some problems and themes of mutual interest. The Canadian Geoscience Council is a fledgling in comparison to the much longer established American Geological Institute. This was especially evident in the area of education where the CGC representatives were particularly impressed by the resources compiled and results achieved by William H. Mathews, III in promoting the teaching of the earth sciences.

Miscellaneous Activities

The Foreign Secretary in consultation with the Executive of the Council and representatives of the Canadian National Committee of IGCP compiled a response to a questionnaire by UNESCO concerning the future of the program. The Foreign Secretary also proposed initiatives to be taken in possible future meetings with the American Geological Institute, the US National Committee on Geology, and in providing input to the United Nations Conference on Science and Technology which is to be held in 1979.

At the meeting of CGC held in Halifax on October 14th, 1977, E.R.W. Neale was unanimously appointed to the post of Foreign Secretary. He will take up office early in 1978.

W.W. Hutchison
Foreign Secretary
December 1977

Report of Canadian Geodynamics Subcommittee

The Geodynamics Project is an international program of research on the dynamics and dynamic history of the Earth with emphasis on processes affecting the lithosphere. The program is co-ordinated by the Interunion Commission on Geodynamics (ICG) established by the International Council of Scientific Unions (ICSU) at the request of the International Union of Geodesy and Geophysics (IUGG) and the International Union of Geological Sciences (IUGS).

National participation in the Geodynamics Project is structured through the agency of national committees; in Canada, this role is filled by the Canadian Geodynamics Subcommittee. In its 1977 annual meeting, the Subcommittee dealt with several topics of importance to the geoscience community in Canada. A special project on Plate Margins is under way, involving the preparation of a series of sections through the Pacific and Arctic continental margins and the Cordilleran and Innuitian orogenic belts, with a view to joint publication of the results with a similar project developed by the U.S. Geodynamics Committee. Preparations for the final report to mark the end of the Geodynamics Project (in 1979) are progressing; the final report of the Canadian Subcommittee will take the form of a series of review papers on each of seven main areas which have been identified as encompassing the main Canadian contributions to the Project (Global dynamics; Phanerozoic fold belts; Paleomagnetism; Short-term motions; Precambrian evolution and the Canadian Shield; Continental margins; Oceanic crust).

The ICG held its annual meeting in Durham, England, August 1977. The Canadian Subcommittee was represented by its Chairman, R.A. Price. During the Commission meeting, the framework of an international project on "Crustal Dynamics" to succeed the Geodynamics Project was discussed and steps toward its establishment were taken.

Among the many international meetings connected with the Geodynamics Project, the Canadian Subcommittee sponsored a symposium on "Large-scale displacements in the northern Cordillera", co-ordinated by J.W.H. Monger and held in Vancouver in April 1977 concurrently with the Geological Association of Canada/Mineralogical Association of Canada annual meeting.

G. Ranalli
Secretary
December 1977

Report on International Geological Correlation Programme

The 1977 activities of the IGCP Canadian National Committee are summarized in IGCP Newsletter 4. Copies are available from the National Secretary, Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8.

E.T. Tozer
National Secretary
December 1977

REPORT OF THE EDUCATION COMMITTEE

During the year, two Edgeo workshops were held in Saskatoon and Toronto. Over 42 teachers attended and the total cost to the Council was about $4700.

Sixteen Resource Guides were sold and 20 were distributed free.

Dr. George Lammers of Winnipeg, and Dr. Alan Gordon of Saint John, New Brunswick have accepted vice-chairman positions for western and eastern Canada regions, respectively.

Edgeo workshops will probably be held in Winnipeg, Manitoba and Saint John, New Brunswick during 1978. The possibilities of workshops in Calgary and Toronto exist. Efforts in Quebec remain fruitless.

Shell Canada has renewed the contract for another three years for month-long workshops at the University of Western Ontario.

A year ago, a request was made of member societies to provide a résumé of education activities. Two submissions were received. It is evident no duplication of effort is occurring.

Edgeo Program

During the 1977 period, workshops were held at Saskatoon and Toronto. The following is an assessment of each workshop on the basis of evaluation forms, attendance, and casual conversations with co-ordinators and participants.

> Saskatoon: The Edgeo program was held May 6-8, 1977, with Dr. Earl Christensen as co-ordinator and sponsored by D.B. Ferguson, a Saskatoon teacher. The workshop covered geology, astronomy, meteorology, and geomorphology. Five Saskatoon teachers, assisted by a teacher from Minnesota conducted the class sessions. The field trip to the Qu'appelle Valley had a recently completed popular field guide as a resource document. Five other professionals on soils, plant ecology, geotechnique and natural history participated. Three observers from the University of Saskatchewan Geology and College of Education Departments attended.
>
> The twenty-six teachers of whom twenty-two were from Saskatoon, had teaching responsibilities mainly in grades 7 to 9. The evaluation forms show that on 26

queries, 'excellent' was checked for all but one – "too many participants". (Ideally, these workshops could be kept below 20 participants.)

The Saskatchewan Edgeo $3500 grant from the Canadian Geoscience Council and some additional funds from Saskatchewan Science Teachers funded the program. An informative, comprehensive report was prepared.

Toronto: The Toronto Edgeo was a limited success. A more lengthy period of planning would have insured a greater number of participants. Preparations began in the spring of 1977, but the original chairman left the area during the summer and the organization was rejuvenated only four weeks before the October workshop. Another teachers meeting at the Ontario Science Centre attracted some potential participants.

There were 16 teachers at the sessions and 14 on the field trip. Class sessions were held at the Inn-on-the-Park by two experienced teachers. Four professionals gave specialized talks. The field trip on Sunday concentrated on environmental aspects.

The Canadian Geoscience Council provided $1200 in funds for the project. The participating professionals were Bryan Whitehead, Ed Freeman, Pat Lee and Bob Guillet, all GAC members. C.G. Winder also gave a talk. The co-ordinators are interested in doing it again.

C.G. Winder
Chairman
December 1977

REPORT OF THE VISITING COMMITTEE TO THE GEOLOGICAL SURVEY OF CANADA

January 1977, the Committee submitted to the Director General of the Geological Survey of Canada a draft Progress Report concerning the GSC, which outlined committee activities for 1976. These included reports of visits to:

Vancouver
Cordilleran Subdivision and Terrain Studies – M.J. Keen and A. Sutherland Brown.
Calgary
Institute of Sedimentary and Petroleum Geology – J.D. Weir and J. Mollard.
Ottawa
Terrain Sciences – J. Mollard.
Regional and Economic Geology Division – M.J. Keen, A. Coope, A. Sutherland Brown.
A General Visit – A. Coope.
Dartmouth
Atlantic Geoscience Centre – D.W. Strangway and J.D. Weir.

February 1977, the full committee met in Ottawa to discuss with D.J. McLaren and J.O. Wheeler of the GSC the results of the committee's activities to that date and to plan activities for 1977.

March 1977, a final version of the progress report and supporting appendices were prepared and submitted to the Director General of the GSC. This report dealt with the committee's observations on:

The Roles of the Geological Survey
Suggestions for Change
Research Scientists
Communications
Decentralization
Future Activities.

Further discussion of this report with the Assistant Deputy Minister and the Director General is anticipated. Activities for 1977 were identified as:

Completion of Visits to GSC Divisions
Reports on particular GSC Programs.

April 1977, at the GAC/MAC meeting in Vancouver, the committee elected J.D. Weir as Chairman to replace M.J. Keen who resigned upon his appointment as Director of the Atlantic Geoscience Centre. The Canadian Geoscience Council has not yet found a replacement for M.J. Keen on the Visiting Committee.

May 1977, the committee completed its review of the GSC Divisions with Coope, Sutherland Brown, and Weir visiting the following Ottawa based divisions: Resource Geophysics and Geochemistry Division, Central Laboratories and Administrative Division, Geological Information Division including the GSC Library. A report and summaries of interviews with division managers and scientists are in preparation.

Particular GSC programs presently being evaluated are:

The Uranium Reconnaissance Program
Radioactive Waste Disposal
Geochronology.

J. Alan Coope heads the subgroup examining the Uranium Reconnaissance Program and will recruit help from outside the committee. A survey of users of the program is under way with A. Sutherland Brown contacting users in British Columbia (i.e. major mining companies, oil company mineral divisions, independent operators and small mining companies). J.D. Weir is contacting users based in Calgary and J.A. Coope is contacting users based in Eastern Canada. Completion of these surveys awaited return from the summer field operations of many users.

D.W. Strangway heads the subgroup examining the Radioactive Waste Disposal Program. The following will serve on this subgroup:

J.A. Cherry – University of Waterloo
W.S. Fyfe – University of Western Ontario
P.Y. Robin – Erindale College
R.E. Asuma – University of Toronto.

R.L. Armstrong of the University of British Columbia agreed to examine the GSC work on geochronology as the CGC Visiting Committee had no expertise on this subject. He visited the Survey during the last week in August for an in-depth look at the current GSC geochronology operations. When his report is received the committee will decide what to do next.

J. Alan Coope continues to examine the problems and rationale for the Survey's program on decentralization, which will be reviewed by the committee as a whole.

No progress has been made regarding examination of the Survey's program in Marine Geoscience. With the loss of M.J. Keen the committee is again lacking competence in this subject and is seeking outside help.

An examination of the Survey's interface with industry on the problems of northern pipelines was postponed due to the rapidly changing pipeline picture this past summer.

The full CGC Visiting Committee expects to meet in Ottawa early in 1978 to discuss with Department and Survey management progress made during 1977 and future activities.

J.D. Weir
Chairman
December 1977

Table 3.1

Data on member societies of the Canadian Geoscience Council

SOCIETY AND MEMBERSHIP	OBJECTIVES	MEETINGS, ACTIVITIES AND COMMITTEE (attendance in parentheses)	PUBLICATIONS
ASSOCIATION OF EXPLORATION GEOCHEMISTS P.O. Box 523 Rexdale, Ontario. M9W 5L4 Active membership in Canada 140 Student membership in Canada 13 Corporate members in Canada 10 World membership 559	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, Van. B.C. – Symposium on "Current Commodity Trends in Mineral Exploration and Evaluation" (with Geological Society of Australia), Adelaide, Australia. – Regular Council Meetings. COMMITTEES: Admissions Case Histories Geochemical Analysis Research and Education Bibliography Computer Applications Membership Technical Meetings	Journal of Geochemical Exploration (6 issues/year) Newsletter (quarterly to members only) Application of Geochemistry to the Search for Crude Oil and Natural Gas, Elsevier Scientific Publishing Company, Amsterdam. Proceedings, Sixth International Geochemical Symposium – Sydney, Australia, 1976. Elsevier Scientific Publish. Company, Amsterdam.
CANADIAN EXPLORATION GEOPHYSICAL SOCIETY (KEGS) c/o Duncan McNeill Secretary-Treasurer Geonics Ltd. 1745 Meyerside Drive, Unit 8 Mississauga, Ontario. L5T 1C5 Active members in Canada 137 Members outside Canada 9 Student members 8 154	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.	No formal journal. Abstracts, summaries, and complete papers of talks given to KEGS are appended on the monthly notice of meetings and announcements mailed to all members.
CANADIAN GEOPHYSICAL UNION c/o Dr. J.L. Roy Secretary-Treasurer Earth Physics Branch Department of Energy, Mines and Resources 3 Observatory Cres. Ottawa, Ontario. K1A 0Y3 Active membership in Canada 291	To advance the science of geophysics and to promote a better understanding thereof throughout Canada.	– Meeting with Geological Association of Canada, Vancouver, April, 1977. – Meeting in London, Ontario, May, 1978 (KEGS is co-sponsor of one session). SUBDIVISIONS: Gravity, Seismology and Physics of the Earth's Interior, Exploration Geophysics, Geomagnetism, Geochronology and Stable Isotope Studies, Geodesy, Mathematical Geophysics. – International Union of Geodesy and Geophysics – appoint 5 members to the Canadian National Committee.	Canadian Geophysical Bulletin
CANADIAN GEOTECHNICAL SOCIETY c/o Dr. Gerard Ballivy Secretary Department of Civil Engineering University of Sherbrooke Sherbrooke, Quebec Members 722 Student members 83 Affiliates 31 Of the 836 total membership, 620 are members of the Engineering Institute of Canada of which the Canadian Geotechnical Society is a constituent society.	To stimulate activities and co-operation 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.	– 30th Annual Canadian Geotechnical Conference, Saskatoon, October 5-8 included annual business meeting and presentation of awards (260) – Board of Directors met twice (in Ottawa and Saskatoon) – Local sections met approximately 9 times per year for technical sessions.	Canadian Geotechnical Journal published by National Research Council as 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 2 750	(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 3.1 (cont'd.)

AWARDS	BRIEFS AND POSITION PAPERS	ASSOCIATIONS WITH OTHER ORGANIZATIONS Canadian and (non-Canadian)	OTHER INFORMATION
Constitution provides for Honorary members.	The Research and Education Committee has completed a study of educational requirements for exploration geochemistry with a view to developing a recommended curriculum for university undergraduates wishing to enter the field of exploration geochemistry with the proper scientific background.	Canadian Geoscience Council	The Association of Exploration Geochemists (AEG) was founded in 1970 in Toronto as an international organization. Approximately 30 per cent of the members are Canadian with the balance spread over some 53 other nations. The Geochemical Analysis Committee of the AEG has assembled analytical data for 44 elements on a series of six geochemical standard reference samples. The AEG publishes an annual Bibliography List of recent papers on exploration geochemistry which incorporates cross-referenced publications to keep information as current as possible.
– Don Salt Memorial Scholarship is awarded to the most promising third and fourth year students enrolled in geology or geophysics at the University of Toronto who have an interest in the exploration for mineral deposits.	In conjunction with a number of other interested groups, KEGS was involved in discussions with the Ontario Government concerning the declining state of the mineral exploration industry in Canada.	Canadian Geoscience Council (Society of Exploration Geophysicists)	KEGS 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 reside outside the Toronto area with members living in most provinces of Canada and as far abroad as South Africa and the Philippines.
J. Tuzo Wilson medal for 'Outstanding Contribution to Canadian Geophysics'.	Letters to P.E. Trudeau with suggestions for new granting council members; letter to Faulkner with views for granting council; letter to Treasury Board on the restrictions of civil servants for conference travel.	Canadian Geoscience Council Division of GAC and CAP	
– 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 3.1 (cont'd.)

SOCIETY AND MEMBERSHIP	OBJECTIVES	MEETINGS, ACTIVITIES AND 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 favor 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 W.E. Moore 612 Lougheed Building Calgary, Alberta. T2P 1M7 Active Members in Canada 2116 Active Members – Foreign 88 Associate Members – Canada 53 Associate Members – Foreign 1 Student Members in Canada 157 Student Members – Foreign 3 Honorary Members 19 Emeritus Members 8 Corporate Members 66 2418	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 (19) – Technical Meetings, luncheon meetings (600) – Technical Symposia, three CSPG Field Conf. Waterton (120), CSPG Core Conference (570), First Int. Symposia on Fluvial Sedimentology (170). 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, 1977 CSPG/CIM Convention Committee, 1978 International Convention Committee.	Approximately 50 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.J. Wall, Secretary Ontario Institute of Pedology University of Guelph Guelph, Ontario. N1G 2W1 Total membership 346 Active in Canada 325 Honorary 11 Active Fellows 10	To foster all branches of soil science by: – providing forums for communications among soil scientists – assisting in communication among users of soil science information – co-ordination of soil research, teaching and extension.	– Annual Convention, Guelph, 15-18 August (100) COMMITTEES: Journal, Awards, Rules, Co-ordination, Adhoc committee on Organization, Committees for hosting 11th International Soil Science Congress.	Canadian Journal of Soil Science Three issues per year.
CANADIAN WELL LOGGING SOCIETY c/o Secretary P.O. Box 6962, Postal Station D Calgary, Albèrta. T2P 2G2 Active members 368 Honorary members 5 Corporate members 23 (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 (80) – Nine Executive Meetings COMMITTEES: Membership, Publication Sales, CWLS Journal Editor and Business Manager, Nominating Award 1978, Formation Evaluation Symposium Organizing, Water Resistivity Catalogue, Well Log Standards, Seminars for Research.	The CWLS Journal – annually CWLS Symposium transactions published occasionally, next – 1979 Formation Water Resistivity Catalogue – 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, Ontàrio. N2L 3G1 Fellow 1717 Associates 865 Retired 50 Honorary Members 7 Life Members 4 Patrons 1 2644 Corporate Members 87 2731	To advance the science of geology and closely related fields of study and to promote a better understanding thereof throughout Canada.	– Annual Meeting, May, 1977, Edmonton (750) – Annual Meeting, April, 1977, Vancouver (1516) – Council and Executive Meetings Sections and Divisions meet independently COMMITTEES: Finance, Program, Projects, Membership, Editorial, Public Information, Status of Women, Education. Logan Medal, Past President's Medal.	Geolog – Newsletter published quarterly Geoscience Canada – published quarterly Special Papers – Sixteen 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 Dept. of Mineralogy and Geology Royal Ontario Museum Toronto, Ontario. M5S 2C6 Life Members 29 Sustaining Members 44 Corporate Members 617 Ordinary Members 788 Student Members 305 Total 1783	To advance the knowledge of mineralogy, crystallography, petrography, geochemistry, economic geology and applied disciplines of the earth sciences.	– Executive Committees 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 3.1 (cont'd.)

AWARDS	BRIEFS AND POSITION PAPERS	ASSOCIATIONS 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 Canadian Society of Geophysicists Convention March, 1978. "Energy – A Geophysical Challenge".
– 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)	Will host conference "Facts and Principles on World Oil Occurrence of Hydrocarbons", June 26-28, 1978.
– Fellowship Award. Fellow of the Canadian Society of Soil Science.		Affiliation with Agricultural Institute of Canada. Member – Canadian Geoscience Council. Affiliation with International Soil Science Society.	
– 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 CIMM (Society of Professional Well Log Analysts – USA)	
– Logan Medal – annual for outstanding contributions to the Earth Sciences. – Past President's Medal – annual for outstanding achievements in the Earth Sciences. (Awarded to a younger scientist.) – Youth Science Foundation -three awards given annually for the best Earth Science exhibit at National Science Fair.	Information Circular No. 3 entitled "Sources of Free Materials for Canadian Earth Science Teachers and Students" was published in 1977. Field guides for Montreal and London, Ontario are 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: 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, Structural Geology, Volcanology. Regional Sections of GAC exist in Edmonton, Newfoundland, Winnipeg and Vancouver (Cordilleran), with a branch of the Cordilleran Section in Victoria. Atlantic Geoscience Society (Halifax) is an affiliated society.
– Hawley Award – presented to the author(s) of the best paper printed in the Canadian Mineralogist during the preceding year. Awarded in 1977 to F.J. Wicks and E.J.W. Whittaker.		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).	

REPORT ON GEOSCIENCES IN THE PROVINCES

A Submission by the Geological Association of Canada to the 34th Annual Provincial Mines Ministers Conference, Québec, September 13, 1977.

Background

In June of 1977, the Geological Association of Canada was invited to present a brief on matters of common interest to the Provincial Mines Ministers and representatives of industry and government who would be present at the 34th annual Mines Ministers Conference. GAC executive unanimously agreed to do this; below is a shortened version of the written submission. The Canadian Geoscience Council's most recent report was of much help in preparing the brief (The Geosciences in Canada – 1976 – a Status Report; Geol. Surv. Can., Paper 77-6, 75 p., 1977). It is encouraging to report that one province, Ontario, has responded to many of the challenges outlined in the brief by establishing a new program of Applied Geoscience Research, as announced November 15, 1977. Under this new program, a sum of $555 000 will be made available annually for five years, with the intention of fostering a program of mission-oriented research at Ontario universities. The new program will be complementary to, and closely integrated with, the activities of the Geological Branch of the Ontario Ministry of Natural Resources; funds are new and not at the expense of the current program of the Geological Branch. The new program includes research a) aimed at better understanding of all aspects of mineral deposits and mineral exploration, thereby stimulating exploration, and b) designed to improve knowledge of geological properties and processes important in construction materials, waste repositories, urban development, and geological hazards.

Introduction

The Executive of the Geological Association of Canada (GAC) accepts with pleasure the opportunity to address the 34th session of the Provincial Mines Ministers Conference. In Canada, as abroad, this has been a time of retrenchment for the scientific community, but it is also one in which the technical demands are increasing. It is clear that to work toward the solution of pressing resource, energy and environment problems of the remaining quarter of the 20th century we shall need new goals, new approaches, and a new level of commitment and dedication. Although there is a tendency to view many resource and environmental problems as philosophical and sociological in nature, these are equally technical problems and as such depend continuously on the level of understanding attained by the scientific community. It is our view that human resources – specifically the talents of the scientific community – are among Canada's most important means of problem-solving. This assumes a centralist position for science, not the peripheral position (easily regarded as irrelevant) that is commonly taken by those of limited vision or those with inadequate comprehension of the full dimensions of resource-energy-environment issues and problems.

Because many of these issues fall clearly within the provincial domain, we ask to what extent the provincial governments have developed the base of knowledge and informed opinion needed for worthwhile decisions?

We perceive several problem areas of immediate concern in the earth sciences:

A) Metallic mineral exploration in Canada has declined significantly during the 1970's. Although the reasons for this decline are complex, perhaps three factors are responsible in the main: (a) the economic and political climate in Canada is not as favorable as that elsewhere, (b) the world price for minerals is low at present, (c) targets are harder to find, and therefore require increased sophistication and high level technology that is either very expensive or as yet undeveloped.

B) Energy issues – specifically, the discovery of new resources of oil, natural gas, coal, and uranium – have already assumed major importance in thinking about Canada's future. There are major ongoing geological and geophysical inputs to the discovery of new energy resources.

C) Disposal or storage of man-made wastes (nuclear, chemical, and other) are already a pressing environmental issue in Canada's most populous provinces. Large volumes of material presently on hand necessitate major programs aimed at identifying and developing suitable disposal/storage sites at once.

D) Again in Canada's more populous areas, supplies of some industrial minerals, commonly sand, gravel, and concrete aggregate, are at critically low levels, requiring delineation of new resources of such materials in less environmentally sensitive regions.

E) Terrain use, especially in urban and northern locales (and thereby environmentally delicate), is proceeding at a rapid pace commonly without the kinds of geological studies which can minimize long-term environmental damage.

These are some of the more important geoscience issues of immediate concern: all of them have major technological components, no matter what philosophical, sociological, or economic components are also present. We argue for greater co-operative efforts among the earth science community in working toward increasing levels of understanding of resource-energy-environment issues and options. Thus a major challenge before Canada's political leaders is to develop the climate in which the whole of the scientific community, including the earth science community, can respond positively to the questions and problems of the present and future.

Because resource, energy, and environmental issues lie within the provincial jurisdiction, a major provincial commitment to the related scientific and technological endeavours is called for. In the environmental field alone, most of the problems of contamination and environmental degradation are the responsibility of provincial or municipal agencies, and thus a strong case can be made for greater development of locally available technical competence.

Geoscience in the Provinces

All of the problem areas identified above, as well as others discussed below, have a geoscience component which involves earth sciences in the provinces. Examination of the data of Table 3.2 indicates that the level of earth science activities in Canada is modest when compared either with the monetary contribution made by the Canadian mineral industry, or with the magnitude, range and scale of the problems identified above.

It seems clear that there is insufficient in-house manpower in provincial agencies to deal effectively with the new challenges noted above. Thus, a major strengthening of provincial geoscience programs is in order in many areas. In what follows, we attempt to identify programs and approaches which, while involving existing and new provincial geoscience personnel, will also make better use of the entire geoscience community.

Not all of the issues and approaches discussed below fall squarely within the domain of the Provincial Mines Ministries: some involve provincial Environment Ministries or Parks and Recreation Ministries. Nevertheless, all do involve the earth,

Table 3.2

Costs of Federal, Provincial, and University Earth Science Programs in Canada in 1975/76[1]

	Total	Approximate[2] Operating Funds
Federal		
Geological Survey of Canada	24.30	9.720
Earth Physics Branch	5.90	2.500
CANMET	0.30	0.300
Department of the Environment (glaciology and geohydrology)	2.50	0.875
Department of Indian and Northern Affairs	0.96	0.410
	33.96	13.805
(less approximately $3 million for contracts for routine surveys)		3.000
		10.805
Provincial		
Provincial surveys (these are rough estimates)	26.00	9.000
Federal-Provincial Programs Federal Share	3.20	
Provincial Share	1.40	
	30.60	9.000
Universities		
Operating Budgets (subject to confirmation)	20.000	
National Research Council	4.500	4.500
Research Agreements (EMR, DOE, Etc.)	0.823	0.823
OVERALL TOTAL	89.883	25.128

[1]Source – Submission to Department of Energy, Mines and Resources, July 1977 by Canadian Geoscience Council.

[2]Millions of dollars excluding salaries.

and thus require the continuous expert knowledge of the earth science community.

Some provinces are already responding to some of the issues discussed below, through new staff, new programs, and revised priorities. We applaud and encourage these steps: taken together, however, the challenges facing Canadians require a much greater effort in the earth sciences than yet seen.

Regional Geological Studies

Perhaps the most important geoscience activity that is most useful to mineral exploration, mineral or terrain evaluation, and land-use planning, is the production of geological maps and accompanying reports, based on regional geological studies (including both small-scale and large-scale geological mapping). It is thus a matter of some urgency to study and publish the geology of areas as yet unstudied in any detail. Nevertheless, Canada's current outstanding record in the area of regional studies is well illustrated by F.R. Joubin's estimate (as a United Nations geological consultant) that the geological services provided mostly by the provincial and federal governments in Canada, and including geological maps and reports, are equivalent to a discount of 25% on the costs of mineral exploration projects. This discount may serve to attract risk capital away from other jurisdictions endowed with an equally or more favorable geological setting. Such an estimate of the value of government services is further supported by Miller's (1976) recognition of the fact that during the last 25 years, about half of the major mines discovered in the western world were found in Canada (Miller, L.J., Econ. Geol., v. 71, p. 836-847, 1976). Thus the value of such studies and services is well established, especially comprehensive technical reports and accompanying coloured geological maps. The following comments relate to the continuing need for such regional studies to provide the essential base for informed decision-making and to provide continued stimulus to exploration activities.

Bedrock and surficial geology studies

Studies of areas previously unmapped are of continuing interest for all of the purposes noted above. It must not be lost sight of, however, that a geologic map, like the earth scientist who produces it, has a lifespan. New concepts, new techniques, new exploration and new understanding combine to render maps completed decades in the past virtually obsolete. The importance of continued field studies and preparation of comprehensive technical reports cannot be overemphasized. Such studies can now integrate surface geology, aerial geophysical studies, remote sensing data (e.g. LANDSAT), colour photography, and drill-hole information, as well as new unifying approaches derived from the new view of the earth – global tectonics. Provincial Mines Ministries have a major and continuing role to play in ensuring that such studies are completed and that high quality maps and reports are produced as quickly as possible. No other data are so basic to intelligent use of the earth and its resources.

Access to remote areas

Because of spiralling costs, many remote areas now studied may not be restudied "on the ground" for some time. Thus study of such areas should yield the maximum amount of information attainable. This is achievable with a team approach, involving provincial or federal personnel, university, and industry geoscientists. Administrative structures commonly act as a barrier to such co-operation: modification, encouraging co-operative studies, is overdue.

Provincial Parks

We applaud the establishment of new provincial parks to protect geological features of educational or scientific value. Consultation with members of the earth sciences community is urged – especially those with site-specific resource, bedrock geology, or terrain expertise – before new parks are designated. We also urge that parks usage policy regarding collection of geological materials should be established and administered with the help of qualified research studies in parks.

Unique geological features

Several provinces are compiling inventory data on features which illustrate geological processes or products and are therefore worthy of preservation: this is admirable. Perhaps GAC can help, through its membership, in compiling such data. Study of such features for undergraduate course work requirements or B.Sc. thesis projects should be encouraged, with special concern directed toward those features threatened by human activities at present or in the near future.

Reclamation of quarries, open pit mines, gravel pits

Efforts in this direction are commendable. Reclamation may result, however, in the loss of valuable information where bedrock or surficial material exposures are few. As a first step, an inventory of such features could be made, with a view toward possible preservation of quarry or pit stratigraphic sections of particular value. Usage of quarries or pits for disposal of industrial wastes should not take place without prior studies by qualified geoscientists, normally hydrogeologists and structural, stratigraphic, or engineering geologists. Where in-house knowledge is not available in these disciplines, every effort must be made to determine the geological character in total of quarries or pits contemplated as disposal sites.

Diamond drill core

From time to time efforts have been made to encourage preservation of drill core obtained in mining exploration. Little seems to have been accomplished because of reluctance to commit money and people on the part of governments, and lack of enthusiasm in the mineral exploration community. Four factors suggest that this policy should be reviewed. These are the increasing difficulty in discovering new mineral deposits, the fact that new deposits are likely to be located at depths below the surface, recognition of the role that stratigraphy appears to play in governing the occurrence of mineral deposits, and the success which the oil industry has enjoyed in provinces such as Alberta, where extensive core and sample repository facilities have been established. The cost of establishing and maintaining drill core repositories is but a small fraction of the costs of obtaining the cores, costs borne entirely by the private sector. Additionally, diamond drill core commonly provides the only third dimensional lithologic information that is obtainable over large parts of the essentially flat and poorly exposed Canadian Shield. Drill core is thus a resource of continuing value for both exploration and research, if preserved. A sensible approach should begin with discussion between earth scientists from industry and provincial ministries.

Guidebooks

A variety of guidebooks written for the general public exists. Agencies include the Geological Survey of Canada, university earth science departments, interested individuals, and at least five of the ten provincial mines ministries. We encourage new guidebook publications as one important means of reaching the public. Meanwhile, it is of immediate interest to make existing guidebooks more widely known and more widely available. Provincial Ministries could look at achieving both better publicity and a wider distribution system.

Mineral Deposits Genesis

Exploration for ore deposits is guided by conceptual models for the mechanism(s) of ore formation. The development, refinement, and testing of models of ore genesis is currently of great interest, and involves understanding of petrological processes, of the migration of fluids through rocks, and of the chemical processes involved in metal precipitation. New analytical tools using trace elements and isotopes are being used extensively in determining migration and concentration mechanisms and histories. Co-operative research studies of mineral deposit genesis hold much promise, and should involve our best earth scientists, whether they reside in government, universities, or industry. Administrative frameworks can evolve which both permit and encourage such co-operative studies, perhaps beginning with known classic ore bodies or areas and progressing to regional studies. It is clearly in the interest of the provinces to encourage the development of such work as it relates their mineral deposits.

Deep Exploration Technology

According to the Mining Association of Canada, exploration for minerals at depth is 'the new exploration frontier'. Most sizeable minerals deposits at or near the surface in Canada appear to have been found; thus geophysical methods exploiting drill holes, high sensitivity systems and remote sensing techniques must be developed to effectively explore for metallic minerals to depths of several hundred metres. At the same time, regional soil and bedrock geochemical surveys are needed to further establish regional patterns within which deep targets may occur. Although Canada has an enviable record in the development of geophysical exploration techniques, the challenge of 'the new exploration frontier' requires continuing efforts to preserve and stimulate this small technology sector of Canada's industry. Political and financial mechanisms to do this require attention now. The private sector in Canada has an enviable record in the development of geophysical tools of world fame. Yet the magnitude and expense of the task is unequaled. Accordingly, serious consideration should be given to funding research and development of those methods and techniques which are relevant to deep exploration in the provincial geological environment. A first step could involve discussions among earth scientists from industry, the geophysical community, and provincial ministries and universities.

Exploration for Hydrocarbons; Geothermal Energy

A number of provinces maintain core, sample-cuttings, and geophysical log repositories for information collected by the private sector during exploration for oil and gas. These repositories provide a very valuable stimulus to exploration as well as data basic to determination of the regional stratigraphic framework of Canada's sedimentary basins. In-house scientific study of such materials is uneven from province to province; some provinces employ geoscientists to establish and publish the subsurface geology of local sedimentary units, whereas others do not. As surface geological studies encourage mining exploration, up-to-date subsurface studies and syntheses are basic to exploration for oil, natural gas, and coal, and also to evaluate potential for geothermal energy derived from recovery of water heated by subsurface flow in suitable settings. In the geothermal energy field, the provinces should have competent scientists in-house or locally available, if only to keep abreast of new developments in this fast moving field.

Terrain and Engineering Studies

Engineering projects carried out in urban areas require subsurface information which is costly to obtain. Although such information is of considerable value to the geological community, commonly it remains in consultant's files or in limited distribution reports. Synthesis of subsurface information in urban areas is a major provincial concern which can be of great value to those concerned with urbal geology, land-use studies, slope stabilities, water supply, liquid waste control, transportation, contaminant studies, and construction of road cuts, tunnels, or underground cavities. Synthesis of subsurface information is best accomplished by the employment of permanent geological staff and facilities to handle these data as they become available. Provincial Ministries are the most logical entity to do this, and establish working groups on urban subsurface geological studies. Geological hazards are also the concern of provincial or municipal agencies. In Canada, hazards are likely to be earthquake-prone areas, areas with high landslide potential or sensitive clays present in quantity, areas with rock-fall potential, and areas downstream from dam structures, or subject to flash floods. Identification of such hazards is a requisite first step in minimizing their potential as natural disasters.

Hydrogeology

Most provinces employ staff who are active in hydrogeological work, often within Environment departments rather than Mines Ministries. Much work is concerned with the quality and quantity of groundwater, and thus may be considered to have short-run management objectives as opposed to longer term requirements. Better understanding of natural systems is needed urgently in several areas, particularly to deal with contaminants in ground water systems. These areas include trace elements in natural waters; solution, migration, and precipitation of elements in natural waters; interaction of contaminants with natural materials, particularly clays; and integration of work on saturated zone problems (hydrogeology) and unsaturated zone problems (soil physics). There is need for co-operative projects with organic chemists, microbiologists and others. Contaminant problems within provincial and municipal jurisdictions already require a high level of technical understanding if rational responses are to be made. Funding of hydrogeological research either within provincial agencies or to outside groups under contract to provincial agencies appears to be at a level that is an order of magnitude below the level and complexity of the problems.

Subsurface Environments as a Resource for Storage or Disposal

In the more populous areas of Canada particularly, there is a need to develop a means for storage or disposal of hazardous industrial wastes. Use of subsurface repositories may be feasible for this purpose, but the need for a thorough understanding of the stratigraphy, structure, rock mechanics characteristics and long-term stability is apparent. Although research has gone forward elsewhere, there is not much effort in this field in Canada at present. This problem is of importance to those provinces which encourage the development of industries producing sizable amounts of waste products, and requires very difficult decisions to be made. Some investigations currently underway in structural geology, rock mechanics, and stratigraphy are relevant to this need, but must be co-ordinated and focussed to be of value for storage or disposal. Both laboratory and field studies are required, to identify and characterize subsurface units suitable as storage or disposal sites, to study flow systems, and to devise continuous monitoring techniques.

To use underground space as a resource we shall need a much better understanding of groundwater flow at intermediate depths, and, for specific sites, knowledge of such factors as fracture type and spacing, permeability, existing stresses or stored strain energy, and character of subsurface fluids. The lead time required to develop underground space as a resource is considerable. It is not too early for consideration of the development of underground mined cavities at selected locales, for example along the Niagara Escarpment of Southern Ontario. Mined caverns at shallow depths could provide space which has uniform temperatures year-round and is suitable for warehouse storage of materials or for various human activities. The rock mined could provide aggregate for the construction industry.

Marine Geosciences

Nearly all of the provinces have marine coastline or major lakes within their boundaries. These important regions require much more study for the following reasons: A) Tidal power — With the recent four fold increase in the world price of crude oil, tidal power is much closer to being economically viable. It is clear that a major factor in developing tidal power is the sedimentary budget of the region being considered. Errors in calculation of the sedimentary budget could render costly developments obsolete within a decade or two. B) Nuclear waste disposal — If cannisters containing low-level radioactive wastes are to be disposed of in shallow marine waters, as has been suggested elsewhere, we must have a detailed knowledge of rates of erosion, source and nature of sediment, long-term tectonic stability, rates of subsidence, and other related factors. C) Coastal regimes — In order to deal effectively with oil spills, or to plan pipelines or port facilities, detailed knowledge of coastal regimes and processes is needed. D) Hydrocarbon exploration — Knowledge of the offshore sedimentary framework is variable in Canada, from well delineated (for example off Nova Scotia) to virtually unknown in more remote localities.

A better understanding of coastal dynamics and processes is perhaps the outstanding need for the provinces. Provincial governments are in a position now to consider socio-political problems and technical problems of coastal areas. Thus it is most important for the provinces to have available technical advice in marine geosciences to help them deal with issues in this developing field. This may well mean co-operating with others in the field, so that decisions can be made on the most informed basis possible.

Measured against these needs, the marine geosciences picture in Canada at present is not encouraging. As noted by Keen, Sly and Chase (The Geosciences in Canada — 1976 — A Status Report; Geol. Surv. Can., Paper 77-6, 75 p., 1977) marine geosciences in Canada at present are characterized by: a) inadequate ships, b) few studies of coastal zone processes, c) few centres of excellence, d) no format to bring marine geoscientists together, e) inadequate international participation by Canada's marine geoscience community.

Special Expertise and Analytical Facilities

Approaches to many of the problems noted above could benefit from use of special abilities or analytical facilities which exist in many university geoscience departments and in industry — and commonly not available to provincial geoscientists. At present, such facilities are not widely used in team projects. In some cases, expensive analytical facilities are not used to capacity because of the lack of permanently employed trained technicians. Such facilities, including isotopic analysis, radiometric dating, etc. could contribute much to the success of regional geological studies conducted by Mines Ministries personnel, whether through contractual arrangements or, better, through team research projects. Indeed, the National Research Council recently has recognized the value of such approaches by establishing a new program of group operating grants (Team, Co-op, and Core grants).

Scientific Exchange and Interchange

Exchange and interchange is a major means by which progress is made in science and technology. Meetings and symposia, such as those sponsored by GAC and its sister societies, form a key link in the chain of knowledge transfer and progress. Indeed, some have argued that "the importance of a scientific meeting as a clearing house for geological ideas cannot be over-emphasized" (Mannard, G.W., Geol. Surv. Can., Paper 77-6, p. 47, 1977). Provincial Ministries can a) permit and encourage their geoscientist employees to attend such sessions; b) encourage joint research projects whenever possible, and permit their employees to actively contribute to workshops, symposia, and publications held by national and international bodies to further basic understanding of geological questions; c) support exchange of earth science personnel between the various sectors: provincial and federal governments, universities, and industry.

Earth Science Education at the Pre-university Level

Over the past decade, several earth science groups, including GAC, have recommended that provincial departments of education promote and encourage the teaching of earth science in secondary schools. Although evaluations have not been made of the response to these recommendations, an informal survey indicates that the quantity and quality of earth science material taught varies widely from province to province – indeed, even from teacher to teacher within a given province. Part of the reason for this is the fact that science teachers commonly are inadequately prepared to teach earth sciences even at this introductory level.

To remedy this situation, the Canadian Geoscience Council has been conducting a series of weekend workshops for teachers of earth science at various locales across the country. GAC has an education committee; the Chairman, a member of the Geology Department at the University of British Columbia, has assembled a volume on sources of free and inexpensive material for earth science teachers, published as GAC Information Circular No. 3.

All of these activities are worthwhile, but it is useful to restate our earlier recommendation: that Provincial Mines Ministers use their influence with Provincial Ministries of Education to encourage the teaching of earth science in secondary schools. The problems and challenges outlined earlier in this brief strongly support efforts to increase the level of public understanding of earth science issues. The pre-university education system is one of the most suitable vehicles to do this; we endorse and applaud present efforts in this direction, and ask that they become more widespread.

Provincial Mines Ministries can also help in this work by making basic courses in earth science and prospecting, and rock and mineral sets widely available to teachers. This is currently done in at least two provinces, British Columbia and Ontario.

Recommendation

Our recommendation is for Provincial Mines Ministries to examine the earth science capabilities available to them in their particular province. What talent is available in-house, in the universities and in industry, in view of the increasing demands and the magnitude, scale and range of problems existing in their province? What mechanisms are available for strengthening capabilities both in problem-solving and in providing the earth science knowledge-base critical to sound decision-making on resource-energy-environment questions? Approaches could include:

a) increased staffing in critical fields, especially those relating to energy, environmental contaminants, subsurface disposal, terrain use, geological hazards and urban geology:

b) study of means of co-ordinating existing provincial in-house expertise, which is now fragmented or dispersed within several administrative structures in a number of provinces;

c) establishment of a provincial working group of earth scientists from all sectors – government, industry and universities – to:

- identify key areas and problems in each province, and in-province earth science expertise capable of contributing to new programs or approaches,
- examine means of strengthening provincial capabilities in the earth sciences,
- examine financial and administrative mechanisms by which new programs and co-operative projects can go forward.

Prepared for the
Geological Association of
Canada by
R.W. Macqueen[1]
(President) and
D.W. Strangway
(Vice-President)1

[1] Although the Executive of the Geological Association of Canada concurs with the general views put forward here, the specific comments and recommendations are those of the authors.

REPORT FROM THE COMMITTEE OF CHAIRMEN OF CANADIAN EARTH SCIENCE DEPARTMENTS – GRADUATION STATISTICS AND PATTERNS OF EMPLOYMENT

Current Enrolments

This committee has been compiling statistics of undergraduate and graduate students enrolled in Canadian universities and trying to develop data indicating where our graduating students are employed. The departments contributing data are those where there is a significant geology or geophysics effort.

The data are collected and compiled by individual representatives from the Maritimes, Quebec, Ontario, and western Canada (Table 3.3). It is our impression that the statistics of current levels are reasonably accurate since most departments in Canada have submitted data.

In these statistics a few general trends can be seen:

i) The faculty in Earth Science departments has been almost constant for the last four years (Fig. 3.1),

ii) The total number of students graduating with a degree in Geology or Geophysics at the bachelors level is roughly constant running at a level close to 700 a year (Fig. 3.2),

iii) The number of master's candidates in the system as a whole is rising steadily. (We cannot tell from our statistics how much of this is due to longer times required to complete the degree.) The total number of master's candidates is now over 700 (Fig. 3.3),

iv) The total number of Ph.D. candidates is also rising slightly (Fig. 3.4),

v) One of the major strong trends is for students to be taking an optional introductory course in geology. We do not have national data showing this trend but if the Ontario statistics are representative the trend is quite strong reflecting additional teaching demands (Fig. 3.5),

vi) There has been a fairly stable number of postdoctoral fellows and research associates in the system but these seem now to be decreasing, perhaps the result of the research funding squeeze (Fig. 3.6).

Table 3.3

Total enrolment

	YEAR	ATLANTIC	QUEBEC[1]	ONTARIO	WESTERN	TOTAL
1st Year (all students taking a course)	73/74	–	–	3280	–	–
	74/75	741	–	3569	–	–
	75/76	869	–	4270	–	–
	76/77	734	–	4666	–	–
2nd year Majors – Arts & Science & Engineers	73/74	–	190	374	249	–
	74/75	163	205	372	231	971
	75/76	113	202	387	253	955
	76/77	197	202	351	312	1062
3rd Majors – Arts & Science & Engineers	73/74	–	177	320	245	–
	74/75	155	164	341	226	886
	75/76	73	176	338	199	786
	76/77	147	172	310	279	908
4th Year Majors – Arts & Science & Engineers	73/74	–	131	283	268	–
	74/75	85	153	276	233	747
	75/76	102	124	254	212	692
	76/77	120	144	244	236	744
M.Sc Candidates enrolled	73/74	–	68	195	136	–
	74/75	48	106	217	160	531
	75/76	54	112	261	203	630
	76/77	78	111	279	226	694
Ph.D. Candidates enrolled	73/74	–	32	141	86	–
	74/75	46	30	156	85	317
	75/76	34	30	182	90	336
	76/77	65	35	152	94	346
P.D.F. and Research Fellows	73/74	–	13	14	28.5	–
	74/75	9	15	22	33	80
	75/76	6	14	23	34	77
	76/77	2	9.5	24.5	22	58
Faculty Full-Time	73/74	–	77	156.5	119.5	–
	74/75	66	80	159.5	120	425.5
	75/76	83	79	160	121	443
	76/77	93	81	152	139.5	465.5
Faculty Part-Time	73/74	–	8.75	–	12	–
	74/75	–	8.5	–	14	–
	75/76	–	5.75	17	12.5	–
	76/77	–	3	17	21	–
Secretaries and Admin. Assts.	73/74	–	19	36.5	30.75	–
	74/75	38	19	37	31.75	125.75
	75/76	48	19	38.25	30	135.25
	76/77	19	20	39	39.75	117.75
Technicians	73/74	–	35	87.75	64	–
	74/75	18	36	97.5	63.5	217
	75/76	20	36	96	68	220
	76/77	27	47	100	80.5	254.5

[1] 1st Year is at CEGEP, therefore totals for undergraduates combine 1st Year Science with 2nd Year Engineers, etc.

Patterns of Employment upon Graduation

We have attempted to compile statistics for 1973/74, 1974/75, and 1975/76 which represent the places which employ the graduates of our departments. These statistics are subject to many possible interpretations but there are significant general patterns as can be seen in Tables 3.4-3.6 and Figures 3.7-3.9.

A Bachelor's Candidates

i) Only a small proportion of our graduates at this level are employed by government. There are considerably more at the provincial level than the federal level and very few leave the country.

ii) Many graduates are employed by industry almost all in Canada. Somewhat more are employed in the mining industry than in the petroleum industry.

iii) Very few graduates leave the country for employment in foreign countries.

iv) More students go on to master's degrees than to either industry or government. Almost none leave the country for graduate school — a truly remarkable observation.

v) A small number go into school teaching.

vi) The large number of unknowns probably represent people who did not get employed immediately, or who were marginally qualified or who chose to drop out of the profession.

B Master's Graduates

The general pattern for master's degree graduates is similar except that there are very few whose location is unknown. General comments:

i) A significant number of these graduates are employed by government. The largest group is provincial and very few go to foreign governments.

ii) Many graduates are employed both in the petroleum and in the mining industry in Canada — somewhat more in the mining industry. Very few are employed by industry outside Canada.

iii) A significant number go on to Ph.D. degrees but very few go on to foreign schools or leave the profession.

C Doctoral Degrees

The comments about graduates with Ph.D. degrees are much like those for the masters candidates. The graduates go into government, industry, and university in significant numbers and by far the largest number stay in Canada. Almost none go to foreign industry and only a few go to foreign governments.

D Post-Doctoral Fellows and Research Associates

There were a small number of these who moved on to other positions. The total movement was as follows:

	73/74	74/75	75/76
Provincial Government	0	0	1
Federal Government	6	1	0
Foreign Government	1	2	0
Canadian Industry			
-mining	0	1	0
-petroleum	0	0	0
-other	1	0	0
Foreign Industry			
-mining	0	0	0
-petroleum	0	0	0
-other	0	1	0
Faculty Positions	2	2	2
Other Research Associate or PDF positions	4	3	0

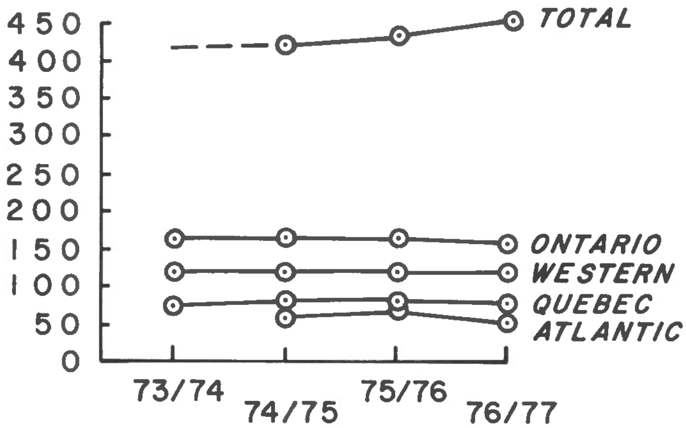

Figure 3.1. Full-time faculty.

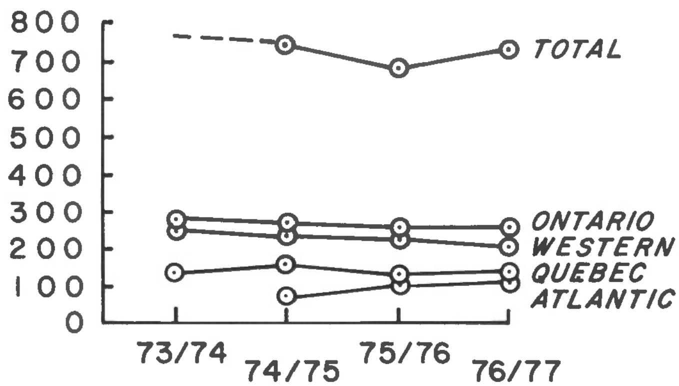

Figure 3.2. Fourth-year students.

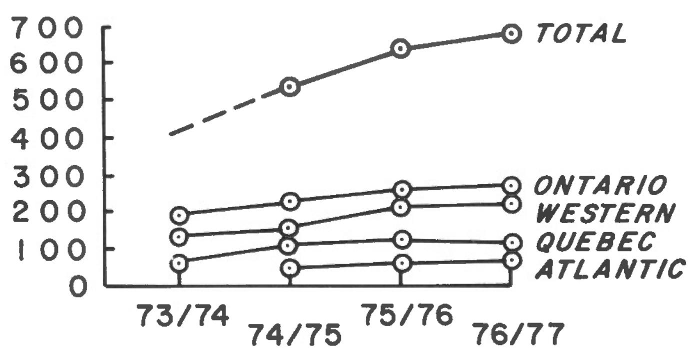

Figure 3.3. M.Sc. candidates.

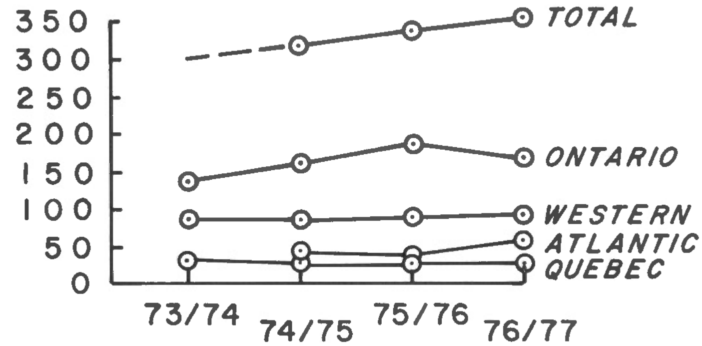

Figure 3.4. Ph.D. candidates.

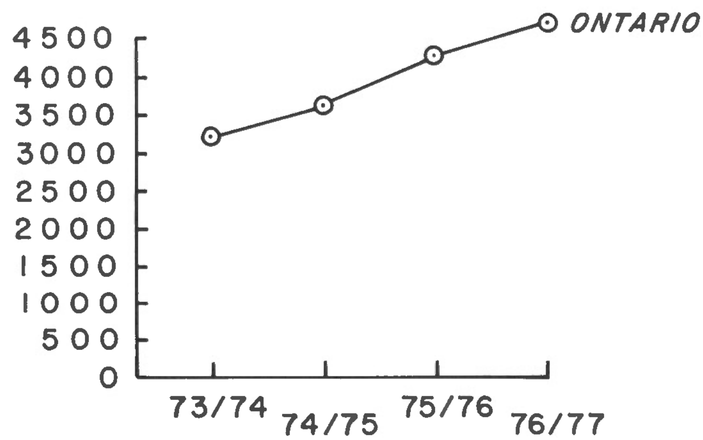

Figure 3.5. Students taking an introductory course in earth science.

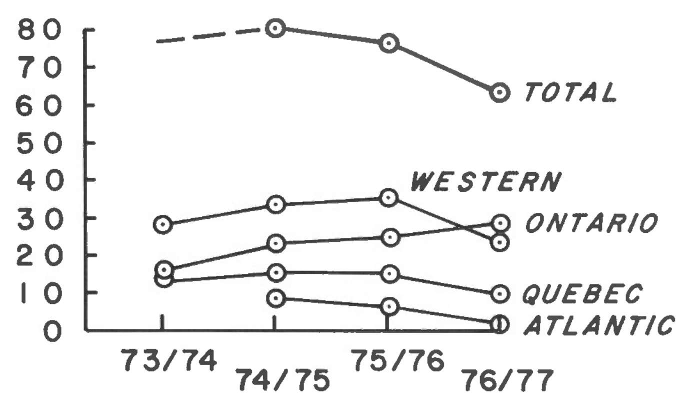

Figure 3.6. Post doctoral fellows and research associates.

The small number of these statistics makes them not very meaningful. In general it can be commented that post-doctoral fellowship and research associateship positions in Canadian universities are very small in number indeed. We assume that this is a category that should expect to grow as research problems become more complex. The few people who have these positions seem to go either to government or to university positions but not to industry.

General Observations

The graduates from Canadian universities either continue to graduate school in Canada or they are employed by industry and government in Canada. Very few leave the country to go on to graduate school or to seek employment. These data suggest that Canadian universities are almost exclusively serving Canadian needs. Contrary to the popular views that we are training people who have to leave the country for opportunities, we find in fact that we are training people who largely stay in Canada.

The data also suggest that most graduates are finding employment in all sectors. Future needs cannot of course be predicted by this type of survey. An interesting point is that, according to these statistics, very few Québec students are hired by the federal government at any of the levels reviewed here.

It is worth noting that last year's data on the earth science patterns was compared by personnel in the Ministry of State for Science and Technology with data compiled by

Table 3.4

First place of employment on graduation of Bachelor's Graduates

Bachelor's Graduates	ONTARIO [1]			QUEBEC [2]			ATLANTIC [3]			WEST [4]			TOTALS		
	73/74	74/75	75/76	73/74	74/75	75/76	73/74	74/75	75/76	73/74	74/75	75/76	73/74	74/75	75/76
Provincial Government	10	12	11	16	8	2	5	7	6	10	11	12	41	38	31
Federal Government	7	10	8	0	3	3	1	1	1	5	8	3	13	22	15
Foreign Government	0	2	1	6	0	2	1	0	0	0	3	0	7	5	3
Canadian Industry															
- mining	39	40	28	29	29	28	16	5	9	32	25	24	116	99	89
- petroleum	18	13	18	3	3	5	1	2	4	39	33	32	61	51	59
- other	5	13	78	1	1	19	1	1	1	16	4	5	23	19	33
Foreign Industry															
- mining	0	0	2	4	0	1	1	1	0	6	0	0	11	1	3
- petroleum	1	2	0	0	0	1	0	2	0	2	0	1	2	4	2
- other	0	1	0	0	2	0	0	0	0	5	1	0	5	4	0
Graduate School															
- Canadian	50	69	64	19	35	29	12	13	8	21	27	16	102	144	117
- Foreign	1	1	3	2	0	1	0	0	0	11	0	3	14	1	7
Teaching	6	5	12	2	1	2	3	5	3	5	0	0	16	11	17
Non-Earth Sciences	7	11	12	2	4	4	2	8	6	7	13	7	18	36	29
Unknown	30	37	42	40	39	15	9	5	4	43	42	70	122	123	131
TOTAL	174	216	209	124	125	112	52	50	32	201	167	173	551	558	535

[1] for 73/74 no report from Carleton, Guelph, Laurentian, Toronto Geophys., Western Geology; for 74/75 no report from Guelph, Laurentian, Western Geology; for 75/76 no report from Laurentian.

[2] complete reports for all years.

[3] for 73/74 and 74/75 no reports from University of New Brunswick; 75/76 data from Acadian, U.N.B. (Fredericton), Memorial and Mt. Allison.

[4] for 73/74 and 74/75 no report from Calgary, Alberta Geophys., and Brandon; for 75/76 no report from Alberta Geophys., and Brandon.

Table 3.5

First place of employment on graduation of Master's Graduates

Master's Graduates	ONTARIO [1]			QUEBEC			ATLANTIC [2]			WEST [3]			TOTALS		
	73/74	74/75	75/76	73/74	74/75	75/76	73/74	74/75	75/76	73/74	74/75	75/76	73/74	74/75	75/76
Provincial Government	7	9	8	1	8	1	2	1	2	2	6	1	12	24	12
Federal Government	2	1	2	0	0	1	2	3	0	2	1	0	6	5	3
Foreign Government	3	1	2	0	0	4	0	0	1	2	0	1	5	0	8
Canadian Industry															
- mining	4	10	7	9	8	8	5	2	3	4	5	4	22	25	22
- petroleum	2	12	7	0	0	2	0	0	0	11	5	4	13	17	13
- other	4	6	3	1	0	0	0	0	0	0	0	3	5	6	6
Foreign Industry															
- mining	0	1	3	6	0	2	0	1	0	0	1	0	6	3	5
- petroleum	0	1	1	0	0	0	0	1	0	1	1	1	1	3	2
- other	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
Graduate School															
- Canadian	3	11	14	9	12	2	4	1	2	1	5	3	17	29	21
- Foreign	6	3	4	0	0	1	1	0	1	0	0	0	7	4	6
Teaching	0	2	1	0	0	0	1	0	1	0	0	1	1	2	3
Non-Earth Sciences	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1
Unknown	1	1	2	2	1	1	1	1	0	2	0	2	6	3	5
TOTAL	32	58	54	28	29	22	16	10	10	27	24	21	103	121	107

[1] for 73/74 no report from Carleton, Guelph, Laurentian, Toronto Geophys., and Western Geology; for 74/75 no report from Guelph, Laurentian, and Western Geology; for 75/76 no report from Laurentian.

[2] for 73/74 and 74/75 no report from University of New Brunswick; 75/76 data only from Acadia, U.N.B. (Frederiction), Memorial and Mt. Allison.

[3] for 73/74 and 74/75 no data from Calgary, Alberta Geophys., and Brandon; for 75/76 no data from Alberta Geophys., and Brandon.

Table 3.6

First place of employment on graduation of Doctoral Graduates

Doctoral Graduates	ONTARIO[1] 73/74	74/75	75/76	QUEBEC 73/74	74/75	75/76	ATLANTIC[2] 73/74	74/75	75/76	WEST[3] 73/74	74/75	75/76	TOTAL 73/74	74/75	75/76
Provincial Government	2	3	3	1	0	2	2	1	0	0	0	2	5	4	7
Federal Government	3	3	4	1	0	0	2	3	0	3	0	0	8	6	4
Foreign Government	1	1	3	0	0	0	0	0	1	3	0	0	4	1	4
Canadian Industry															
- mining	0	4	2	0	0	1	1	0	0	3	0	2	4	4	5
- petroleum	1	1	0	2	0	1	0	1	0	2	0	1	5	2	2
- other	0	0	1	0	0	0	0	0	0	1	1	0	1	1	1
Foreign Industry															
- mining	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0
- petroleum	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
- other	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1
Post-Doctoral Fellowships and Research Associates	1	4	6	2	0	1	0	1	0	3	1	4	6	6	11
Faculty Positions	5	1	9	0	0	2	0	3	3	4	1	1	9	5	15
Teaching	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Non-Earth Science	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown	0	0	1	1	1	0	0	0	0	0	0	1	1	1	2
TOTAL	17	17	30	6	1	7	5	9	4	20	3	12	48	30	53

[1]for 73/74 no report from Carleton, Guelph, Laurentian, Toronto Geophys., and Western Geology; for 74/75 no report from Guelph, Laurentian, and Western Geology; for 75/76 no data from Laurentian.

[2]for 73/74 and 74/75 no data from University of New Brunswick; 75/76 data only from Acadia, U.N.B. (Fredericton), Memorial and Mt. Allison.

[3]for 73/74 and 74/75 no data from Calgary, Alberta Geophys., and Brandon; for 75/76 no data from Alberta Geophys. and Brandon.

Statistics Canada. It appears that the numbers are remarkably similar when we consider that we are including geology and geophysics groups even when these are associated with other departments. The same is true both for faculty and graduate students and it appears that our data are clearly supported. (Note: we did not show the number actually obtaining advanced degrees so this comparison is not meaningful and must be based on average stay times in graduate programs.) There is a large discrepancy in graduate student enrollments. This probably reflects the difference between students actually in residence and those officially included in provincial counts.

It is also interesting to note that Statistics Canada has no information on how graduating students in earth sciences are employed in the work force. This unique aspect of our compilations should continue for at least three more years to see if changing patterns develop. Since the current statistics are useful to ourselves in a general way, we should also continue to compile these and publish them in the annual Canadian Geoscience Council report. It is to be noted that since the chairmen collectively have started compilations, the quality of data that each department provides annually to the CIMM compilations has improved sharply.

Prepared by
D.W. Strangway
Chairman

SUMMARIES OF THE MAIN ACHIEVEMENTS OF THE CGC MEMBER SOCIETIES IN 1977

THE ASSOCIATION OF EXPLORATION GEOCHEMISTS

Although the Association of Exploration Geochemists (AEG) did not by itself sponsor any major scientific meetings in 1977, the Association was represented by J. Alan Coope as Geochemistry Convenor for "Exploration 77", an international symposium on geophysics and geochemistry applied to the search for metallic ores. The symposium, sponsored by the Canadian Geoscience Council was held in Ottawa, October 16-20, 1977. Additionally, the Association and some of its members were active in conducting and promoting geochemical exploration workshops in Lusaka, Zambia, and Denver, Colorado. A joint meeting organized by the Geological Society of Australia and the Association of Exploration Geochemists held a symposium on "Current Commodity Trends in Mineral Exploration and Evaluation with reference to Uranium, Tin, Tungsten, Chromium and Manganese" in Adelaide, Australia, December 5-7, 1977. The Seventh International Exploration Geochemistry Symposium to be sponsored by the AEG will be held in Denver, Colorado, in 1978.

The process of incorporation of the AEG under the Canada Corporations Act as a corporation without share capital was completed in 1977 following approval by the Members at the Annual General Meeting held in Vancouver, April 1977. Another landmark in the history of the AEG was reached with the election of H.W. Larkin, H.E. Hawkes, and J.S. Webb as the Association's first Honorary Members.

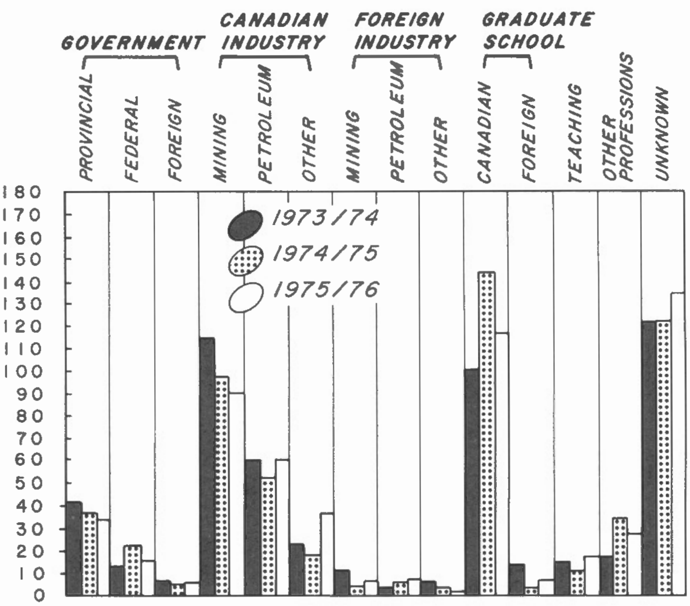

Figure 3.7. First place of employment of Bachelor's degree graduates.

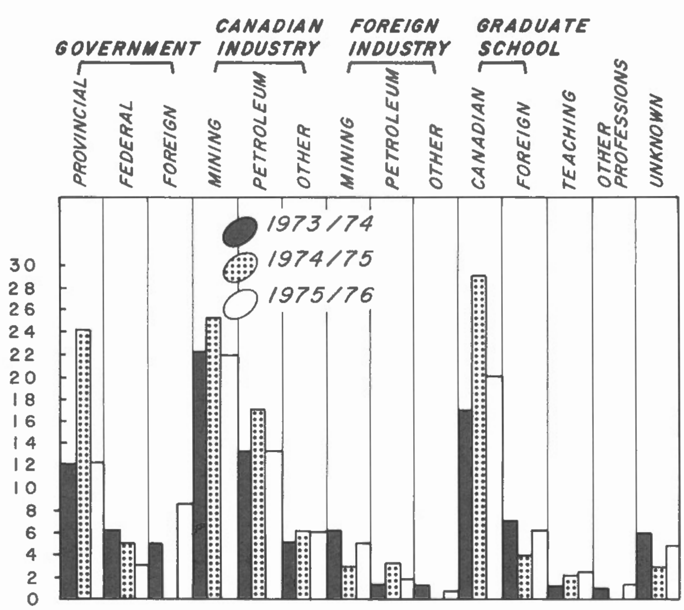

Figure 3.8. First place of employment of Master's degree graduates.

Subscriptions to the Journal of Exploration Geochemistry, the official scientific journal of the AEG, continue to grow and have now passed the 1250 mark. Negotiations are now underway to arrange for full-time students to receive the Journal at a reduced rate.

Membership in the Association continued to increase during the year with over 50 new Members admitted during the last meeting of Council. Membership on a world-wide basis now exceeds 550 with Canadians comprising 30 per cent of the total.

CANADIAN EXPLORATION GEOPHYSICAL SOCIETY

Throughout 1977, 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: Case histories of geophysical techniques leading to the discovery of new orebodies, discussions of several airborne geophysical systems, new induced polarization and ground electromagnetic instrumentation and interpretation procedures, and the GSC's new site for calibrating gamma ray spectral logging instrumentation for uranium assaying.

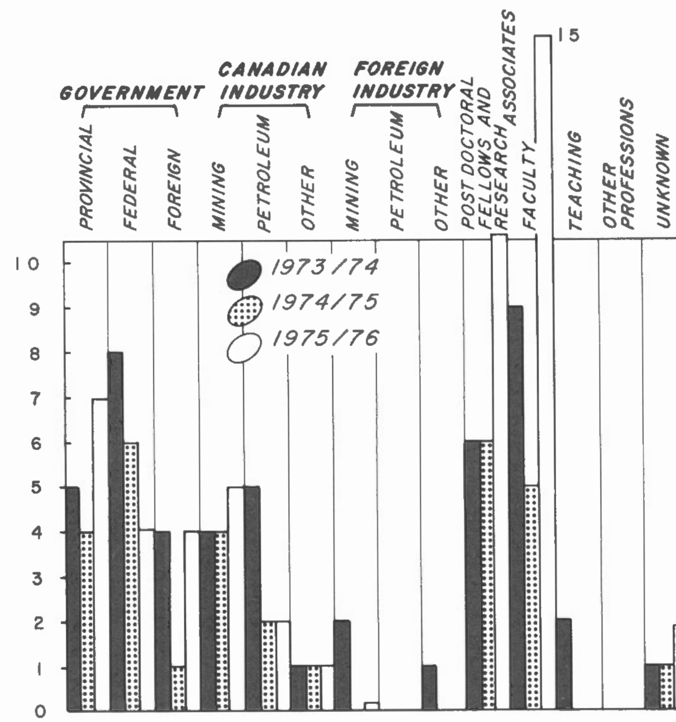

Figure 3.9. First place of employment of Doctor's degrees.

In conjunction with the Prospector's and Developer's Association Annual Meeting, a special "Eye Opener" breakfast was held. The guest speaker was S.H. Ward from the University of Utah who discussed exploration for geothermal resources in western United States.

During 1977, KEGS participated in discussions with the Ontario Government concerning the depressed state of mineral exploration in Ontario. KEGS is concerned about the future of the geophysical service and manufacturing industry presently located in Ontario (and Canada) and the general decline in exploration for new mineral deposits in Canada. KEGS participated in this discussion with the Ontario Government along with five other interested groups. The Society's main statement was that an overall climate of uncertainty and high risk for the mineral industry exists in Canada forcing exploration efforts elsewhere. The Society felt that the importance of the resource industry to Canada was not well appreciated and that if current trends continue, Canada will lose the highly specialized technological skills required to find new resources.

KEGS was one of the organizations participating in the CGC sponsored Exploration '77 Symposium on mineral exploration geophysics and geochemistry held in Ottawa in October 1977. KEGS members were on the organizing committee and a number of members presented papers.

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

CANADIAN GEOPHYSICAL UNION

Meetings

The Canadian Geophysical Union is a division of the Geological Association of Canada and of the Canadian Association of Physicists. In April 1977 we met jointly with the Geological Association of Canada in Vancouver. Don Russell very ably organized Canadian Geolphysical Union contributions and we had several successful sessions. In May 1978 we will meet for the first time independently in London, Ontario. Dr. H.C. Palmer is acting as the program chairman. KEGS (Canadian Exploration Geophysical Society) has arranged to co-sponsor one full day session on various aspects of Mining Geophysics. We will award the J.T. Wilson medal for "outstanding contributions to Canadian geophysics" for the first time at this meeting. In 1978 we will meet in Fredericton, New Brunswick under the chairmanship of P. Vanicek, where both KEGS and CSEG (Canadian Society of Exploration Geophysicists) will co-sponsor sessions with us on Mining Geophysics and Offshore Marine Geophysics respectively. We plan to meet with the GAC in Banff in 1979 and then in 1980 we are co-hosts to the American Geophysical Union meeting in Toronto.

Activities in Geophysics

There is no major status report on geophysics this year, and we have asked our national reporters to provide short statements of highlights in 1977. Detailed reports are incorporated in the annual Canadian Geophysical Bulletin produced by the Earth Physics Branch under the editorship of Prof. R.M. Farquhar.

Geomagnetism (M.E. Evans, University of Alberta)

Activity

Canada is richly endowed with geomagnetic phenomena and has a long history of excellence in their investigation. The North Magnetic Pole lies within its territorial limits, the auroral zone runs centrally through the Canadian landmass, crustal structure is such that several important induction and magnetotelluric anomalies are present, more than two billion years of geological history provide an almost unique geomagnetic 'tape-recording', and oceanic magnetic 'stripes' in the Atlantic and Pacific offshore regions provide examples of both 'active' and 'passive' continental margins. Two federal government agencies and about ten university departments are engaged in studying these and related topics, and some 50-100 scientists are involved.

Highlights

Marine magnetic anomalies have been successfully exploited to work out the details of crustal evolution in both the Pacific and Atlantic offshore areas. A wide variety of geophysical data including marine and aeromagnetic data has been shown to favour the idea that Canada's active western margin results from on-going subduction. Concurrently, landbased paleomagnetic data are beginning to establish the complex evolution of the West Coast, perhaps resulting from collision with fragments of a 'lost' continent — Pacifica. Electromagnetic induction studies on the Atlantic coast are thought by some authors to provide evidence of fossil subduction processes associated with the 'proto-Atlantic'. Thus, understanding of the fundamental geotectonic framework of Canada's continental margins is now well advanced.

Investigation of the magnetization of the ocean crust — so vital to the new global dynamics — has been greatly advanced by results from record penetration deep sea drillholes (>500 m); it is now clear that the source of the 'magnetic stripes' is much more complex than hitherto envisaged. Detailed study of older continental formations is establishing the widespread occurrence of polyphase magnetization, particularly in metamorphic and sedimentary rocks. New methods are being developed to properly isolate and interpret these distinct magnetic components, which promise to yield far more useful data than has been traditionally recovered. Paleomagnetism has always been based on the assumption that the geomagnetic field has been that of a dipole. A new test, incorporating data from the entire Phanerozoic, now lends strong support to this central concept.

The first reports of ancient magnetic fields as high as 16 oersteds have been published, using chondrules from the Allende meteorite. This suggests that the high fields proposed for the early solar system accretion stage may now have been directly detected.

Arrays of magnetic variometers have been deployed in several areas of Canada and have provided much important new data. A narrow conductor has been traced from the Southern Plains to the vicinity of Hudson Bay, and is regarded as marking the site of an ancient Proterozoic subduction zone. Audio frequency studies suggest that there are prominent conductive layers in the middle crust inferring perhaps the presence of pore space fluids. There have also been reports of sharp changes over a period of three years by factor of 2 or 3 in the electrical conductivity in the seismically active La Malbaie region, Québec.

Canadian space scientists have played an important role in the International Magnetospheric Study, particularly through the operation of large magnetometer arrays in Alberta and Manitoba. Research is being carried out in the areas of large scale current systems in the magnetosphere and ionosphere and in the field of geomagnetic micropulsations. Exciting new results are being obtained regarding the latitudinal and longitudinal asymmetries of auroral oval current systems and the localization of micropulsation disturbance regions.

Gravity (J. Tanner, Earth Physics Branch)

Acquisition of gravity data by federal and provincial government agencies in 1977 continued at approximately the same level as 1976. Major surveys were carried out by the Earth Physics Branch and the Atlantic Geoscience Centre in the Arctic, Hudson Bay, eastern Québec, and areas offshore from Newfoundland, Labrador and Vancouver Island. In the petroleum and mining industries, activity appears to be down from 1976. A significant proportion of government gravity work, including reference network and microgravity surveys, is now carried out by private contractors.

The Latin American Gravity Standardization Net 1977, compiled and adjusted by the Earth Physics Branch from survey data supplied by many nations was adopted as a reference standard for Latin America at the 1977 Quito meeting of the Pan American Institute of Geography and History.

Compilation and interpretation of Labrador Sea marine gravity data was completed and new gravity and bathymetric maps for the Arctic north of 60°N are in advanced preparation.

Geodynamic investigations included the detailed comparison of simultaneous satellite and astronomic observations for polar motion studies and precise gravity and continuous strain and tilt measurements in areas of high seismic activity. Models were developed for sedimentary basin formation in a viscoelastic lithosphere, lithospheric subduction under Vancouver Island, and tilt of Beaufort Sea pack ice.

The emerging technology required to measure gravity to the required precision for offshore, mountainous, and Arctic conditions, and for the application of satellite technology in geodynamics will require greatly increased capital expenditures.

Geodesy (D. Wells, Environment Canada)

Major developments in geodesy in Canada during 1977 were:

1. The application of inertial technology to geodesy (organizations involved are the Geodetic Survey, Earth Physics Branch, Canada Centre for Remote Sensing, University of New Brunswick, Shell Canada, Institute of Ocean Sciences). The highlight of this work was the "1st International Symposiumon inertial technology for surveying and geodesy", held in Ottawa in October 1977;
2. Continued work towards the redefinition of the horizontal and vertical geodetic networks in Canada, and on the maintenance of the redefined networks (Geodetic Survey, Land Registration and Information Service, University of New Brunswick);
3. Preparation of a map of vertical crustal movements in Canada (Earth Physics Branch, University of New Brunswick);
4. Continued work on transcontinental and intercontinental Very Long Baseline Interferometry (University of Toronto, National Research Council, Geodetic Survey);
5. Development of a better approximation to the gravity field and its components (Geodetic Survey, Earth Physics Branch, University of New Brunswick);
6. Sea surface topography from satellite altimetry (Bedford Institute, Dalhousie University, Geodetic Survey, Earth Physics Branch, University of New Brunswick).

Continuing major deficiencies in geodesy in Canada are:

1. Too few people well-qualified in geodesy, unequally distributed across Canada;
2. Insufficiently accelerated application of geodetic techniques in the marine environment, particularly in the light of the 200 mile offshore jurisdiction assumed by Canada in 1977.

Seismology and Physics of the Earth's Interior
(E. Kanasewich, University of Alberta)

Seismology was in a state of unprecedented activity during the past year. This is due largely to the increased demands for geophysical graduates with expertise in seismology in the efforts of exploration for hydrocarbon supplies. Most geophysics students are requesting to specialize in seismology and this has meant that seismological research has doubled or tripled over what it was two or three years ago. Resources at most University departments offering seismology have been taxed to the limit as a consequence. Canadian seismologists are also seeing the influence of the large American demand for seismologists due to the expansion of research into earthquake prediction and also the requirement for more environmental studies involving seismicity of nuclear reactor and hydroelectric dam sites.

A major crustal studies program involving near-vertical incidence seismic reflections was carried out by University and Canadian government scientists. The study also involved refracted arrivals and was in southern Manitoba near the boundary of the Superior and Churchill geological provinces. The co-ordination was headed by D.H. Wall from the University of Manitoba and Toronto. The funding was provided by the Department of Energy, Mines and Resources and seismologists from the Earth Physics Branch participated in some aspects of the experiment. It is hoped that this will be the first of a series of similar projects in various parts of Canada to help us understand the major structural boundaries of the continental crust and to provide insight into the processes by which the continent was formed. From such a fundamental upgrading of our knowledge it is hoped that a more scientific approach can be developed in the exploration for our natural resources. It is also hoped that new instrumentation and interpretation techniques will be developed which will be applicable to the exploration of energy reservoirs.

The major deficiencies stem from the effects of our high inflation rate on operating budgets. Most research groups have had to shift much of their research away from fundamental field exploration because of the high cost of field work. Computer modelling is very much in vogue as a result but without new real earth data, this will soon become a sterile exercise.

Geochronology and Stable Isotope Studies
(P. Reynolds, Dalhousie University)

The general level of productive activity in Canada over the past 12 months would appear to be up rather substantially. The national 'physical plant' has been expanded to some degree — for example, a new 'heavy isotope' mass spectrometer at the University of Alberta, new stable isotope facilities at the University of Western Ontario. Memorial University's proposed new laboratory will, in the future, provide some very much needed heavy isotope facilities in Atlantic Canada. Still, probably not more than about 100 people are at present involved in isotopic studies across the nation. Of these, about 30 are academic-professionals and the remainder are students and technical support staff. The emphasis in the geochronological community continues to be the more or less routine isotopic age determination work; the ages obtained form part of the basic data base of a wide spectrum of geologic projects. The general competence of Canadian labs continues to be high, at or close to the 'state-of-the-art' level in most cases. All the major isotopic fields have their representatives somewhere or other in the country.

The major deficiency in the complete system continues to be the general inadequacy of annual operating funds — money with which to support technical help and to replace obsolete equipment and thereby ensure the most efficient operation of existing facilities.

Exploration Geophysics (G.F. West, University of Toronto)

Exploration geophysics continued at a high level during 1977 in the fields of petroleum and uranium exploration. Demand for new geophysics graduates at the B.Sc. and M.Sc. level was strong, particularly in the petroleum area. While other mining geophysical activity in Canada was at a relatively low level, there still appeared to be unsatisfied demand for experienced mining geophysicists. Strong demand in the U.S.A. for R and D specialists in electrical methods to work in geothermal exploration and for Ph.D.'s in exploration geophysics to take academic positions may be partly responsible for the apparent shortage. Also, the year has seen a noticeable drift of experienced mining geophysicists from Canada to other countries.

Two major conferences on exploration geophysics were held in Canada during the year. The Society of Exploration Geophysicists held its annual international meeting in Calgary in September. About 5000 persons registered. The CSEG and KEGS are directly affiliated with the SEG and CSEG members were responsible for much of the local arrangements and program. In Ottawa, an international symposium on geophysics and geochemistry applied to the search for metallic ores (Exploration '77) was held in October under the sponsorship of the CGC and several of its member societies. Its purpose was to review the current state of the art via invited papers. About 600 persons attended, from some 25 countries. The GSC will be publishing complete papers from this conference and this will undoubtedly be a popular volume.

Technical developments in mining exploration geophysics in 1977 seemed evolutionary rather than revolutionary. In uranium exploration, the trend was to more quantitative and therefore more elaborate radiometric instrumentation and to using a wide variety of other geophysical techniques as indirect exploration aids. In base metals, interest continues in complex resistivity IP and in wide-band and time-domain EM. EM sounding methods are also growing in popularity for a variety of exploration purposes. Detailed accounts of new instrumentation for mining geophysics are to be found in P.J. Hood's annual review in the January issue of Canadian Mining Journal.

In the universities, undergraduate enrollments in geophysics seem steady or slightly declining. Graduate school enrollments are in noticeable decline. Worth noting, is that the new (1976) textbook, "Applied Geophysics" by Elford, Geldhart, Sheriff and Keys (3 of the 4 authors are Canadian) is being widely adopted in Canada and abroad for teaching exploration geophysics, particularly to geologists.

Mathematical Geophysics (E. Nyland, University of Alberta)

Mathematical geophysics in Canada continues to concentrate most of its activity in solid earth geophysics. Mike Rochester and his colleagues at Memorial University work on the theory of motions in the earth, C.H. Chapman at the University of Toronto and F. Hron at University of Alberta work on improved methods of synthesizing and analyzing seismograms. Geodynamics of non-linear materials is studied by G. Ranalli at Carleton University and E. Nyland at University of Alberta. Time series analysis continues at Universities of British Columbia, Western Ontario and others.

The level of mathematical geophysics in Canada is controlled largely by the need for such work in support of studies relating to physics of the earth. Although the level of activity in global geodynamics problems is adequate, university activity in technical support for such areas as earthquake risk analysis, response of the lithosphere to large engineering structures and improvements in seismogram analysis is not as high as it should be. This is due in part to the limited opportunity in Canada for specialists in this area (such limits are not apparent outside Canada). It is also due to the very limited support received for research in this area. If such research is to become more than an academic curiosity ways must be found both to prove to a doubting industry that there is value in the work and to meet the challenge for better funding available outside of Canada.

CANADIAN GEOTECHNICAL SOCIETY

The year 1977 has seen the Society continue its growth in membership to a total of 836, most of whom are associated with one of the 12 local sections established across the country. The year has also been marked by the final preparations for the publication (expected early in 1978) of the Manual on Foundation Engineering and by the establishment of four technical committees of the Society, i.e. on Foundations, Slope Stability, Tunnelling, and Dams and Embankments.

The 30th Canadian Geotechnical Conference was held in Saskatoon in October 1977 and was attended by 260 people. The theme "Geotechnical Aspects of Glacial Deposits" was well supported by subthemes on "Terrain Analysis and Subsurface Exploration", "Theory and Design Approaches" and "Case Histories and Construction Experience". Excellent keynote addresses opened each day's activities and were followed by a good variety of well presented papers. The papers on the first day were largely related to engineering geology as were the field trips. The Conference also marked the inauguration of the Canadian Geotechnical Colloquium. This was presented by Dr. J.F. Nixon of Calgary on the topic "Design Approaches in Geotechnical Engineering in Permafrost Areas". The Colloquium is to become an annual commissioned work, selected by the NRC Associate Committee on Geotechnical Research for presentation at the annual Geotechnical Conference. The 1978 Colloquium will be presented by Professor D.G. Fredlaud of Saskatoon on the topic of the "Engineering Behaviour of Unsaturated Soils".

The Conference of the International Society of Soil Mechanics and Foundation Engineering was held in Tokyo in July 1977 and was attended by 23 Canadian members. Ten Canadian papers were presented. Canada is now the third largest national society and is expected to play an increasing role in the activities of the International Society in the near future.

Two awards were made by the Canadian Geotechnical Society during the year. The R.F. Leggett award went to Professor Pierre LaRochelle of Laval University for his outstanding contributions to geotechnique in Canada and particularly in the Province of Québec, to the geotechnical program at Laval University, and to research into sensitive clays. Professor LaRochelle was also one of the members of the original Editorial Board of the Canadian Geotechnical Journal. The Society prize for the best paper published in the Journal in 1976, was awarded to Drs. H.K. Mittel and N.R. Morgenstern for their paper "Seepage Control in Tailings Dams".

The Society continues to be well served by its publications, The Canadian Geotechnical Journal under the firm editorship of Mr. Don Bazett of Vancouver and by the Newsletter published six times a year under the reliable hands of Mr. W.J. Eden of Ottawa. The Society also seeks to maintain communications amongst its membership by arranging two cross-country lecture tours each year. In 1976 these were presented by Dr. Lorne Gold of the NRC, Ottawa on Ice Engineering and by Professors D.H. Shields and J.D. Scott, University of Ottawa on the design of shallow foundations and bridge abutments.

CANADIAN SOCIETY OF EXPLORATION GEOPHYSICISTS

During 1977, new oilfield discoveries in Western Alberta acted as a catalyst for the geophysical industry. Toward the end of the year, the demand for seismic crews exceeded the supply. Along with the upsurge in activity, the Canadian Society of Exploration Geophysicists (CSEG) had an extremely busy year endeavouring to achieve its many objectives of science and fellowship.

To promote continual technical updating of the membership, courses were offered in Log Interpretation for geophysicists and Nigel Anstey's "The New Seismic Interpreter". An update in digital processing is planned for early next year. The education courses have proved to be most successful.

The Society still functions in close co-operation with its sister society the Canadian Society of Petroleum Geologists (CSPG). To provide fellowship and exchange of ideas between geophysicists and geologists, the CSEG and CSPG held a joint poster session in November with fourteen different displays. The session, entitled "Oyster and Intellect" was designed to get as much audience participation as possible in a social atmosphere.

In September the CSEG hosted the annual SEG convention. The organizational committees made up of CSEG members spent much time and effort in making this event one of the largest and most successful conventions ever held (5000 registrants).

The major activity on the horizon for 1978 is the 5th CSEG Convention, scheduled for May 10-12 in Calgary. The Conference theme is "Energy — A Geophysical Challenge".

The Alberta Government has announced a two-year extension to the Alberta Seismic Incentive Program, with a reduction by one-half in the amounts. The CSEG has forwarded a memo to the Alberta Government for its consideration on the proposed changes.

The Society continued to provide assistance in the form of scholarships to students at post-secondary institutions. At its annual meeting in February, members were recognized for their outstanding contributions, best paper, and Meritorious service.

CANADIAN INSTITUTE OF MINING AND METALLURGY

The Geology Division of the CIM participated in the CIM 1977 Annual Meeting in Ottawa with three half-day technical sessions as well as half day joint technical sessions with the Industrial Minerals Division and the Mineral Economics Committee. An innovation at the 1977 meeting was a short course in geophysics, presented by Dr. C.D. Anderson, which was very successful with over 40 in attendance. The Barlow Memorial Medal was awarded to Dr. D.R. Pyke at the Ottawa meeting for his paper "On the relationship between gold mineralization and ultramafic volcanic rocks in the Timmins area, northeastern Ontario". The medal is awarded annually for the best geological paper published in the CIM Bulletin during the preceeding year. Also at the Ottawa Meeting, the 1st prize for the Undergraduate student essay was awarded to J. Castonguay for the paper "Etude de dépôts d'ilménite de la région du lac Allard".

There was no prize awarded for the graduate student essay competition.

The Annual CIM Field Trip was held in the Flin Flon-Snow Lake area, October 2-6. This was arranged by representatives of the CIM Flin Flon and Snow Lake Branches. The Field Trip included underground visits to the Centennial, Anderson Lake, and Chisel Lake Mines and surface geology tours of the Flin Flon and Snow Lake areas.

At the end of 1976 Special Volume No. 15 "Porphyry Deposits of the Canadian Cordillera" was published by CIM for Geology Division. This special volume was edited by A. Sutherland-Brown and was dedicated to Charles S. Ney.

During the 1976-77 academic year the CIM University Visiting Committee Lecturers Program, organized by Geology Division, operated in 26 universities. These universities were divided into seven regions and involved eleven guest speakers. The objectives of the CIM University Visiting Lecturers Program is to provide visiting lecturers for universities, especially for those outside the "main flow" of visitors, and also to create a liaison between universities and industry and government as well as between universities. The 1977/78 CIM University Visiting Lecturers Program is organized in eight regions involving 31 universities.

CANADIAN SOCIETY OF PETROLEUM GEOLOGISTS

The CSPG comprises 2418 members, of which 2116 are active and the remainder are student, honorary, associate and corporate members. During the past four years, membership in the society has been increasing at an average rate of about 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, Québec, Dartmouth, Winnipeg, in Canada, and Houston in the United States. They keep in touch with the Executive of the Society in Calgary.

Principle Activities

Conferences, Symposia and Field Trips

The Society has been instrumental in staging the following symposia and field trips in 1977:

1. CSPG International Field Conference, Waterton Glacier National Parks, September 9 to 11.

   120 participated in the conference and field trip. Stratigraphy from the Precambrian to the Quaternary was examined.

2. Core Conference on the Geology of Selected Oil, Gas, and Lead-Zinc Reservoirs in Western Canada, November 24 and 25.

   Eight papers and a display by Gulf Oil were presented at the conference. 570 delegates attended.

3. The First International Symposia on Fluvial Sedimentology, October 20 to 22.

   A lecture series on Fluvial Sedimentology was held on October 19 and was followed by a research symposium on October 20 to 22. A volume based on the symposium papers will be published in 1978.

   Forty-eight papers were presented by the authors to about 170 delegates.

4. Field Trips

   (a) under initiative of the CSPG, the first university student field trip was held in 1977. A total of 31 third and fourth year students from across Canada took part. A trip to the Rocky Mountains and Drumheller areas was followed by visits to a number of oil and gas companies where exploration for oil, gas, coal and minerals was discussed.

   (b) a number of one-day field trips were held; the Jura Creek field trip was run on May 28 with a total of 40 participants from 26 companies; the Lake Minnewanka trip was held on June 25 with 110 participants from 45 companies; the Kickinghorse field trip was held on July 15 with 40 participants from 20 companies; and the Burnt Timber field trip was held on October 1 with a total of 40 participants from 22 companies.

5. National Conference on Earth Sciences was held May 2 to 6 at the Banff Centre for Continuing Education. The subject was Carbonate Reservoir Rocks. Presentations were made by Drs. Bathurst, Liverpool; Playford, Australia; P. Roehl, Consultant, Calgary and Wardlaw, Calgary.

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 a 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 1977 were:

1. The Bulletin of Canadian Petroleum Geology, a quarterly publication. During 1977, 60 papers were published in six issues.
2. CSPG Reservoir, which is published monthly, brings news to the membership of the Society's activities, reports from the Society's area representatives, and other items of general interest.

Speakers — Technical Program

1. Calgary Program — Perhaps the single most important activity of the Society is the Technical Speaker's Program. During 1977, 19 luncheon meetings took place in Calgary at which total attendance was more than 11 400 with an average attendance of about 600 per meeting.
2. Distinguished Lecture, Link Award, and Business Trip Talk tours are intended to bring the significant contributions of petroleum exploration geology of Canada to the attention of university geology students across Canada. Dr. W. Kerr of the CSPG presented his Link Award paper on controls for lead-zinc deposits of Cornwallis Island, while Mr. P. Gordy talked at 12 universities on gas fields in the Foothills of Alberta.

   Business trip talks are intended to take advantage of business where talks on petroleum geology can be given to students and staff of universities on rather short notice.

Other Education Programs

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

Business Affairs

Over fifty 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.

Highlights for 1978

A number of symposia, field trips, and conferences are planned for 1978. Some of the major events are as follows:

1. "Facts and Principles on World Occurrences of Hydrocarbons", conference sponsored by the CSPG will be held June 26 to 28.
2. Field trip and conference to the Hummingbird Reef, September 1978.
3. The CSPG student field trip will be continued.
4. Arthur A. Meyerhoff, visiting professor at the University of Calgary, will present two winter-term classes:

   — Petroleum and non-metallics

   — Topics in Global Tectonics and Earth Dynamics.

   He will conduct two seminars — global tectonics and earth dynamics in February, and petroleum exploration techniques used in the Soviet Union in March.
5. Other field trips and symposia are in the planning stage.

CANADIAN SOCIETY OF SOIL SCIENCE

The Canadian Society of Soil Science has members of which 15 are from outside Canada. There is an increasing awareness among members that soils are one of Canada's most important renewable natural resources. The interest in soils is reflected by the fact that members represent fields such as agriculture, forestry, land use planning, natural resources, geochemical prospecting, archeology, and physical geography.

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

i) Eleventh Congress of the International Society of Soil Science to be held in Edmonton, June 19-27, 1978 which will bring together several thousand Canadian and foreign participants. Over three hundred papers have been received from over 30 countries. Local, trans-Canada, and Arctic tours have been scheduled.

ii) Soil Methods Manual and Reference Soil Samples. "A Manual on Soil Sampling and Methods of Analysis", prepared by Agriculture Canada is now out of print in English and only a few copies in French remain. Critical comments on and corrections to the first edition should be sent to the Soil Research Institute, Agriculture Canada, Ottawa, K1A 0C6. It is anticipated that a revised edition will be printed in the near future.

Reference soil samples for various uses but especially methodology standardization have been prepared for distribution to those who apply to Mr. B.H. Sheldrick at the Soil Research Institute.

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

iv) 1977 Annual Meeting was held in Guelph in conjunction with the Agricultural Institute of Canada. The Soil Science Symposium reviewed the soil related activities in the research program to assess the effect of various land use activities on the pollution of the Great Lakes. The soil research described included stream-flow monitoring, for quantity of flow, chemical constituents, and sediment load; soil erosion and associated transport; transport of nutrients within soil and groundwater zone. Assessment of results is now underway. The next annual meeting will take place in Edmonton in June 1978.

The CSSS honoured four members with Fellowships in 1977 for their contributions to Soil Science.

v) A major contribution to the Canadian Geoscience Council Annual Report for 1977.

vi) Internal Organization. The historical connection of CSSS to Agriculture has tended to limit the scope of the society. In an effort to correct this the CSSS has appointed a task force to investigate and recommend operational procedures which will provide the best opportunity for CSSS to 'foster all branches of soil science'.

CANADIAN WELL LOGGING SOCIETY

The highlight of the activities of the Canadian Well Logging Society during 1977 was the bi-annual Symposium entitled "Formation Evaluation — the Team Approach". The Symposium was held in Calgary in late October. Thirty-one papers were presented covering the full range of formation evaluation subjects. Special attention was given to shaly sand log analysis. The President's Award for the best paper presented by a member of the Society during 1977 will be made early in 1978. An outstanding paper which was presented by a Society member to the October Symposium (Gas is Where You Find It — G.E. Dawson-Grove) has previously received an award from The Society of Professional Well Log Analysts in the United States.

Regular technical meetings were held from September to June with presentation of the usual array of topics on Formation Evaluation.

Ground work was laid for the planned "Seminars for Research" during 1977. Mr. R. Wyman has been appointed Chairman of the committee. This is a new direction for The Canadian Well Logging Society who hope to provide direction and co-ordination to the various research groups in industry, universities, and technical institutes.

The Canadian Well Logging Society journal is published annually. Contributions for 1978 are being received until the end of the year.

GEOLOGICAL ASSOCIATION OF CANADA

Over 1500 geoscientists, a new record for the Association, attended GAC's successful annual meeting in Vancouver in April 1977, held jointly with the Mineralogical Association of Canada and the Society of Economic Geologists. GAC's Cordilleran Section and Canadian Geophysical Union Division played a major role in conducting the meeting. Membership of GAC showed a slight increase in 1977, attaining a total membership of 2731.

Dr. A.R. Barringer of Barringer Research Ltd. was the 1977 recipient of the Logan Medal, in recognition of his outstanding and innovative contributions to exploration geophysics and geochemistry in Canada and abroad. Dr. C.R. Barnes of the University of Waterloo won the Past-President's Medal for his major contributions to the taxonomy and biostratigraphy of Lower Paleozoic conodonts, distinctive microfossils proving very useful in intra and intercontinental correlation.

Geoscience Canada, Geolog and the Canadian Journal of Earth Sciences (published by the National Research Council of Canada) are GAC's major periodical publications. Two Special Papers were issued during the year: "Conodont Paleoecology", edited by C.R. Barnes as Special Paper 15 and "Volcanic Regimes in Canada", edited by W.R.A. Baragar, L.C. Coleman and J.M. Hall, as Special Paper 16. Several more special papers are nearing publication, including "Siluro-Devonian Fossils", edited by D.E. Jackson, A.C. Lenz and A.E.H. Pedder. Also published during the year was Information Circular No. 3, "Sources of Free Materials for Canadian Science Teachers and Students", compiled by J.L. Rau. Guidebooks earlier published on "Vancouver Geology", and "Garibaldi Geology", have stimulated requests for production of popular guidebooks to the geology of other parts of the country: W.H. Mathews has agreed to serve as guidebook editor.

Divisions continue to play a useful role in GAC activities. Special Paper 16 on Volcanic Regimes in Canada is a direct result of the efforts of the Volcanology Division. The Paleontology Division hosted the 1977 Eastern Canadian Paleontology and Biostratigraphy Seminar held in October at the University of Waterloo; Environmental Earth Sciences Division (central Canada region) held a two day conference at Sir Sanford Fleming College, Lindsay, Ontario, in November. Other Divisions, including Structural Geology, Canadian Geophysical Union, and Precambrian, are planning symposia at forthcoming annual meetings, or separate meetings. GAC Sections include Cordilleran (Vancouver and Victoria branch), Edmonton, Winnipeg, St. John's; the Atlantic Geoscience Society is an affiliated society based in Halifax. These and a number of university geoscience departments were visited by Dr. Harold Williams, GAC's 1977 annual lecturer and 1976 Past-President's Medal winner. Dr. Williams' talk was entitled "The Appalachian Orogen: A Model for Paleozoic Plate Tectonics".

At the request of the Provincial Mines Ministers, a brief entitled "Geosciences in the Provinces" was prepared and delivered for GAC at the 34th annual Provincial Mines Ministers Conference, held in Québec City in September 1977. It is reproduced in shortened form in this publication.

Plans are well underway for the 1978 Annual Meeting in Toronto to be held in association with MAC and the Geological Society of America, together with its attendant associations and societies. Following Annual Meetings will be held in Québec City, Halifax, Banff, and Winnipeg.

MINERALOGICAL ASSOCIATION OF CANADA

The 1977 annual meeting of the Association was held in Vancouver in April, jointly with the Geological Association of Canada, The Society of Economic Geologists, and the Canadian Geophysical Union. MAC-sponsored sessions consisted of "Geothermometry and Geobarometry of Mineral Deposits", "Research in Sulphide Geochemistry of Mineralogy", "Low Grade Metamorphism and Hydrothermal Alteration" and "General and Experimental Petrology". MAC also sponsored a pre-meeting short course on "Application of Thermodynamics to Petrology and Ore Deposits", which has been published as a short course handbook, Volume 2, edited by H.J. Greenwood. The 1978 annual meeting in Toronto, will include a short course entitled, "Uranium Deposits: Their Mineralogy and Origin", with M. Kimberley as organizer.

The Association's regular publication, the Canadian Mineralogist (Editors: L.J. Cabri, J.L. Jambor (retiring), R.F. Martin (incoming)) consisted of four issues, including a special issue devoted to "Silicate Melts and Magmas" (C.M. Scarge and A.J. Piwinskii, editors) and "Garnets" (E.D. Ghent, editor), stemming from symposia on these topics held at the 1976 Edmonton annual meeting. Financial aid for these issues was received from the National Research Council of Canada, the Geological Survey of Canada and the Canadian Geological Foundation. The 1978 publication year will see an issue dedicated to Professor J.D.H. Donnay.

Membership in the Association increased by some 13 per cent in 1977 to a total of 1783, of which combined ordinary and student memberships surpassed the 1000 mark. Student memberships included 25 membership prizes awarded for the first time this year to outstanding students in introductory mineralogy courses in universities across Canada.

The Hawley Award was presented jointly to Drs. F.J. Wicks and E.J.W. Whittaker for their paper on the structures of serpentine minerals, judged to be the best publication in the Canadian Mineralogist. Five nominees and three alternate names were submitted from among the Association membership for receipt of the Queen's Silver Jubilee Medal.

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