GSCHIS-A003.pdf

Author: John S. Scott

Title: Terrain Sciences Division, Geological Survey of Canada: Its Origin and History from 1972 to 1987

Date of this version: April 2007

Number of pages in document: 95 pages

Author Biography:

John S. Scott graduated from McMaster University (B.Sc. 1953) and from the University of Illinois, Champagne-Urbana (Ph.D. 1960). He then joined the GSC as an engineering geologist where he worked on a study of slope failures in Upper Cretaceous shales of the Prairie provinces, reconnaissance engineering geological investigations of potential tidal power sites in the Bay of Fundy, and advising the Manitoba Water Control and Conservation Branch on possible hydrogeological problems that could be encountered during construction of the Red River Floodway.

In 1967 he joined H.G. Acres Consulting Engineers, Niagara Falls to broaden his experience in engineering geology on commercial construction projects, and during the next two years gained valuable experience in the application of geology and hydrogeology to tunnels, dam sites, industrial plant foundations and a major tidal power project. In 1968 he was invited by Dr. C.H. Smith to participate in a Science Council of Canada study of the Solid Earth Sciences in Canada with responsibility for the geotechnical aspects and he returned to the GSC in 1969. In 1974 he was appointed Director, Terrain Sciences Division and held this position, as well as responsibility for Departmental participation with Atomic Energy Canada Limited in the Nuclear Fuel Waste Management Program, until 1987 when he was appointed Director General, Terrain Sciences and Geophysics Branch following amalgamation of the Geological Survey and Earth Physics Branches. Following further changes in 1989 he was appointed Director General, Sedimentary and Cordilleran Geology Branch. Dr. Scott retired from the Geological Survey at the end of March, 1993 and was appointed scientist emeritus. In April, 1994 he was invited by the Departmental Siting Task Force for Low level Nuclear Waste Disposal to serve as a senior science advisor and continued in this capacity until the conclusion of the Task Force in September, 1995.

His review of factors affecting slope stability in marine clays of the Ottawa valley was published in 2003 as GSC Open File 4475 on the geological and geotechnical characteristics of Champlain Sea clays in the Ottawa River valley. He completed his term as a scientist emeritus in April, 2007 with the submission for publication as a GSC Open File of his account of the development of Quaternary Geology in the Geological Survey and the history of Terrain Sciences Division during the period 1972 - 1987.

GEOLOGICAL SURVEY OF CANADA

OPEN FILE

Terrain Sciences Division, Geological Survey of Canada
Its Origin and History from 1972 to 1987

J.S. Scott

2007

TERRAIN SCIENCES DIVISION, GEOLOGICAL SURVEY OF CANADA
Its Origin and History from 1972 to 1987

PREFACE

Introduction

Prior to his departure from Terrain Sciences Division in 1999, through promotion to Branch level,7 Dr. J-S Vincent, then Director, Terrain Sciences Division, asked me if I would consider preparing an historical account for the Division for the period (1972-1987) during which time I was Division Director. I agreed to this request but without specification as to schedule or format. It is now 7 years since Dr. Vincent made his request and approaching 20 years since I left Terrain Sciences Division. Thus, it is perhaps time for me to attempt an historical account before memory fades further and file documents for that period become even more difficult to locate.

The principal objectives of this historical account are to record the various events, activities and achievements of the Division, to highlight some of the important contributions of the scientific staff during my tenure as Division Director and to record some of the challenges that I faced in assuming responsibilities as manager of a scientific unit. I have attempted to present a reasonably objective historical account of the activities of Terrain Sciences Division during my term of service as Division Director. It will become apparent, however, to any reader familiar with the work of the Division during the account period, that historical objectivity may well be strongly influenced by my personal recollections and viewpoints.

In addition, however, this account also provides an opportunity to place in perspective the role of Quternary or surficial geology within the Geological Survey of Canada since its` inception in 1842, and to provide some information on how Quaternary geology and related activities became integrated into the organizational structure of the Geological Survey.

Within the Geological Survey during my time as a Division Director, and no doubt well before that time, Division Directors were accorded a fair degree of latitude in the formulation and conduct of the scientific program to be undertaken by their Division within the overall mandate of the Survey as established by a long succession of Acts of Parliament, Cabinet directives and imperatives developed by senior levels of government departments. Thus, the Director's influence upon the scientific program may well derive from that person's training, experience and scientific interests. Accordingly, the following brief account of my background may assist in understanding some of the program initiatives and directions taken within Terrain Sciences Division during the time that I served as a member of its scientific staff and later as Division Director.

Autobiographical notes

My undergraduate degree (B.Sc.) in geology was obtained from McMaster University, Hamilton, Ontario in 1953. For the most part the elective courses in geology that I chose were in the field of sedimentary geology. Following graduation I was employed by the

Photographic Survey Corporation, Toronto as part of a field crew assigned to reconnaissance geological mapping of the southwestern part of what was then West Pakistan. This work, undertaken as a Canadian contribution to the Colombo Plan, covered about 130,000 square miles, required two years of field work for about twelve geologists and another few years of map compilation and report work for several geologists in Toronto. While in Pakistan the headquarters for survey project was located in Quetta, the principal city of the Province of Baluchistan and also, both then and now, the location of the headquarters of the Geological Survey of Pakistan. At the time Quetta was a most pleasant place located along 30°N. Lat. at an elevation of about 1,600m which provided for a year round agreeable climate in a hot, arid country. The airstrip at Quetta was convenient for the aerial photography that preceded the geological and later soil surveys. The city was also a major regional base for units of the Pakistan army and was the location for a military command and staff college that had been established during the earlier British presence in India.

The experience in Pakistan proved to be excellent training in geological observation, data and sample collection, map compilation, cross section preparation and geological formation description writing. The experience also stimulated an interest in geology applied to engineering works and hydrogeology.

Thus, in 1957 I accepted an opportunity provided by the University of Illinois, Champagne-Urbana to enroll in post graduate studies with a major focus upon Quaternary geology, engineering geology and hydrogeology and a minor focus upon Civil Engineering (soil mechanics). During this time I was afforded an opportunity by the Geological Survey of Canada to undertake a field mapping project in the Elbow-Outlook area of Saskatchewan which contained the site of the Gardiner Dam on the South Saskatchewan River, upon which construction was then just beginning. This work formed the basis for a Ph.D. thesis, which along with successful completion of course work and other requirements enabled the university to grant me a Ph.D. degree in the spring of 1960. The University of Illinois enjoyed a close relationship with the Illinois State Geological Survey which was then undertaking pioneering work in the application of geological studies to various environmental issues including urban areas. This influence was later to have an impact on work at the Geological Survey of Canada.

Upon completion of studies at the University of Illinois I joined the Geological Survey of Canada on a continuing basis and returned to the Outlook area, Saskatchewan to complete surficial geology mapping of N.T.S. map-area 72 O. In the fall of 1960 I relocated to Ottawa and joined the Engineering Geology and Hydrogeology Section then headed by Dr. I.C. Brown. This unit was part of the Economic Geology Division then under the direction of Dr. Y.O. Fortier.

Career highlights over the next several years included my assignment as a hydrogeological consultant to the Manitoba Water Control and Conservation (WCC) Branch then responsible for design and construction of the Red River Floodway. It became immediately apparent that the WCC Branch required a full time hydrogeologist and they made a wise choice in the selection of Mr. Frank W. Render who did an excellent job of acquiring and analysing the hydrogeological information required to resolve construction and offsite impact issues resulting from the Floodway project. The Geological Survey of Canada also produced a report[1] that had a significant impact on both the scheduling of construction to avoid problems of groundwater inflow and in determining the extent to which Floodway construction would cause groundwater table lowering in the surrounding area. Further highlights included my appointment during the 1960's as a member of the National Research Council's Associate Committee on Snow and Soil Mechanics chaired by Dr. R.F. Legget then Director of the NRC Division of Building Research. This Committee was later to become the Associate Committee on Geotechnical Research mainly under the chairmanship of Victor Milligan of Golder Associates, Consulting Engineers. I once again served as a member of this Committee from 1979 - 1986.

In 1965 I became involved in trying to control flow from the "Coldstream Ranch well". The "well" resulted from stratigraphic drilling on Coldstream Ranch property east of Vernon, B.C. as part of a Quaternary geology project in the area by R.J. Fulton. At a depth of about 150 feet the rotary drill encountered a high pressure flow of groundwater that proved to be both difficult and expensive to bring under control. A report[2] describing the initial attempts to bring the flow under control was published by the Geological Survey of Canada. Although the flow was never stopped it was some years later before it was stabilized by further remedial action.

During the mid-1960's the Hydrogeology group within the Geological Survey of Canada was transferred to the Inland Waters Directorate, a part of a newly-formed Department of Energy, Mines and Resources. This Directorate was later to become part of the new Department of the Environment. The departure of the hydrogeology group from the Geological Survey left two engineering geologists (E.B. Owen and me) on their own. By 1967 I concluded that I might benefit from industrial experience in engineering geology thus I accepted the offer of a position in the Geotechnical Department of H.G. Acres and Company, Consulting Engineers, Niagara Falls, Ontario. This experience provided an opportunity for direct involvement in geological and hydrogeological investigations directly related to the design and construction of dams, tunnels and industrial structures. Moreover, the commercial work environment provided a particular appreciation of the value and cost of employee time in the provision of professional service and the need for accountability for time in the conduct of a project. This concept of time accountability, based upon a profit motive and a need for accountability in client billing, was not one that found ready acceptance, either then or later, within the Geological Survey.

---

[1] Hobson, G.D. Scott, J.S. and van Everdingen, R.O. 1964, Geotechnical investigations, Red River Floodway, Geological Survey of Canada Paper 64-18 .

[2] Scott, J.S., 1968, Flow Control Program, Coldstream Ranch Well, Vernon, British Columbia, Geological Survey of Canada Paper 67-56.

The experience gained while at Acres was particularly valuable and in1968 I was asked by Dr. C.H. Smith, then Chief, Crustal Geology Division, Geological Survey of Canada and project officer for the Science Council of Canada, Solid Earth Sciences Study Group, to become a member of the Study Group to deal with geotechnical and related matters. The management at Acres agreed to my participation in the study and I was able, to the extent work commitments allowed, to participate in site visits and other work of the Study Group. Participation in the Study Group in general, and in particular through providing authorship for Chapter V, "Geotechnique and the Physical Environment" contained in the Science Council of Canada report[3] provided a perspective on then current issues and priorities in earth sciences of concern to Canada.

Structural changes occurred within H.G. Acres and Company not long after I had joined the company which limited the opportunities that had previously existed for participation in the company. I remained with H.G. Acres and Company until June 1969 at which time I resigned and rejoined the Geological Survey of Canada. I was then assigned to the relatively new Quaternary Research and Geomorphology Division under the direction of Dr. John G. Fyles.

At that time I brought with me continuing responsibilities for participation in the Solid Earth Sciences Study Group and I was assigned responsibilities for activities in engineering geology and related projects.

Among the recommendations contained in the Science Council's report are the following that pertain to the interests of Terrain Sciences Division:

Conclusion V.3, p.236:

"Provincial governments should accelerate their detailed geological mapping (at scales of 1:50,000 or larger) of the urban and surrounding population growth areas, with particular emphasis on surficial materials, land forms and hydrogeological data. Federal government agencies should assist in these programs, particularly in individual pilot studies, and provide geotechnical compilations and analyses of national interest."

Conclusion V.11, p.249:

"New geotechnical programs within the various of responsibility of federal and provincial government agencies should be directed toward providing new knowledge in the fields of urban geology, engineering geology, rock mechanics, hydrogeology, muskeg and permafrost, as an aid to national development and to increasing Canadian geotechnical competence and manpower capacity in these fields."

---

[3] Science Council of Canada, 1971, Special Study No. 13, Earth Sciences Serving the Nation

Conclusion VI.6, p.264:

"Geological mapping agencies in Canada, and particularly agencies of provincial governments, should increase markedly their output of geological work oriented specifically to environmental and land use planning. This work should be concerned with bedrock as well as unconsolidated earth materials and terrain."

Conclusion VII.4, p.282:

"The Government of Canada should establish a task force to study its present allocation of financial and personnel resources to the national survey of "surficial geological" materials and to formulate a plan toward co-ordinating and accelerating the federal effort to meet rising needs of urbanization, groundwater resources, engineering construction, waste disposal and pollution, as well as the continuing needs of agriculture."

It will become apparent in subsequent parts of this account that much of the substance of the foregoing recommendations contained in the Science Council report were incorporated into the scientific program of Terrain Sciences Division.

Acknowledgements

I am grateful to Natural Resources Canada and the Geological Survey of Canada for my post-retirement appointment as a scientist emeritus and for the accompanying provision of office and clerical support that have facilitated the preparation of this account. Dr. Charles H. Smith generously shared the results of his research into the contributions of Sir William E. Logan to the understanding of Canadian Quaternary geology materials and features. This information, which pertains particularly to the period from the inception of the Geological Survey in 1842 until the publication of the first comprehensive report on the geology of Canada in 1863, is reflected in the following section on the development of Quaternary Geology in the Geological Survey. I am also indebted to Ms. Sharon Parnham of the Geological Survey for her capable assembly of my disaggregated components of this account. I am also grateful to my long-term colleagues at the Geological Survey Dr. Weston Blake, Jr. and Mr. J. A. Heginbottom for their most helpful comments and suggestions arising from their critical review of this report. Dr. R.N.W. DiLabio kindly provided helpful identification of Divisional scientific staff who were involved in various projects supported by the Federal/Provincial Mineral Development Agreement Program that was active during the period 1984 - 1987.

DEVELOPMENT OF QUATERNARY GEOLOGY WITHIN THE GEOLOGICAL SURVEY OF CANADA

Prior to founding of the Geological Survey of Canada in 1842, by W.E. Logan, various explorers and scientists in Canada had made observations on the unconsolidated materials found above the underlying bedrock and upon landscape forms, flora, fauna and other elements of natural history. These observations, for the most part, were isolated one from another and no attempt had been made in any area to undertake systematic observations aimed at understanding the origin, composition and properties of surficial materials.[4]

Louis Agassiz (1807-1873)[5], a prominent Swiss-American naturalist, had proposed in 1837 that continental glaciation was the "great agent" for the creation of striations on bedrock surfaces and for the distribution of deposits of erratic boulders and unsorted clays. His views were countered by those of Charles Lyell (1797-1875), a well known British geologist, who favoured an ice berg origin for the formation of these "drift" deposits[6].

In his report for the year 1845-46 Logan[7] records in a section entitled "Glacial Action" observations made on alluvial materials in the Ottawa area and, in particular, on grooves, polished surfaces and gravel deposits that he observed along the shores of Lake Temiskaming in the upper Ottawa River valley. With respect to these gravels and other features Logan noted (p.73) :

"The mass is not unlike the remains of an ancient *moraine,* and, combined with the smooth rounded surfaces, and parallel grooves and scratches, and the changes in their direction, the circumstances of the case may well suggest that this part of the valley of the Ottawa may have been the seat of an ancient glacier".

This interpretation of his observations clearly indicates that with respect to glacial materials and features Logan subscribed to the views of Agassiz rather than those of Lyell.

During the 1850s, GSC geologists - W.E. Logan, A. Murray and J. Richardson - routinely recorded information on the composition of the drift, and the location and direction of grooves (striae) in their annual reports. This information was later summarized in the section on *Superficial Geology* which appears on pp. 887-930 of the Geology of Canada, 1863

A few years prior to the publication of Logan's report on the geology of Canada the Canadian and British governments launched two expeditions for the exploration of the territorial regions of western Canada. The British expedition (1857-60) was headed by Captain John Palliser with James Hector, M.D. as naturalist and geologist. This expedition explored the country between the 49th and 54th parallels from the prairies through the Rocky Mountains and west to Vancouver Island. The Canadian expedition (1857 and 1858), under the direction of Prof. Henry Y. Hind of Trinity College, Toronto covered the southern part of the area west from Lake Superior to the eastern part of what is now the province of Saskatchewan. Both Hector and Hind observed the thick glacial drift that covered the prairie region as well as other glacial

4 Fulton, R.J., 1989: Foreword to the Quaternary Geology of Canada and Greenland; *in* Geology of Canada and Greenland, R.J. Fulton, (ed.); Geological Survey of Canada,no. 1 (*also* Geological Society of America, The Geology of North America, v. K-1)

5 1993-1999 Microsoft Corporation, Microsoft Encarta Encyclopedia 2000, contribution by Newton E. Morton

6 Silliman, Robert H., 1994: Agassiz vs. Lyell: Authority in the assessment of the diluvium-drift problem by North American geologists, with particular reference to Edward Hitchcock; Earth Sciences History, v.13, no.2, pp 180-186.

7 Logan, William E., 1847: Geological Survey of Canada, Report of Progress for the year 1845-46, p.71-75.

features. Both accepted[8] the then prevailing theory of the deposition of drift from floating icebergs and attempted to account for moraines and other features as a result of erosion.

In 1863 Sir William Logan[9] published a major report on the geology of Canada accompanied by a folio of maps and sections illustrating both bedrock and surficial geology. These maps were the forerunners of a series of national maps portraying the bedrock and surficial geology of Canada that the Geological Survey has published at intervals throughout its history up to the present time. In Logan's time, however, Canada's geographic extent was much less than at present. The map of "superficial" deposits that accompanied the report portrayed those along the south side of the St. Lawrence River from Gaspé to Quebec City, in the Lake St.John area of the Saguenay River, west along the St. Lawrence River to Kingston, west along the Ottawa River to Ottawa, Lake Nipissing and Sault Ste. Marie, and into southwestern Ontario bounded by Georgian Bay and the Great Lakes.

The "superficial "deposits portrayed on the map accompanying Logan's 1863 report on the geology of Canada were referred to as diluvium or drift and were grouped into three principal categories. The first and oldest category of the succession, although not shown on the map of 1863, was designated as boulder formation or glacial drift. The second category, separated into lower and upper deposits for western and eastern Canada respectively, consisted of clays, sands and gravels. These materials were in turn overlain by younger deposits of marl, peat, bog ores of iron and manganese and alluvium. The account of the superficial geology in the 1863 report contains extensive descriptions of the type and character of the boulders found in the glacial drift and extensive lists of the location and attitudes of glacial grooves that had been observed and measured.

Authorship of the section on Superficial Geology contained in the 1863 report is not clear from the report itself but it is obviously based upon the work of Logan and Murray. In the absence of definitive attribution of authorship for the section on Superficial Geology, Zaslow [10] attributed such authorship to Logan. Zaslow also noted that in spite of observations and measurements on glacial features Logan remained perplexed by the evidences of glaciation that he encountered in his pioneering geological survey work. This interpretation of Logan's position on glacial features is rather contrary to Logan's views as contained in his 1845-46 report as noted above.

By 1870 Agassiz's glacial theory was generally accepted in North America but the delay in its widespread adoption, particularly in Canada, has been attributed[11] to the influence of Sir William Dawson who maintained, even until his death in 1899, the iceberg theory as a sort of respect for Lyell. The divergence of opinion between Agassiz and Lyell on the origin of glacial features is due to Agassiz's observations on the effects of alpine glaciers as well as floating ice in coastal regions whereas Lyell was more familiar with the effects of floating ice. Lyell also perhaps enjoyed the greater stature and reputation in North America as a geologist and thus exerted greater influence on geological thought.

---

[8] Zaslow, Morris, 1975: Reading the Rocks; The story of the Geological Survey of Canada 1842-1972 ,The Macmillan Company of Canada Limited, Toronto, 599 p. p.107

[9] Logan, William E., Alexander Murray, T. Sterry Hunt, and E. Billings [The Geology of Canada] *Geological Survey of Canada: Report of Progress from its commencement to 1863.* Dawson Bros. Montreal.

[10] Zaslow, op. cit. (p.44),

[11] Silliman, op. cit. (P.184)

Throughout most of the 19th century work on surficial geology by the Geological Survey was included as part of general field surveys which, by the end of that century, had extended to cover much of the western, northern and eastern parts of mainland Canada. Notable contributions to the understanding of the character, distribution and origin of glacial deposits is found within the reports[12] of Robert Bell, G.M.Dawson, A.P. Low, J.B. Tyrell and D.B. Dowling. Among about twenty field geologists employed by the Geological Survey during the latter part of the 19th century only one, Robert Chalmers[13] (1882-1908) was primarily concerned with glacial geology. Chalmers performed excellent surficial geological work in the Maritimes, southern Quebec, St. Lawrence lowlands and in western Canada. Chalmers might well be designated as the Geological Survey of Canada's first surficial geologist and, with respect to his primary responsibilities and the substance of his reports, such a designation could be fairly claimed.

It is of interest to note, however, that authorship of the section on surface geology contained in Logan's 1863 report was later claimed by Robert Bell[14]. Bell commented that since writing the section he paid particular attention to the subject of glacial geology. Bell commented further[15] that with respect to glacial action:

"The proofs are innumerable that the denuding agency could have been nothing but land ice acting as a semi-fluid. There is no evidence that ice-bergs or other forms of floating ice had anything to do with the erosion."

and:

"To those who have seem (sic) much of the glacial phenomena in Canada, it seems incomprehensible that any man calling himself a geologist could believe these phenomena to have been produced by ice-bergs, provided he had opportunities of observing at all. Such totally unsupported views could only be held on the "authority" of some of the older geologists who paid more attention to theory than observation, . . ."

While Chalmers deserves recognition as the Geological Survey's first surficial geologist per se., Bell's account of glacial phenomena in Canada based upon over 25 years of his field observations and interpretations regarding glacial materials and processes, are sufficient to accord him a place of prominence and respect in the annals of Canadian surficial geology. The work of Chalmers and others on the Pleistocene regarding past and present landforms and materials was of great practical value as Survey geologists were asked to provide advice on such matters as locations of sand and gravel, landslides, water supplies etc.

In 1907 the Geological Survey of Canada published a report by J.W. Spencer on *The Falls of Niagara*. This work was a major contribution to understanding of the origin of the falls, the magnitude of the Niagara River and its potential for water power. An interesting account of Spencer's education and career as a geologist is given by Middleton[16]. From this account it is

---

12 Zaslow, op. cit. p.193-194

13 Zaslow, op. cit. (p. 194), Note: years in parentheses denote period of service with Geological Survey

14 Bell, Robert, 1890: On glacial phenomena in Canada, Geological Society of America, Bull. v.1, p.287-310.

15 Bell, Robert, op. cit. p.292

16 Middleton, Gerard V., 2004, J.W. Spencer (1851-1921): his life in Canada, and his Work on Preglacial River Valleys, Geoscience Canada, v.31, no.2, p.49-56.

noted, as a matter of personal interest and coincidence, that J.W. Spencer was born in 1851 in the present author's home town of Dundas, Ontario and that Spencer was also buried there in 1921.

Impediments to the development of any sort of systematic understanding of the Quaternary geology of Canada during preConfederation time and even toward the end of the 19th century can be attributed to two principal factors. The first may be found in the relatively few scientists of the time with an interest in the subject. The second factor may well have been, as noted by Silliman[17], the prolonged divergence of opinion between Lyell and Agassiz regarding the origin of glacial drift that persisted throughout much of the 19th century. In spite of Agassiz's more plausible theory of glaciation Lyell's prominence and scientific authority appear to have influenced Sir William Dawson of McGill University and his son G.M. Dawson, a prominent Geological Survey geologist (1875-1895) and Director of the Survey (1895-1901) to adopt the iceberg theory for glaciation.

Brookes[18] has provided an excellent account of the remarkable contributions of G.M. Dawson to our understanding of the glaciation of the Interior Plains and Cordillera of Western Canada including Dawson's conception of a "Cordilleran glacier" over British Columbia. As noted by Brookes (op. cit., p.169) Dawson's concept of a Cordilleran glacier:

" should have placed him squarely within the group of later nineteenth century Canadian geologists who switched their allegiance from the Drift Theory (*i.e. floating icebergs;* present author's italics) to the Glacier Theory, or who matured wholly with the latter. However, from this first detailed examination of Dawson's works of glaciation , it emerges that, except for the "Cordilleran glacier" hypothesis, in a majority of cases he argued not even the most obvious objections or the plainest of alternatives to his 'Drift' explanations, although he cannot have been unaware of them. No explanation of this rigidity readily presents itself, other than possible filial respect for the reputation of his scientifically conservative father, J.W. Dawson. Dawson's later contemporaries, including Bell, Low and Tyrrell, ignored rather than challenged his interpretations, developing 'Glacial' theory along paths it has followed to the present day"

Late in the 19th century, however, Agassiz's theory became more widely adopted and ultimately persisted as the basis for the interpretation of glacial deposits and related glacial phenomena. It has also been suggested by Eagan[19] that the development of multiple glaciation concepts and the widespread adoption of continental glaciation theory by American geologists late in the 19th century had a profound influence on Canadian geologists with respect to glacial geology. Notable among the early American glacial geologists who had an impact upon the development of glacial geology concepts in Canada are N.H. Winchell, Warren Upham and T.C. Chamberlain. Winchell and Upham were both members of the Minnesota Geological Survey. Upham worked extensively upon the geological history of glacial Lake Agassiz that had

17 Silliman, Robert H., 1994, Agassiz vs. Lyell: Authority in the assessment of the diluvium-drift problem by North American geologists with particular reference to Edward Hitchcock, Earth Sciences History, v.13, no.2, p.180-186.

18 Brookes, Ian A., 2002, G.M. Dawson and the Glaciation of Western Canada, Geoscience Canada, v.29, no.4, p.169 - 178.

19 Eagan, William E., 1986, The multiple glaciation debate the Canadian perspective, 1880-1900, Earth Sciences History, v.5, no.1, p.144-151

previously occupied the Red River Valley and in 1889 published a report[20] for the Geological Survey of Canada on glacial Lake Agassiz in Manitoba. Chamberlain[21] was a member of the Wisconsin Geological Survey and later the United States Geological Survey who studied and published on various aspects of glacial geology in the lower Great Lakes and other regions of the United States.

As Director of the Geological Survey (1907-14) R.W. Brock recognized the advances in glacial geology[22] that had been made in the United States and in 1908 obtained the services of Americans F.B. Taylor and J.W. Goldthwait to trace the old beaches of Glacial Lake Algonquin that occupied the Lake Michigan - Lake Huron - Georgian Bay basins during late Quaternary time. They were assisted in this work by W.A. Johnston who went on to become a prominent Pleistocene geologist within the Geological Survey during the first three decades of the 20th century. Johnston worked extensively across Canada[23] including studies of Champlain Sea and other surficial deposits of the Ottawa area, surficial deposits of southern Manitoba and Saskatchewan, shorelines of the Great Lakes area and deposits of the Fraser River delta. Other early 19th century surficial geologists of the Geological Survey included L. Reinecke who identified sand and gravel deposits of interest for road material in Saskatchewan, Ontario and Quebec during the period 1914-19, J. Stansfield who produced a report on the surficial deposits of Montreal Island in 1915 and Ernst Antevs, a Swede, who was supported by the Geological Survey during the 1920's for work on varved deposits in the Maritimes and on the Lake Agassiz basin in northern Manitoba[24].

Throughout the first 90 years in the history of the Geological Survey attention was given to the glacial features and materials that formed such an important part of the Canadian landscape. For most of this time observations and reports on surficial geology were provided by geologists whose primary occupation was bedrock geology. With the advent of the 20th century the Geological Survey recruited, from various sources, additional scientific staff that were directed toward surficial geology studies but an operational unit with specific responsibility for surficial geology had yet to be created.

It was not until 1930 that an initiative was taken by W.H. Collins[25], then Director of the Geological Survey, to establish an organizational unit that would have specific responsibility for Pleistocene geology and related matters of groundwater and records of borings. The new division, with Mr. W.A. Johnston as acting head, was given the name of "Pleistocene Geology, Water Supply and Borings" in the absence of a shorter name that would accurately describe its functions. Scientific staff of the Division such as R.T.D. Wickenden, D.C. Maddox and B.R. MacKay carried out Pleistocene geology and/or groundwater studies particularly in southern Saskatchewan during the mid part of the 1930's. By 1936 the Department of Mines was downsized and restructured such that the Geological Survey was reduced to a division within the

---

20 Upham, Warren, 1890, Report on the exploration of glacial Lake Agassiz in Manitoba; Geological Survey of Canada, Annual Rept. 1888 - 89, v. IV, Rept. E., 156p.

21 Totten, Stanley M. and White, George W., 1985, Glacial geology and the North American craton: Significant concepts and contributions of the nineteenth century *(in)* Geologists and Ideas: A History of North American Geology, Geological Society of America, Centennial Special Volume 1, p.125-141

22 Zaslow (op. cit.) p.297

23 Fulton (op. cit.), p. 4

24 Prest, V.K. 1989, Organization history of G.S.C., unpublished internal G.S.C. document

25 Collins, W.H., 1931, *in* Report of the Department of Mines for the fiscal year ending March 31, 1931, King's Printer, Ottawa, No.2297

Bureau of Geology and Topography and the Pleistocene geology function was eliminated. The Water Supply and Borings functions, however, remained as a section which persisted until 1947[26].

Following World War II the Geological Survey, primarily through the influence of its Chief Geologist, Dr. George Hanson, began to recruit a number of geologists for work in Pleistocene geology and groundwater studies. Some of these new recruits were veterans recently discharged from military service while others were civilian graduates from Canadian universities. At that time few Canadian universities offered any significant instruction in Pleistocene or groundwater geology thus many of the new recruits obtained their early training on the job. In order to upgrade scientific staff skills, particularly in Pleistocene geology, the Geological Survey obtained authorization to support postgraduate studies for some of its staff at such American universities as University of Illinois, University of Michigan, University of Kansas, Ohio State University, University of Chicago and others. Among the beneficiaries of postgraduate training in Pleistocene geology during this early postwar period were N.R. Gadd, B.G. Craig, H.A. Lee, J.G. Fyles and O.L. Hughes all of whom made significant contributions to the Pleistocene geology studies of the Geological Survey.

In 1950 the former Department of Mines and Resources was reorganized with a portion becoming the Department of Mines and Technical Surveys. Among the branches of the new department was the Geological Survey and a newly-formed Geographical Branch that was later to become, in part, a component of the Quaternary geology organization within the Geological Survey. At the time of the 1950 departmental reorganization the Geological Survey consisted of nine divisions one of which was the Groundwater, Glacial and Engineering Geology Division. By 1951 the number of divisions within the Geological Survey was reduced to seven with one renamed as the Pleistocene and Engineering Geology Division. It is probable that groundwater work continued as sectional activity within this Division which remained as one of either seven or eight operational divisions within the Geological Survey until 1955.

Departmental annual reports for the period 1951-55 clearly indicate increasing activity by the Geological Survey in Pleistocene geology across Canada. This work included coverage of the northern territories where Pleistocene geologists were attached to helicopter-supported bedrock reconnaissance-mapping parties. Although the Departmental annual reports for the 1951-55 period do not identify the person responsible for the Pleistocene and Engineering Geology Division it is probable that V.K. Prest had at least part of this responsibility in addition to carrying out his own field work. Other Pleistocene geologists at that time such as J.G. Fyles, C.P. Gravenor, J.A. Elson and J.E. Armstrong, among others, also played prominent roles in the development of Pleistocene geology while E.B. Owen was prominent in engineering geology assignments such as work on the St. Lawrence Seaway.

One of the early modern compilations of the surficial geology of Canada was that of V.K. Prest. This work was published in 1957 by the Geological Survey as Chapter 8, Pleistocene Geology and Surficial Deposits in the Economic Geology Series volume “Geology and Economic Minerals of Canada” edited by C.H. Stockwell

Pleistocene geology became firmly established in the Geological Survey as a scientific activity during the 1950's through increases in the numbers of scientific and support staff and through recognition of the activity in the organizational structure. By 1955, however,

26 Prest, V.K. 1989, (op. cit.)

the Geological Survey once again underwent organizational restructuring with a reduction in the number of divisions from eight to six. The former Pleistocene and Engineering Geology Division was reduced to sections within the newly-formed Post Precambrian Division under the direction of L.J. Weeks. This organizational arrangement with V.K. Prest as Head of a Pleistocene and Engineering Geology Section remained until about 1959. By this time, however, Prest was becoming increasingly involved in major syntheses concerning various aspects of Quaternary geology in Canada. As a consequence, responsibilities for management and direction of Quaternary geology activities in the Geological Survey increasingly devolved to J.G. Fyles.

Also in 1959 the Geological Survey was influenced by a number of significant events. Foremost among these was the relocation of the Survey's staff and laboratories from the Natural History Museum and other locations in Ottawa to new headquarters at 601 Booth St. This enabled the establishment of modern sedimentological, palynological and radiocarbon laboratories and other facilities to support Quaternary geological activities and to adequately accommodate scientific and support staff. During the same period the Geological Survey was provided with the resources to hire a number of new hydrogeologists which created pressure for organizational change.

In 1966, through an act of Parliament, the Government of Canada replaced the former Department of Mines and Technical Surveys through creation of the Department of Energy, Mines and Resources within which the Geological Survey of Canada was a component part. This new Department was given much broader policy functions for energy, mineral and water resources than had previously been the case with the primarily technical and scientific functions of the predecessor department.

One year later, in 1967, further organizational changes had occurred in the Geological Survey. A new scientific division, "Quaternary Research and Geomorphology" (QRG) under the direction of Dr. John G. Fyles was formed through amalgamation of the Pleistocene Geology Section, the Physical Geography group with attendant support staff from the then recently disbanded Geographical Branch and the small Engineering Geology unit of the Geological Survey. The Hydrogeology Section, of which the Engineering Geology unit was formerly a part had been transferred earlier from the Geological Survey to the Inland Waters Directorate that was an initial part of the Department of Energy, Mines and Resources. The Inland Waters Directorate would eventually become part of Environment Canada. This organizational arrangement firmly established Quaternary Geology at the divisional level within the Geological Survey. It is to the credit of Dr. Fyles that the newly-formed QRG Division was structured and staffed in such a manner as to ensure integration of the scientific activities necessary to deal with Quaternary geology on a national basis. These included mapping, at various scales, surficial deposits on land and in coastal regions, examining the Quaternary record to be found in lake bottom sediments, interpreting the postglacial and earlier paleoecological record, providing radiocarbon age determinations, evaluating terrain hazards and assessing the role of surficial materials in mineral exploration and various land use applications. While operating primarily from the Ottawa headquarters of the Geological Survey individuals or small groups of scientific and support staff of QRG Division were located at other locations such as the Inland Waters Directorate, Burlington, Ontario and at offices of the Geological Survey in Calgary and Vancouver. In contrast with the regional geographic mandates of most other scientific Divisions of the Geological Survey, except for Geophysics Division, QRG Division had scientific responsibilities for the entire country including coastal regions.

The division persisted under the name “Quaternary Research and Geomorphology” from about 1967 until sometime during the period April, 1971-March 1972. At this time it was recognized that while the divisional title was descriptive of program activities it was also overly long, esoteric and generally incomprehensible to the general public. Dr. Fyles suggested to his management committee, of which I was a member, that a new and hopefully less cumbersome name be found for the division. I suggested the name “Terrain Sciences” which was inspired by the name “Mineral Sciences” which then existed as a division within a sister branch of the Department. Further the name “Terrain Sciences” reflected the primary divisional concerns with surficial materials and processes that occur throughout Canada’s diverse terrains. At the time no other suggestions for a change in divisional name were offered and the Division under its new name continued as an operational scientific unit of the Geological Survey of Canada for the balance of the 20th century and for a few years beyond that time.

TERRAIN SCIENCES DIVISION HISTORY 1972 - 1987

Introduction

As noted in previous sections of this account Terrain Sciences Division came into existence during fiscal year 1971-72 as the result of a change in name for the evolving and expanding operational unit that served as the focus for Quaternary geological work within the Geological Survey. In preceding years, and until about 1988, the Geological Survey produced, on an annual basis, an internal report compiled from submissions from various units within the Survey that recorded information on program directions and priorities, changes in continuing personnel, conference attendance, resource allocations and other matters deemed of interest during the year to the contributing unit. Although these internal annual reports tend to be uneven in content from year to year, particularly with respect to financial and personnel resource information, they do provide for the period of their existence the most readily available historical account of operations of the various units of the Geological Survey. These reports, along with some Departmental and Sector annual reports, constitute the primary sources of information for this account, and they have been invaluable in enlarging upon the author’s own recollections of events that occurred during the above noted period. Both the written record and my own recollections, however, are not entirely complete. Thus, this account may well be subject to errors and omissions for which the author is responsible.

In February, 1972 Dr. J.G. Fyles, then Chief, Terrain Sciences Division, was seconded to the Department of Indian Affairs and Northern Development (DIAND) on a continuing basis as co-ordinator for the then newly-created Environmental-Social Program, Northern Pipelines (ESPNP). As replacement during Dr. Fyles secondment I was appointed Acting Chief, Terrain Sciences Division for a period of three months. My acting appointment was immediately followed by instruction from Branch level to restructure the Division into two subdivisions, a Mackenzie Subdivision reflecting the extensive work then being done by the Division in the Mackenzie River Valley and arctic coastal regions pertaining to terrain conditions for proposed oil and gas pipelines in those areas and a Quaternary Subdivision to encompass other work by the Division. In addition to my role as Acting Chief of the Division I was assigned responsibility for the Mackenzie Subdivision and Dr.B.G. Craig was assigned as head of the Quaternary Subdivision. This was not a particularly satisfactory organizational arrangement. Thus, later in the year I was given responsibility for a Geotechnical Subdivision in addition to continuing as Acting Chief of the Division while Dr. Craig continued as head of the Quaternary Subdivision. Dr. J.G. Fyles, although *in absentia,* retained the responsibility as Division Chief. This arrangement continued until Dec. 1973 at which time I was appointed A/Division Chief while still retaining responsibility for the Geotechnical Subdivision. Although it was not until June 1974, following an internal competition, that I was appointed as Chief, Terrain Sciences Division, the year 1972 marks a time of significant transition in the management of the Division and serves as an appropriate time at which to begin this historical account.

DIVISIONAL ADMINISTRATION, ORGANIZATION AND MANAGEMENT 1972 - 1987

Administration

Headquarters for Terrain Sciences Division remained throughout the period on the 3rd floor of the Geological Survey of Canada building at 601 Booth Street, Ottawa The Director occupied Room 361 and adjacent offices were occupied by the Divisional secretary, Ms. L.S. Morency, and the Assistant Director, Dr. B.G. Craig, until his retirement in 1981 and then Dr. Craig's replacement, Mr. J.A. Lowdon, as Assistant to the Director, for the balance of the period. A suite of offices opposite that of the Director housed the Divisional Administrative Officer, Mr. L.A. Jackson until his retirement in 1978 followed by Mr. Yvon Claude until 1979 and then Mr. A.J. Casey for the remainder of the period. The several Administrative Officers were assisted at any one time by two clerks whose positions were occupied by capable staff who served for various lengths of time. The names of these staff who are identified as Administrative Clerks are contained in Appendix I.

The presence of an experienced and fully functional headquarters staff was of great benefit to me as I assumed the duties of Division Chief. This was particularly so in the absence of any specific training for the job or orientation briefing from Branch level that might well have assisted in facilitating the transition to the position. As it was, the early months, and in fact the first couple of years in the position, were accompanied by a rather steep learning curve that seemingly attended the incessant internal and external demands that confronted a newly-appointed chief of division. One of the first tasks that I undertook as Division Chief was to create, in concert with Divisional headquarters staff, a calendar of recurrent events such as budget submissions, scientific program submissions, project instructions, staff appraisals etc. with identification of deadlines and responsible individuals. Another task was the establishment of a divisional file index to facilitate divisional file storage and retrieval. Both of these tasks were to pay continuing dividends in terms of operational efficiency. As time went on I became more familiar with the wide range of managerial training courses available through the Public Service Commission. Over a period of some years I attended several short courses on personnel and financial management that I found to be of benefit. It was not until 1983, however, that I attended the week-long orientation course for executive (EX) level managers that was held at the Government Training Centre, Touraine, P.Q. Although I was rather overdue in attending the course I believe I derived greater benefit from it through the perspective of a number of years of operating experience at the EX level.

The approximate levels of resources provided by government to the Geological Survey, in terms of dollars and person years, (as obtained from GSC internal annual reports), are shown in Table 1 below:

Year	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
$ Mil	12	16	18	19.5	25.5	26	29.5	31	32.5	34	35.5	38	50.5	55	70	81
P.Y.s	590	625	745	795	800	800	795	780	770	760	755	760	775	800	805	810

Table 1. Approximate levels of GSC resources 1971 - 1986

Throughout the period covered by this account, and in the preceding and subsequent years that Quaternary geology was organized at Divisional level within the Geological Survey, the resources allocated for this activity by the Branch were of the order of 8 to 10 per cent of the total resources allocated annually to the Geological Survey. As will be noted further on in this account, however, Terrain Sciences Division commonly was able to obtain additional resources from sources other than the annual Geological Survey allocation.

In 1972 most of the scientific and support staff of the Division were housed at various locations within the Geological Survey headquarters at 601 Booth Street with small detached scientific units of the Division being located at Geological Survey offices in Calgary and Vancouver. The administrative requirements of these detached units were kindly provided by the GSC divisions based in Calgary and Vancouver and coordinated with Terrain Sciences administrative officer in Ottawa. By about 1974-75, as may be noted from Table 1 above, the size of the Geological Survey had increased to about 800 person years which placed considerable strain on the facilities at 601 Booth Street to accommodate the increased numbers of staff. As a means to relieve the accommodation pressure at 601 Booth Street most of the Ottawa-based scientific staff of Terrain Sciences

Division were relocated from 601 Booth Street to 401 Lebreton Street. This alternate location, a two-level affair due to the significant slope upon which the building was located, was once the headquarters for the National Capital Commission. In its prime the building contained some rather unique and elegant features, such as a landscaped interior courtyard and mahogany-panelled offices. By the time Terrain Sciences occupied the place, however, it was well past its prime and in serious need of repair or replacement of windows as well as heating and plumbing systems. Initially the staff were much less than enthusiastic about their new quarters. The location of the library, administrative and personnel services at 601 Booth St. was inconvenient and time-consuming for staff located at 401 LeBreton St., particularly during winter months. In time, however, the repair efforts of Public Works, the novelty of sharing a part of the building with a Fisheries Department Test Kitchen (a noon-time Mecca for some), the presence of congenial coworkers from Resource Geophysics and Geochemistry Division and, perhaps, a feeling of remoteness from Divisional headquarters all contributed to an attitudinal shift by the staff to one of collective congeniality and a generally positive attitude about the place.

The Divisional radiocarbon laboratory remained in the basement of 601 Booth St while the paleoecology laboratory and a soil geochemistry/mineralogy laboratory remained on the 6th floor of 601 Booth Street. The Divisional sedimentology laboratory had various locations such as in government buildings at Tunney's Pasture, rented commercial space on Spencer Street near the Parkdale Market and at 401 Lebreton Street.

Dispersal of staff both within and beyond Ottawa did not pose significant operational problems but did limit the opportunities for personal interaction between Divisional management and both scientific and support staff.

Organization and Management

During 1971 - 72 the Division consisted of several small headquarters units and a number of operational sections each of which was responsible for some aspect of the Division's scientific program such as Quaternary geological mapping, Quaternary paleobiology, Sedimentology and Mineral Tracing, Engineering and Environmental Geology etc. Between 1972 and 1974 the Division included subdivisions as part of its organization but reverted in 1974 to a structure based on headquarters units and scientific sections. This fairly simple organizational arrangement (see Appendices II and III) continued until 1986 when once again a subdivisional mode of organization was adopted. Designation of individuals, primarily from the scientific staff, as Heads of Subdivisions or Sections was entirely an assignment in recognition of the individual's scientific leadership and contributions to the Division's scientific program. These individuals were also important contributors to the management of the Division including the development of scientific directions, liaison with the scientific community and the allocation of resources to the many scientific and support activities within the Division.

The Geological Survey of Canada continues to be Canada's oldest scientific organization and one that is well known both across Canada and throughout the world. One of its unique features was, that apart from its first Director, William E. Logan, all of its subsequent Directors (or whatever title applied to the head of the Survey) until January 1982 had been drawn from staff serving with the Geological Survey. The appointment in January, 1982 of Dr. R.A. Price, then on staff at Queens University, as Director General was a departure from previous tradition. It may be noted, however, that Dr. Price had been a serving officer of the Geological Survey of Canada for a number of years prior to his appointment to the Geology Department at Queens at some time during the 1960's.

During the period covered by this account the Management Committee of the Geological Survey was chaired by the Head of the Survey and comprised the Chief Geologist, Directors of Divisions and such finance, personnel and program officers as were required by the agenda. Most of the Branch Management Committee meetings were held at GSC headquarters in Ottawa but not infrequently the meetings were held at regional offices in Halifax, Calgary and Vancouver. The meetings at regional offices provided a useful opportunity for interaction with staff at those locations.

The management style practised by the Branch was, for the most part, one of top-down direction derived from Departmental and Governmental imperatives combined with bottom-up responses and proposals from Division Directors and scientific staff with significant efforts to mesh individual scientific interests with higher level objectives. This style of management was generally reflected at divisional level throughout the Branch and certainly within Terrain Sciences Division. The Divisional management committee of Terrain Sciences was chaired by the Division Director and consisted of the Assistant to the Director, Divisional Administrative Officer, and the Heads of Sections and/or Subdivisions. The meetings of the management committee that I chaired tended to be scheduled on a fairly frequent but irregular basis dependent upon the magnitude and significance of the business and information requiring attention. In order to assist in adhering to meeting agenda I generally held these meetings for a duration of not more than two hours between 10:00 a.m. and noon. This scheme of things seemed to work well as I do not recall much time at these meetings being spent on extraneous or non-business matters.

Each of the scientific divisions of the Geological Survey had responsibility for one or more aspects of the Survey's geoscience program on a regional and/or national basis. The overall geoscience program of the Branch thus consisted of a very large number of individual projects. Many of the projects had a field component, others were laboratory and/or office based of finite duration while still others were of an on-going nature to provide support for various field and/or laboratory projects. A system designed to assist in the management, or at least tracking, of the many projects was designed by Dr. C.S. Lord, the Survey's Chief Geologist from 1954 until his retirement in 1973. Dr. Lord had a distinguished career as a field geologist with the Geological Survey for many years prior to being appointed as Chief Geologist. He was a rather taciturn man, and perhaps to some appeared stern and distant, but on my occasions of interaction with him, both during my time as a scientist and later as a manager, I found him to be quiet, thoughtful and an unfailing source of sound advice.

One of the principal duties of the Chief Geologist was to provide oversight on the entire scientific program of the Geological Survey, a task for which Dr. Lord was well suited. In order to document the many projects that constituted the scientific program at any given time a series of project forms were created as listed below:

- GSC 227 Project Identification and Approval
- GSC 228 List of Scientific Projects (for an individual as leader or participant)
- GSC 229 Project Annual Instructions
- GSC 230 Project Progress Report (annual)
- GSC 230A Interim Progress Report (introduced in early 1980's ?)

Examples of these forms in their completed state can be found in the Central File Registry of the Geological Survey under File No. GS 0501. I am not certain about the origin of the project forms but it would be no surprise to find that Dr. Lord had been involved in their development. One form that he did create, however, was an immense document that more than covered a full-sized drafting table upon which, on an annual basis, details of every project within the Division was recorded. This huge creation was intended to capture all manner of information on Geological Survey projects such that the Chief Geologist would be able to answer to answer any conceivable question that might be asked of him from Departmental Headquarters or any other source. One form that was not part of the project management system and which in fact did not exist (as has been commented upon to me by my long-time colleague Mr. J.A. Heginbottom) was a project completion form. It seemed that the submission of a map and/or report or some other product for publication served to bring a project to completion.

Throughout all of the 1970's and on into the early part of the 1980's word processors and computerized systems for accounting and database management were not in widespread use throughout the Geological Survey. Record keeping for project management purposes was thus a rather labourious manual process but one that served its intended purpose of tracking individual projects.

In retrospect the project management system contained a couple of inherent weaknesses that arose not so much from the system itself but from the then prevalent style of management within the Geological Survey. The first weakness, which can be certainly subject to debate, is the designation and perhaps proliferation of project leaders. There was a strong desire on the part of most of the scientific staff to be designated as a project leader as opposed to that of a professional participant in any particular project. Designation of individuals as professional participants, however reasonable and well intended, was commonly perceived as conferring a lesser status for those individuals.

The negative consequences, most likely quite unintended, of having many project leaders was at least twofold. The first was the proliferation of the number of projects (some multiple of hundreds) each of which required a complete set of documentation with annual updates. The total number of projects was further increased by authorizing project leaders to simultaneously carry several projects commonly to meet some newly imposed program imperative. The large total number of projects thus led to to a second negative consequence of which there were several facets.

Among these facets were a.) the extended span of control required by Divisional management at various levels to maintain oversight of resource allocations and the progress of many projects, b.) the difficulties faced by project leaders in the allocation of their time to several projects such as to effect timely completion of all of those currently active; many projects with a field component had a nominal duration of four to five years but it was not uncommon for field projects to extend far beyond that time span and c.) the preeminence of individual project leaders did not particularly assist in the development of group projects, particularly those involving staff from more than one Division.

During the two years that I had spent with a consulting firm prior to rejoining the Geological Survey I obtained a considerable appreciation for the importance of accounting for the time spent by an employee on a particular project. In consulting work time accounting was the principal means for the company to obtain revenue from a client. Non revenue-producing time spent by an employee was charged to some overhead account carried by the company. It is recognized that the overall objectives and motives of the Geological Survey and other scientific organizations of government are quite different from those of commercial ventures. In spite of these differences, however, it is of interest to reflect upon my recollection of the treatment of resource allocations in the Geological Survey.

With respect to the annual allocation of financial resources provided to the Geological Survey (Table 1) and redistributed to Divisions, approximately 70-75 per cent was for salaries, about 20 per cent for operations and the balance of a few per cent for capital expenditures. While Divisions were accountable for their annual consumption of person years (i.e. 1 person for 12 months or 3 persons for 4 months each etc.) the actual payment of salaries was external to the Divisions. Thus, in terms of "hands on" management of funds Division Directors dealt with only 25-30 per cent of their total budget. In my view this situation tended to minimize the importance of time spent by staff on any particular assignment and it was not until the early '80's that interim reporting of project progress was required.

While I did have a particular concern over the matter of time management and accounting by project leaders I also recognized the considerable differences between the operational modes of a scientific organization such as the Geological Survey and a commercial venture operating on a fee for service basis. The quest for new knowledge, whether in the field or in the laboratory, commonly follows unfamiliar pathways on a journey of uncertain direction or unknown duration. Thus forecasting the duration of such a journey is no easy task and may well be subject to considerable error. In the commercial world of providing service the duration and extent of the service provided is strictly limited by the available budget.

In spite of the uncertainties that may be associated with the estimating of time requirements for scientific projects I remain of the view that awareness of the costs associated with time consumption is as important as an awareness of the costs related to aircraft usage or any other more visible expenditure of resources related to the conduct of a scientific project within the Geological Survey.

Additional Responsibilities of a Division Director

The ongoing management of a scientific division and participation as a member of the Branch management committee placed substantial demands upon the time reasonably available to any Division Director. Some directors, apparently reluctant to abandon entirely their former scientific pursuits, also endeavoured to carry on with some degree of active field or laboratory work. I was not inclined to follow that route but there were a significant number of other assignments or activities that came my way as, no doubt, was the case with the directors of other divisions. It is also recognized that many of the scientific staff, as well as some of the support staff of the Division, served as members of committees, commissions or other groups which placed demands upon their time in addition to their normal duties. While the magnitude and value of this additional work is appreciated a detailed accounting of it is beyond the scope of this document.

In my case these additional assignments fell into two main categories the first of which arose from within the Branch or Department and was of either the ad hoc or continuing variety each of which could consume varying amounts of time either intermittently or for some a rather more protracted period of time. A second category was involvement in organizations or activities outside of the Branch such as service on committees of governmental organizations or scientific societies.

Among the Departmental Committees the one that was the most time consuming was that relating to Nuclear Fuel Waste Management. This activity began early in 1973 following a request to the Department from Atomic Energy Canada Limited, Whiteshell Nuclear Research Establishment (AECL/WNRE), Pinawa, Manitoba for assistance in developing a program for the geological disposal of spent fuel from nuclear reactors in Canada. This initial request resulted in the establishment within the Department of a committee that I was designated to chair by the Departmental Science and Technology Committee then chaired by the Deputy Minister, Earth Sciences, Dr. C.H. Smith. This committee consisting of members from Geological Survey, Earth Physics and CANMET Branches met regularly with AECL over the next several years to develop various elements of the program. Initially work, within the Geological Survey of Canada, focussed upon evaluating the potential within Canada for the use of bedded salt as a disposal medium. A few years later emphasis was placed upon igneous rocks of the

Canadian Shield and by 1977 a full scale program involving field work supported by AECL was launched to pursue this work. I was assigned responsibility by the Department for the management of this program on a continuing basis which involved scientific staff from Geological Survey, Earth Physics and CANMET branches as well as personnel seconded from AECL. Participation in the Nuclear Fuel Waste Management Program (NFWMP), described in more detail in a subsequent section of this account, was demanding of my time and continued for the duration of my tenure as a division director and for a few years beyond that time. Involvement in the NFWMP included attendance at frequent program review meetings held at AECL/WNRE, Pinawa, Manitoba as well as in Ottawa. The assignment also brought about my involvement with working groups of the International Atomic Energy Agency (IAEA), Vienna, Austria that were developing guidelines for geological disposal of nuclear fuel waste. Meetings of the working groups were held on several occasions in Vienna and in Columbus, Ohio.

In 1976, after barely becoming accustomed to the duties of a Division Chief, I was nominated by the Department as a potential candidate for participation in a year long course sponsored by the Department of National Defence (DND) and held at Fort Frontenac, Kingston, Ontario. Following submission to DND of a resume endorsed by the Department I was accepted as a member of what was to become Course 30 (designated as Course XXX) of the National Defence College (NDC) which ran from the beginning of September, 1976 until the end of July, 1977. The following summary of the NDC Course does not bear directly upon the history of Terrain Sciences Division other than it records events of a particularly interesting year in the life of the Division's Director.

Participation in the course necessitated my relocation to Kingston with a commute to and from Ottawa on weekends except while in frequent travel status as part of the course activities. Living expenses while I was in Kingston were covered by the Division and all course-related travel expenses were covered by DND.

The course, under the direction of its Commandant, Rear Admiral C.W. Ross, and a directing staff of three Canadian military officers all with the rank of Colonel (2 Army, 1 Air Force), comprised a total of 40 members (38 male, 2 female) drawn equally from civilian and military occupations. The civilian members came from various Canadian Federal and Provincial Government departments, industry, academia, and professional associations as well as from government agencies of the United States, United Kingdom and Australia. All of these members held relatively senior positions in their respective organizations. Military members, drawn primarily from the Canadian Forces with representatives from all major branches of the Service, also included military members from the United Kingdom and the United States. Most of the military members held the rank of or equivalent to Colonel or higher with a few members holding the rank of Lieutenant Colonel or equivalent. It was a most eclectic gathering of individuals that soon formed into a relatively cohesive group conducive to an exceptional learning experience as well as to many continuing friendships.

Canadian security was the principal theme of the course and was addressed in its economic, social, political and military aspects at provincial. national and international levels. While at Fort Frontenac morning sessions during the week were devoted to lectures by distinguished speakers on the many aspects of security or to small group study by course members of some particular topic relating to security or to a geographic region selected for field study. As the course progressed we had the opportunity to visit all of the Canadian Provinces and Territories and their principal cities as well as military bases at Halifax, N.S., Gagetown, N.B., Winnipeg, Man., Cold Lake, AB and Comox, B.C. Field visits in the United States to political, military and commercial centres included those in New York City, Washington, D.C., Norfolk, Va. and Atlanta, Ga. and to the North American Air Defence (NORAD) base at Colorado Springs, Co and the Strategic Air Command (SAC) base at Omaha, Nb.

Other field visits, commonly of two or three weeks duration, occurred at various times throughout the year to international destinations. Included among these trips were those to Seoul and Panmunjon in South Korea, Tokyo and Hiroshima in Japan, Hong Kong, Djakarta and Bali in Indonesia, Teheran and Isfahan in Iran, Baghdad, Babylon and Kirkuk in Iraq, Nicosia in Cyprus, Haifa, Jerusalem and Bethlehem in Israel, Kinshasa in Zaire (now Democratic Republic of the Congo) and Accra in Ghana and a night stop on the island of Trinidad. Visits were made to London in the U.K. and in western Europe to Brussels, Paris, Bonn and Berlin and to Belgrade and Dubrovnic in Yugoslavia. On a separate occasion visits were made to Mexico City and environs, Caracas in Venezuela and Manaus, Brasilia and Rio de Janeiro in Brasil.

Air transport for these field visits was provided by the Canadian Air Force either with a C-130 Hercules transport in seating arrangements varying from rudimentary to conventional but with always the most basic of convenience facilities or a Boeing 707 with much more comfortable seating and other facilities. The aggregate amount of flying time for these field trips was something in excess of 80 hours that covered over 40,000 miles.

In addition to the college-based and field studies each course member was required to produce by the end of the term a written paper on a subject of their choosing, approved by the directing staff. relating to the theme of Canadian Security. I chose the subject of "Petroleum Resources - a Strategic Commodity for Canada" which provided an opportunity to become familiar with the methodology for assessment of Canada's conventional and other petroleum resources and to place Canada's petroleum resource potential in a global context. All of the term papers produced by each Course of the National Defence College were considered by the Department of National Defence to be confidential and were retained in the library of the College for use only by Directing Staff and subsequent Defence College course members.

From a personal perspective I found the National Defence College course to have been a particularly rewarding experience that provided a unique opportunity to obtain a broad perspective of Canada and its place in the world, an awareness of Canada's strengths and weaknesses and an appreciation of the problems faced by many countries around the world. In subsequent years many of these problems would evolve to the point that they became featured items in various news media. The extent to which my participation in the course was of benefit to the Geological Survey and Terrain Sciences Division is a matter for others to judge. During my absence responsibility for managing Terrain Sciences Division was assigned in turn to Dr. W. Blake Jr. and Dr. R.J. Fulton, both of whom discharged their responsibilities as Acting Director in a highly professional manner.

Upon return to my position as Division Director in September 1977 I was able to resume the duties without any particular difficulty. The only major change that I recall making was learning to use a dictaphone for all internal and external correspondence. In a relatively short space of time I found that I could compose both letters and memoranda complete with instructions for structure, punctuation, and spelling where needed and submit them for typing. For the most part there was seldom any need for revision to the typed copy. It became my practice to deal with dictated correspondence at the end of the day and to leave the tape for the secretary's attention early the following morning. It was not uncommon for the completed correspondence to be available for my signature by the time I arrived for work around 08:30 in the morning. Use of the dictaphone for correspondence rather using hand writing probably reduced the time for this task by about 75 per cent and essentially eliminated my taking this work home to complete. During the 1980's word processors and eventually personal computers replaced electric typewriters as the instruments for correspondence and manuscript production and, fortunately from my point of view, it was after my time as Division Director that these electronic devices replaced secretaries as well.

One result of my participation in the National Defence College course was a request that came to me from that institution, several years after my graduation, to give a one-hour lecture to the then current course members on an overview of Canada's mineral, forest and water resources. It took considerable effort to condense each of these major topics into a coherent, concise, illustrated package. As a matter of necessity the material that could be presented within the one hour assigned for the lecture was characterized more by breadth than depth. The first lecture that I gave in 1983 can be considered as a success as I was asked by the College to again give the lecture each fall over the next several years to subsequent courses.

Another Branch activity of the continuing but intermittent variety was service, at the request of personnel officers, to assess the level of classification for various occupational categories that had been documented and submitted in support of recruitment or promotion actions. With time and increasing experience I found myself dealing with classifications for Research Managers, Physical Scientists, Chemists, Engineers and several technical and clerical support categories. As a manager I was quite properly precluded from participating in the classification of positions within my Division. Thus, I felt both an obligation and a responsibility to participate in classification exercises outside the Division to ensure that I was familiar with the process and that my staff would receive fair and impartial treatment in the classification process. Other Directors may well have had other obligations and interests but I do not recall many of them serving on classification committees.

The experience that I gained through service on classification committees within the Branch and Department seemed to attract the attention of personnel officers beyond the Department as on several occasions I was asked to serve on classification committees for positions in Environment Canada and in the Department of Public Works. An additional personnel activity beyond the Department that I undertook on several occasions during the 1980's was that of an assessor of candidates for the Career Assignment Program (CAP) sponsored by the Public Service Commission. CAP was established as mechanism for identifying promising young public servants who might have the potential for advancement to the lowest level of the executive category (EX-1) and probably beyond that level. Candidates were sponsored by their respective Departments and their applications were submitted to the Public Service Commission to be selected for the assessment process. CAP assessors, drawn from various government departments underwent a rigourous training exercise held over several days at the Public Service Commission Training Centre at Touraine, P.Q. The training was based on the simulated exercises to which the candidates would be subject plus additional coaching on traits to be observed in candidates and how to be observant during the simulation exercises without being obtrusive. The actual assessment exercises, involving about six candidates and four assessors, consumed three very full days at the Training Centre. The assessment process, while contributing directly to staff development within the Public Service. had the additional benefit for assessors of providing them with observational skills of value for recruitment interviews.

In addition to intermittent service on various internal committees I was also assigned by the Branch as a participant in two relatively time-consuming activities while continuing my duties as a Division Director. The first of these occurred in 1982-83 as one of a three person Task Force charged with undertaking an intensive review of the A-Base activities of Surveys and Mapping Branch and Polar Continental Shelf Project. These reviews involved extensive interviews with the management of the various elements of these Branches and assessment of the products and services being provided. As part of this review field visits were made to Polar Shelf activities at Resolute, Cornwallis Island, on Ellesmere Island and at Tuktoyaktuk and to a Topographic Survey party operating on Prince of Wales Island. Reports containing the findings and recommendations arising from the review were submitted to the Department as scheduled.

Work with the A-Base Task Force was barely completed when in 1983 the government implemented Access to Information and Privacy (ATIP) legislation. This legislation applied to all departments and agencies of government and demanded records management practices such that timely responses could be made to external requests for information held by government organizations.

In response to the legislative initiative, the Department formed an Advisory Committee on Access to Information and Privacy comprising representatives from the various Sectors of the Department. I was assigned by the Branch as representative for the Earth Sciences Sector but I do not recall any involvement with units other than the Geological Survey. The principal activity of the Advisory Committee, which lasted somewhat over one year, was to effect some sort of a coordinated system of documents management such that an information request directed to a central office within the Department could be readily redirected to the appropriate operational unit for a draft reply. Upon review of the various filing systems operating at Branch and Divisional levels it was apparent that coordination among these systems would be a rather distant goal and that records management within the Branch, while functional, was no close adherent to the records management guidelines established by Public Archives for the purpose of preserving, retaining for various periods of time or disposing of government records. In fact, I only became aware of such guidelines through service on the Advisory Committee. Following the work of the Advisory Committee there may have been some improvement in the management of records within the Geological Survey but I suspect that any such improvements have long since faded with the advent of digital record systems. In any case my recollection is that the Geological Survey was seldom the recipient of an Access to Information request and of those that did arrive the required information was found in the central file repository of the Branch.

Other activities beyond the Branch or Department included my participation, during the period 1979 - 87, as a member of the Associate Committee on Geotechnical Research of the National Research Council. This committee was chaired for many years by the late Dr. R.F. Legget who had a long and distinguished career as Director, Division of Building Research, National Research Council. The Committee, which had its origins during World War II in dealing with terrain trafficability problems for military purposes, disbanded around 1987 as many of its functions became addressed through activities of the Canadian Geotechnical Society.

Membership in professional organizations was commonplace among the staff of the Geological Survey and those to which I belonged included the Geological Association of Canada (Fellow), Canadian Geographical Society (Member), Canadian Geotechnical Society (Member) and the Geological Society of America (Fellow). Only the Geological Society of America(GSA) placed any particular demands on my time as I became involved in the work of some of its many Divisions and Committees. My service with GSA during my time as a Division Director included the Engineering Geology Division (Secretary, 1984; Chairman-Elect, 1985; Chairman, 1986) and the Committee on Geology and Public Policy (Chairman, 1987 and again Chairman, 1988). I also served as a GSA Councillor from 1988 to 1991and on the Committee on Committees as Chairman in 1991. The service with GSA was not overly demanding of time and was an excellent means for broadening contacts throughout the North American geoscience community.

A somewhat unusual extracurricular event occurred in December 1982 when I was contacted by the producers of the CBC Radio program “As it Happens” to provide background information on the possible causes of severe landslides that had occurred at Ancona, Italy. I had no specific information on the geographic location of the event, its geological/geomorphic setting, the kinds of materials involved or the extent of precipitation that may have been involved. Thus, a rather generic sort of response involving the balance between resisting and driving forces and the probable role of excess moisture in leading to instability through reduction in shear strength of the slope materials seemed to be an acceptable response. It may be noted that my response to the CBC’s inquiry was directly inspired by the late Karl Terzaghi’s excellent article on the mechanism of landslides published in 1950 by the Geological Society of America in the volume, in honour of C.P. Berkey, entitled “Application of Geology to Engineering Practice”.

Throughout most of the 1980's the Geological Survey of Canada sponsored an annual event known as the “Current Activities Forum”. This event was similar to other annual public presentations of Geological Survey work held in Vancouver, Calgary, Yellowknife and Toronto. The “Forum”, commonly held over several days in January at either a downtown hotel or the Ottawa Congress Centre, had the purpose of displaying, through talks and poster sessions, the ongoing work of the Geological Survey for the benefit of industry, provincial and federal government departments and the academic community. An evening lecture on a topic of general interest to the public was a feature of the Forum and commonly attracted a large audience. Each year the responsibility for organizing the event was assigned to one of the Division Directors. My turn for this assignment came in 1984. Given the substantial level of administrative and other support available for the task the additional work required of the organizer was not onerous.

While dealing with various aspects of the Division’s scientific program, concern over resource expenditures, participation in committees and other activities as noted above occupied much of my time the most demanding, and indeed rewarding responsibilities were those related to the development of the scientific and support staff of the Division. During the period of this review Terrain Sciences Division had a total continuing staff, including all divisional locations, of about 60 - 70 people (see Appendix I) with the annual addition of about 20 - 25 term employees as field, laboratory or office assistants. The average turnover rate for continuing employees was of the order of 3 - 4 per cent per year due to retirement or the attraction of alternative employment opportunities. Quaternary geologists and other specialists trained at the graduate level required to fill vacancies in the Division were not particularly abundant in Canada . The Division, however, was able to develop and recruit suitable candidates from universities across Canada through their employment as field assistants during summer months and through modest support provided university professors under the Research Agreement Program (RAP) sponsored by the Geological Survey. Under the RAP The Division supported a number of projects at Canadian universities, including then newly developed Quaternary geology studies at universities in Quebec. This support contributed to the development and recruitment of able young female and francophone staff for the Division.

Detachment of Divisional headquarters at 601 Booth St. from the locale of most scientific and support staff at 401 Lebreton St., and elsewhere in Ottawa, as well as at Geological Survey offices in Calgary and Vancouver. unfortunately reduced and restricted the opportunities for interaction between the Director and the staff on an ongoing basis. I endeavoured to do the best that I could with staff interaction as opportunities arose and I made a specific point of spending time with each Research Scientist at all locations at least once per year to discuss their work and to evaluate their progress.

These interviews and subsequent discussion with Section or Subdivision Heads were particularly rewarding when documentation of the individual's productivity provided strong support for, and ultimate success in, promotion to a higher level through the rigorous process at Branch level that applied to Research Scientists. Given the limitations upon the number of Research Scientist positions available for promotions in any given year versus the probable number of applicants, I made it a practice to bring forth only the strongest candidate within the Division. For the most part the tactic was successful with the candidate being approved by the Branch for promotion. Divisions recommending multiple candidates for promotion were inevitably requested to rank their candidates in order of preference. Such rankings were not uncommonly at variance with those of other members of the promotion committee resulting in failure to promote any of the nominees.

Fortunately most of my dealings in the realm of human resources were of the positive variety but, as might be expected there were a few on the negative side. A number of these arose from issues of less than expected levels of productivity or punctuality that could be addressed by a number of positive actions mutually agreed upon to effect the desired improvement. In other cases the employee was either not qualified or not suited for the job and was encouraged to seek alternative employment. The most difficult cases, however, and fortunately very few in number, were those in which the individual displayed behaviour and/or undertook actions that were beyond what any reasonable person might expect from a rational individual. Managers had the authority at any time to request that an employee be subject to a physical medical examination but such an examination was unlikely to reveal the cause of irrational behaviour. It was not unusual for the medical examiner to conclude that the individual was suffering from excessive stress and should be placed on leave for some period of time. I am not qualified to discuss or debate medical practice but I do suggest that managers could benefit from instruction by qualified human resources specialists on how best to deal with those employees whose behaviour is or appears to be beyond that normally encountered in the work place. A recent conversation with one of the Department's Human Resources advisors indicates that current managers have a broader range of actions available to them to assist in dealing with human resource problems than was previously the case.

SCIENTIFIC PROGRAMS 1972 - 1987

Introduction

In 1972 activities of the Geological Survey were designed to support two major programs of the Department of Energy, Mines and Resources, the Mineral and Energy Resources Program (MERP) and the Earth Sciences Program (ESP). Both of these major programs were strongly based on the geosciences. MERP was, as its designation implies, primarily concerned with mineral and energy resources and the means to assist in their exploration and assessment of their distribution and abundance. ESP, in contrast, was primarily concerned with obtaining geoscience information to aid environmental protection, assess occurrence of natural hazards and to provide geological and other information on the onshore and offshore landmass. Most Divisions of the Survey, including Terrain Sciences Division, contributed to the objectives of MERP but for the most part Geological Survey contributions to ESP were confined to Terrain Sciences Division.

In contributing to the Branch's response to the major programs of the Department Terrain Sciences Division had two principal objectives which persisted without major modification throughout the period of this review. The first objective, and primary preoccupation of the Division, was to provide a standard or primary surficial geology-geomorphology coverage for on-shore Canada at a consistent standard scale of 1:250,000 to show the distribution of unconsolidated earth materials (primarily of glacial origin), their composition, physical properties and spatial arrangement as to formations, structures and landforms. In order to provide essential reference information to ensure consistent terminology, description, correlation and specific parameter evaluations of the surficial deposits specialized complementary studies were required. These studies included detailed stratigraphy, geochronology (primarily radiocarbon dating), uplift sequence and pattern, physical and chemical properties of material as well as the development of techniques and methods related to these studies. Also related to this objective were field investigations carried out a smaller scale, mainly in the Arctic and sub-Arctic, to provide information needed in advance of standard coverage or conducted at a larger scale to provide greater detail in selected local areas particularly in the more populous regions of the country.

The second objective was directed toward provision of information on surface and near-surface earth and rock materials with respect to their geological and geotechnical properties as they affect terrain stability and terrain uses by society in relation to natural hazards or pollution. With respect to natural hazards the role of the Division was to identify and to understand the properties of those geological materials and geomorphic processes and settings that posed a hazard to society. Projects undertaken as contributions toward this second objective included, inter alia, studies of slope stability in the Cordillera and other areas, investigations of permafrost and ground ice in arctic regions, evaluation of terrain response to acid rain, analysis of the mineral composition of glacial till as a guide to mineral exploration, compilation of geological information to assist in the development of urban areas and assessment of the distribution and properties of the sensitive Quaternary marine clays that underlie much of the Ottawa-St.Lawrence lowlands. Studies of these natural hazards did not extend to the evaluation of the risk of loss of property or life that such hazards might pose to either individuals or groups of people.

Canada is one of the most extensively glaciated countries in the world with about 95 per cent of its landmass covered with deposits of glacial origin. Soils developed from these deposits form the basis for agriculture and forestry in Canada and the deposits provide the platform upon which most urban and industrial development occurs. Glacial deposits also provide an important source of granular materials for construction and serve in many parts of the country as aquifers supplying groundwater to both communities and individual homes. Thus, the occurrence of glacial deposits is an integral part of the geology of Canada which has been recognized since the inception of the Geological Survey. Throughout the entire history of the Geological Survey, however, effort directed toward the study of surficial or Quaternary geology has always been, not surprisingly, subordinate to that directed toward bedrock geology and its contained treasure of minerals or hydrocarbons.

The proportion of the annual budget of the Geological Survey, as noted earlier in Table1, p.15, that was directed toward Quaternary geology studies since the establishment in the mid 1960's of a Division for such work, has been of the order of 8 to 10 per cent. In prior years it is probable that the proportional budgetary allocation for Quaternary geology was very much less. Accordingly the following comment contained in the internal annual report of the Geological Survey for the period 1 April, 1974 to 31 March, 1975 reflects upon the status at that time of Quaternary geological mapping in Canada:

"Although major features of the glacial geology of Canada have been portrayed at a scale of 1:5,000,000 (Geological Survey of Canada Map 1253A, 1968) systematic surficial geology maps exist for only a small part of Canada. At present approximately only 15 per cent of the surficial geology of Canada has been mapped at a scale of 1:250.000 and less than 5 per cent of the country at a scale of 1:50,000. Thus systematic surficial mapping at scales of 1:250,000 in northern regions and 1:50,000 in the southern populous regions of Canada constitutes a major activity of the Division."

It may be noted that Canada's extensive landmass of approximately 10 million square kilometres requires a total of 918 map sheets at a scale of 1:250,000 for complete topographic or other map coverage. While a number of map areas, particularly those in coastal regions, containing large lakes or adjacent to international boundaries, do not fully contain land areas the overall magnitude of the task of providing full surficial geological coverage for the country at a scale of 1:250.000 can be readily appreciated. It is also recognized that surficial geology coverage at a scale of 1:250,000 or larger for the entire country may never be attained or required but emphasis on surficial geology mapping will continue to be applied to those areas of demonstrable need.

The scientific work of the Division in response to Branch obligations for Departmental Programs and to other initiatives of government can be summarized most conveniently under two main categories: A. Continuing Programs and B. Topical Programs and Events. Scientific work carried out under Category A was continuous in type and reflected the obligations of the Division to the Departmental ESP and MERP activities. While the long-term objective of much of the Category A work was to complete surficial geology coverage for Canada at appropriate scales the geographic locale for such work in any year was highly dependent upon terrain information needs identified by federal and provincial government agencies. This work involved most of the organizational units of the Division. Scientific work reported under Category B was, for the most part of limited time duration and was participated in by one or more organizational units of the Division.

A. CONTINUING PROGRAMS

Surficial Geology Mapping

In the early 1970's much of Canada's surficial geology remained to be mapped at a scale of 1:250,000 and completion of the task at that scale always remained an elusive goal. More realistic and attainable goals, however, were provided by recognition of the relevance of terrain information obtained by surficial geological mapping to the development of the country. This recognition is exemplified by the following statement contained in the introduction to the 1971-72 annual report of the Department of Energy, Mines and Resources:

"Greater social and economic awareness is also evident in the work of such essentially scientific agencies as the Geological Survey of Canada. The much-debated development proposals (*oil and gas pipelines, highway*) for the Mackenzie Valley have prompted an intense effort aimed at understanding the peculiar terrain of that area, and its potential reaction to the various stresses that advancing civilization may place on it. But in the highly populated and southern parts of Canada, too, geological research has moved into the compilation and analysis of terrain maps that will provide a better basis for urban and industrial planning."

In the late 1960's the Geological Survey undertook an extensive program of terrain mapping in the Goose Bay region of southern Labrador under the direction of Dr. R.J. Fulton, then an experienced Quaternary geologist with the Division of

Quaternary Research and Geomorphology. This work was undertaken in response to a request from the Newfoundland Forest Inventory - Land Capability group of the Provincial Department of Department of Mines Agriculture and Resources to provide terrain information to aid in the evaluation of the productivity of forest lands in Labrador. Fulton and his colleagues, who participated in the project, devised a scheme of rapid terrain reconnaissance using air photo analysis combined with selected sites for ground checking that enabled large tracts of ground in the boreal and northern regions of Canada to be mapped in relatively short periods of time. In essence the system of terrain mapping consisted of classifying the terrain into a number of landform systems. Each system was based on one of eight genetic/material categories (e.g. Morainal, Glaciofluvial, Lacustrine etc. with each reflecting a characteristic material) accompanied by letter symbols designating morphological and textural modifiers. The order of placement of the genetic and modifier symbols creates a series of Landform System Designators used to distinguish one map unit from another and from which basic terrain information can be obtained. Symbols were also used to convey additional geomorphic and related terrain information.

This system of terrain mapping was at variance with the traditional approach to mapping sedimentary units based on material/landform, genesis and, to the extent possible, stratigraphic information. It was essentially a two-dimensional system of mapping but one that could be readily adapted to airphoto interpretation and the correlation of landform systems with specific terrain uses or evaluations.

A similar approach to terrain mapping was soon to be extensively applied to the Mackenzie Valley and arctic island regions of Canada. These regions, following the discovery in 1968 of oil and gas at Prudhoe Bay on the arctic coastal plain of Alaska, became active areas for petroleum exploration. Discovery of petroleum resources in the Canadian arctic coastal plain, Beaufort Sea and arctic islands regions led to the prospect of oil and gas pipelines to bring these resources to southern markets. Routes for these pipelines and accompanying access roads would, of necessity, traverse many miles of sensitive soils in a permafrost environment. Thus, an urgent requirement was created for terrain information to serve the needs of both government and industry for environmental protection and pipeline engineering purposes.

By 1969 the Division was already involved in reconnaissance surficial geological mapping in the lower Mackenzie Valley and Mackenzie delta regions with separate projects under the direction of Dr. R.J. Fulton, Dr. O.L. Hughes and Dr. V.N. Rampton. These projects, prompted by petroleum exploration and pipeline interests in the region, were preliminary to a greatly expanded mapping effort in the area that was to follow over the next several years.

During 1970-71 the Division carried out about 65 surficial geology mapping projects that were distributed across Canada as follows:

Prov. or Territory:	B.C.	AB	SK	MB	ON	PQ	NB	NS	PEI	NL	Northern Terr.
Per Cent(No.Proj.)	6	14	2	6	19	6	5	3	2	6	30

It is apparent from this distribution of mapping effort that the Northern Territories received a major part of the work and that eastern Canada received a large proportion of the remainder. At that time, however, most of the mapping projects in the Northern Territories were located in the eastern rather than the western Arctic.

Although the actual distribution of mapping effort throughout the country varied from year to year the relative proportion of effort devoted to the various regions of the country throughout the review period remained more or less as noted above. Many project leaders, particularly those with a number of years of service with the Geological Survey, were responsible for more than one project with the overall average of 2.4 projects per leader. Thus, in any year the actual number of individuals involved in mapping would be less than half of the number of active projects listed.

In the following year (1971) the Government of Canada initiated the Environmental - Social Program, Northern Pipelines (ESPNP) in support of increasing activity in what became known as the Mackenzie Valley Transportation Corridor. This program, centred primarily in the Department of Indian and Northern Affairs provided an opportunity for the secondment of the Division's director, Dr. J.G. Fyles to act as Departmental Co-ordinator for the program. This secondment continued for a number of years and, as noted elsewhere in this account, brought about a change in the Director of Terrain Sciences Division. The ESPNP was also a source of funding that enabled the acceleration of terrain mapping in the Mackenzie Valley.

During 1971 the Division placed greatest emphasis in surficial geology mapping on the Mackenzie Valley Corridor. Approximately 40 map-areas at a scale of 1:125,000 covered the Corridor which had been divided into three major sections. Dr. N.W. Rutter, assisted by Ms. G.V. Minning, was assigned the upper part of the Mackenzie Valley from the Territories boundary to about Wrigley, Dr. O.L. Hughes, assisted by D.A. Hodgson and others, the central part from Wrigley to north of the Arctic Circle, and Dr. V.N. Rampton the remainder of the Mackenzie Valley, Delta and arctic coastal plain. By the end of the field season mapping had been completed for 26 of the map-areas with preliminary maps released through Open File later in the year. Demand for these maps immediately upon their release was substantial as they provided information essential to both government and industry for such uses as land use regulations, pipeline and highway alignments and location of sources of granular materials for construction.

Surficial geology mapping in the Mackenzie Valley and arctic coastal regions was essentially completed by about 1975. Although field work in the Mackenzie Valley had been essentially completed, the upgrading of the Open File maps to systematic surficial geology maps at a scale of 1:250,000 was to continue on until approximately the mid 1980's. This work constituted the largest mapping effort in a specific area ever undertaken by the Division. Large tracts of ground were subsequently mapped in other parts of the country but the magnitude of the Mackenzie project was not duplicated.

Later in the 1970's and on into the 1980's surficial geology mapping related to pipeline routing and territorial land use regulations was undertaken on Melville, Bathurst, and Prince of Wales Islands by D.M. Barnett, D.A. Hodgson and Dr. L.A. Dredge with complementary work on vegetation mapping by Dr. S.A. Edlund. Further east surficial geology studies were undertaken on Somerset Island by Dr. A.S. Dyke and R.B. Taylor and on Boothia Peninsula by Dr.A.S. Dyke. This work continued south through the District of Keewatin (now part of Nunavut) by Dr. W.W. Shilts and Ms. J.M. Aylsworth and was continued in northern Manitoba by Dr. L.A. Dredge. Complementing this work were other arctic islands mapping projects on Banks Island by Dr. J-S Vincent, Victoria Island by D.R. Sharpe, Queen Elizabeth Islands by D.A. Hodgson, Bylot Island by Drs. W.W. Shilts and R.A. Klassen and the Great Bear Lake region of the northern mainland by Dr. D.A. St-Onge. These projects had the aim of determining the distribution of Quaternary materials and landforms and interpreting the glacial history of these areas. In addition to the pipeline related work in the western arctic, the Division also had active projects in the eastern arctic, on Ellesmere Island by Dr. W.Blake, Jr. and on Baffin Island by D.A. Hodgson, with the aim of determining the glacial geology of these areas.

In addition to the support for surficial geology mapping in the arctic islands and northern mainland regions received from special programs such as the Environmental Social Program, Northern Pipelines the Division received substantial logistics support from the Polar Continental Shelf Project (PCSP). As a component unit of Energy Mines and Resources supporting operational units of the Department as well as university research teams, PCSP operated logistics bases at Resolute on Cornwallis Island and at Tuktoyaktuk on an arctic coastal peninsula northeast of the Mackenzie delta. These bases served as effective and efficient embarkation points for field parties moving to field camps in the region, as central communication centres and as sources for rotary and fixed wing aircraft support provided both on an allocation and favourable-price contract accession basis.

During the same period of time Dr. L.E. Jackson of the Division, operating from the Vancouver office of the Geological Survey was carrying out surficial geology mapping in the southern part of the Yukon Territory. This work contributed both to understanding of the glacial history of the area and as an aid to mineral exploration in the area.

In the southern regions of Canada the Division conducted its surficial geology mapping program in co-operation and liaison with various provincial government agencies and other federal government departments. Not all provinces, such as B.C., N.B.

and P.E.I. had surficial geology mapping programs and Quebec preferred to carry out its own work. Most of the mapping in the provinces was either at the regional scale of 1:250,000 or at a scale of 1:50,000 in urbanized areas.

Throughout the review period the main mapping activity was undertaken in the lower mainland, Fraser River Valley and interior of B.C., southern Alberta and southern Saskatchewan, southern and northern Manitoba, eastern Ontario and Ottawa River valley, Rouyn-Noranda - Lake Temiskaming area of Quebec, northern New Brunswick, most of Nova Scotia including Cape Breton Island and throughout Newfounland. Prominent participants in this work were Dr. J.J. Clague of the Vancouver office in B.C., Dr. A.MacS. Stalker in southern Alberta, Dr. R.W. Klassen of the Calgary office in Saskatchewan and Manitoba, Dr. L.A. Dredge in northern Manitoba, Dr. N.R. Gadd and Mr. S..H. Richard in Ontario, Mr. J.J. Veillette in Quebec and Dr. D.R. Grant in Nova Scotia and Newfoundland.

Surficial Geology Mapping Standards

In its various descriptions of its work and responsibilities the Geological Survey made reference, on occasion, to its role in the development and maintenance of “mapping standards”. For the most part such standards were the de facto embodiment of map legends and symbols that evolved through time and which appeared on any map reviewed and published by the organization. Thus the “standards” were primarily a reflection of current practice rather than any sort of adherence to some set of predetermined and published guidelines or instructions other than those pertaining to the structure of map legends that were contained in editions of the Geological Survey’s publication “Guide to Authors”. In the case of surficial geological mapping the matter of “mapping standards” is rather more complicated than for bedrock mapping.

For the most part the portrayal of bedrock units on a geological map is based on some combination of rock types and age relationships among rock types accompanied by symbols representing map unit boundaries, structural attributes or other pertinent information. Rock types can generally be distinguished by visual or laboratory-determined attributes and age relationships determined by superposition and fossil content or some form of radiometric age determination. Most practitioners of bedrock mapping have acquired considerable field experience on the terrain with which they are familiar prior to being assigned responsibility for a mapping project.

In the case of surficial geology two main factors complicate the mapping process. The first factor derives from the nature and origin of the materials and landforms that constitute surficial geology. In Canada surficial geology is essentially synonymous with understanding the materials and processes resulting from continental glaciations that affected the landmass at various times during the past 1.65 million years. The result of the geological events that occurred during this relatively brief period of geological time is a complex assemblage of geomorphic features and unconsolidated deposits arising from direct glacial deposition and from sediments associated with vast quantities of meltwater released during glacial recession. Common characteristics of glacial sediments, with the possible exception of those deposited in large proglacial lakes or marine embayments, are their textural variability and wide ranges in extent of areal distribution and thickness. In some regions, particularly the far north, continental glaciers may have occupied the land for long periods of time but left little record of their presence through either sedimentation or erosion. Further, the platform upon which glaciation occurred was subject to many metres of depression during glacial advances and to similar magnitudes of rebound following glacial recession - a process that is still continuing and one that has had significant impact upon major drainage systems and coastal elevations. These characteristics impose difficulties in the delineation of glacial materials and landforms as mappable units. A further complication in the mapping process is the general absence, other than local limited superposition of lithological units, of materials to aid in age determinations. Demonstrably *in situ* organic materials from which radiocarbon age determinations can be made are relatively rare and when such materials are found they are subject to the limit of about 50K years applicable to radiocarbon age determinations.

The second factor arose from the background, training and experience of those involved in the mapping of surficial geology. Many of the scientific staff of Terrain Sciences Division had training and backgrounds in bedrock geological mapping that they adapted to the mapping of surficial geology. Others, primarily those who transferred to the Division from the former Geographic Branch had backgrounds in physical geography or geomorphology with a greater interest in landscape classification. than materials and stratigraphic sequences. Among both groups were those with tendencies toward highly detailed land classifications while others preferred broader units of classification. These variations in mapping approaches were further complicated by the tendency of some to produce a terrain map oriented toward some specific application such as evaluation of terrain sensitivity. rather than a basic surficial geological map from which various terrain use maps could be derived. The result of the various approaches to surficial geology mapping was the production of diverse maps that did not lend themselves to systematic mapping of the country or to smaller scale map compilations.

In an attempt to bring some sort of order and consistency to the mapping program I established in about 1975, under the chairmanship of Dr. B.G. Craig, a Map Legend Committee with the aim of creating within the Division a mutually agreeable approach to surficial geology mapping. My further motivation for establishing such a committee was my conviction based on personal geological mapping experience and the wisdom contained in United States Geological Survey Professional Paper 837 (1974) by the late David J. Varnes entitled "The Logic of Geological Maps, with Reference to Their Interpretation and Use for Engineering Purposes". It had been my privilege to have been asked to review this paper prior to its publication. One of the principal conclusions of Varnes' work was that geological maps based on factual attributes of map units and their stratigraphic relationships one to another provide the necessary basic information from which various end uses can be made or derivative maps produced.

The Map Legend Committee, with participation by various members of the scientific staff including the chairman, Dr. R.J. Fulton, Mr.J.A. Heginbottom and Dr. D.A.St-Onge with commentary from Dr. D.R. Grant, met on an irregular basis over the next several years. Although no formal document on map legends was forthcoming from the committee it did circulate throughout the Division a number of draft legends for comment and produced a set of guidelines for legends to be used within the Division. These guidelines, which are contained in Geological Survey of Canada file No. GS6200-4-1, enabled the committee to serve as group to review map legends produced within the Division and to bring about a significant measure of map product standardization which persisted in the subsequent work of the Division.

Throughout my period of service as Director, and beyond, surficial geology mapping remained the primary function of the Division. By the latter part of the 1980's the extent of systematic surficial geology mapping at a scale of 1:250,000 throughout the country had probably risen to something in excess of 40 per cent. The emphasis on mapping, however, continued to be placed on information needs in specific parts of the country rather than upon completing systematic mapping per se.

Paleoecology and Geochronology

The Paleoecology annd Geochronology Section, under the leadership of Dr. W. Blake Jr., was established as an initial component of the Division. Work of the Section was designed to serve as a complement to Quaternary geological mapping and related terrain studies, assist in the interpretation of various Quaternary environments and to establish a geochronological framework for late Quaternary sediments.. Scientific staff of the Section, with appropriate technical support provided expertise in a number of specialties such as palynology (Dr. T.W. Anderson, Mr. R.J. Mott), paleoentomology (Dr. J.V. Matthews Jr.), paleobryology (Dr. M. Kuc) and diatoms (Dr. S. Lichti-Federovich). Diatoms are microscopic organisms found in both marine and fresh water environments and are sensitive to such environmental attributes as temperature and salinity. Fossil diatoms thus provide a means for the paleoenvironmental interpretations of both marine and fresh water Quaternary environments. Such interpretations with the use of diatoms, however ,is not a simple matter owing to the very large number of species that could be encountered at a particular site and the range of environmental conditions tolerated by any given species

The Radiocarbon Laboratory operated by the Section under the supervision of Mr. J.A. Lowdon until 1981, then by Dr. R.N. McNeely, provided an important service both to projects of the Division and to other Quaternary geoscientists through provision of radiocarbon age determinations derived from organic material contained within

Quaternary sediments. In addition, the laboratory investigated the radiocarbon content of modern materials to aid in calibration of age determinations.

A particularly important aspect of research, complementary to radiocarbon age dating, was the analysis and identification of all organic material dated thereby providing important paleoenvironmental information. The Radiocarbon Laboratory thus established itself as a standard for age determinations and Quaternary research as opposed to attaining a high annual rate of age determinations. The laboratory commonly produced in excess of 150 age determinations each year. These age determinations were published annually as a GSC paper.

Throughout the period of this review scientific staff of the Section carried out research, essentially on a continuing basis, in widely separated parts of the country. Dr. W. Blake Jr., in concert with scientists from the University of Copenhagen, University of Helsinki, Norwegian Polar Institute, Queen's University, Arctic Institute of North America and Environment Canada, undertook a multidisciplinary study of the glacial history of east-central Ellesmere Island and the adjacent coasts of northwest Greenland. In southern Canada Dr. T.W. Anderson and Mr. R.J. Mott carried out extensive palynological studies in an area extending from the Great Lakes to the Maritimes including Newfoundland. This work had the aim of interpreting environmental change in the area during postglacial time and to resolve chronological problems in the Champlain Sea basin of the Ottawa-St. Lawrence lowlands.

As part of the work in the Maritimes palynological studies were made on buried organic sediments and lake sediment cores from Nova Scotia and New Brunswick. These studies provided evidence for a warming trend prior to 11ka. followed by a cold period that lasted until the abrupt Holocene warming at 10ka. This climatic oscillation has been linked to the Allerod/Younger Dryas event (a period, primarily of European origin, extending from about 11ka to 10.5 ka during which climate warming permitted establishment of birch, pine and willow vegetation). Similarly in the Canadian arctic study of preserved vegetation has indicated the occurrence there of warmer climates during the period 10 - 4 ka. Thus, climate change, particularly warming, in the arctic is not restricted to modern times.

In western Canada a study of diatoms from cores obtained from the Fraser River delta was undertaken to determine the extent of extent of salt water intrusion into the sediments. Also in southern Ontario diatoms contained in lake bottom sediment cores were examined by Dr. S. Federovich to assist in interpreting environmental change such as that caused by acid rain.

During a period of about five years, beginning in 1977, Dr. J.V. Matthews Jr. of the Section in concert with Dr. O.L. Hughes from the Divisional office in Calgary and in cooperation with the National Museum of Man and the University of Alberta contributed to the Yukon Refugium Project in the Old Crow area. The "refugium" refers to an ice-free corridor that existed at various times during the Quaternary Epoch between the Cordilleran and Laurentide ice sheets and which extended at its maximum during the late

Pleistocene from the Yukon to Alaska and Siberia.. In Siberia the collective ice-free area is referred to as Beringian refugium. The corridor thus formed allowed for the distribution of various plant species and for the migration of animals and man.

Scientific staff from the Section and Division provided expertise in fossil insects, plant macrofossils, radiocarbon dating and Quaternary geology to the refugium project. These contributions along with other geological and archeological evidence discovered in the region showed that humans were in North America approximately 30,000 years ago which is about 16,000 years earlier than previous evidence had indicated.

A major event during the conduct of the refugium project was an international symposium on the work held in 1979 at Burg Wartenstein, Austria under the auspices of the Wenner-Gren Foundation. A concise account of the significance of the refugia to the northwest part of North America and beyond and of the paleoecological research devoted to this area by Section scientists and others is contained in a special report[27] on the work done.

Mineral Indicator Tracing

The concept of “mineral indicator tracing” derives from the fact that the process of continental glaciation abrades the bedrock surface upon which the glaciers rest and distributes the resulting abraded material in a down-ice direction. In the event that the glacier traversed a pre-existing mineral occurrence of economic interest evidence of that mineralization would be contained in the down-ice sediments either as distinct and visually identifiable rock fragments or as mineral grains generally identifiable only through laboratory analysis. Thus, in glaciated areas where glacial sediments obscure the bedrock, the location of mineralization in the bedrock can be aided through the discovery of rock fragments or minerals of economic interest in the glacial “drift” and by knowledge of the probable direction from which such indicator materials came. Interpretation of glacial flow directions, however, commonly can be complicated if multiple glaciations from different directions have occurred over an area.

Specific studies of mineral indicator tracing techniques by the Geological Survey were undertaken by Dr. H.A. Lee prior to his resignation from the Survey in 1969 to pursue a private consulting practice. Lee’s work was continued and expanded by Dr. W.W. Shilts first in the Eastern Townships of Quebec and later in the District of Keewatin (now Nunavut). By 1972 work on sedimentology and mineral indicator tracing in the Division had attained sufficient significance that these activities were organized into a separate operational section under Dr.B.C. McDonald. This section, Sedimentology and Mineral Tracing (SMT) was also responsible for the operation of laboratories in support of work in sedimentology, engineering geology and mineral indicator tracing. Most of the chemical analyses required by the Section for the identification of elements

[27] Hopkins, D.M., Matthews, J.V. Jr., Schweger,C.E. and Young. S.B. (Eds.). 1982: Paleocology of Beringia: Academic Press, New York

within glacial sediments were carried out under contract with commercial laboratories. The Section also had responsibility for a hydraulic flume laboratory that is described later in a separate section.

In the fall of 1973 Dr. McDonald opted for participation in the Career Assignment Program and upon completion of training returned to the Division to assume leadership of the Geotechnical Subdivision. Dr. W.W. Shilts was then assigned as Head of the Sedimentology and Mineral Tracing Section, a role that he maintained throughout the balance of this review period. Over the next decade and beyond the Section expanded modestly in numbers of scientific and support staff and diversified its activities.

Throughout the remainder of the 1970's scientific staff of the SMT section, particularly Dr. W.W. Shilts, Ms. I.M. Kettles, Ms. J.M. Aylsworth and Dr. R.A. Klassen, conducted most of their work in the District of Keewatin particularly south of Baker Lake. The aim of this work was to test the applicability of sampling and analysis techniques to the exploration for base metals and uranium. Parallel work on the orientation and extent of glacial dispersal trains in central Keewatin continued to aid in the use of glacial sediments as a prospecting medium. Also studies of lake sediment in Keewatin showed that these sediments tend to be thin, of glacial or marine origin and that "modern" lake sediment is likely to be metal-poor diatomaceous ooze. It was thus discovered that lake sediments may be of limited value compared with till samples as indicators of mineralization. This discovery was to become the source of contention within the Survey over the efficacy of widespread geochemical sampling of lake sediments in northern glaciated regions by another Division of the Survey as a basis for producing geochemical anomaly maps to aid in mineral exploration

Other work on the geochemistry and granulometry of surficial and lacustrine sediments in Keewatin by Dr. R.A. Klassen provided a basis for the interpretation of surficial materials as indicators of bedrock mineralization. The preferential concentration of uranium as well as base metals in the clay-sized fraction of till and the down-ice dispersal of these elements provided a useful guide for the use of till sampling as a prospecting method. In a parallel study of tundra vegetation it was also demonstrated that certain plant species preferentially concentrated such metallic elements as lead, zinc and uranium thereby providing a further medium for mineral exploration in drift covered areas.

In the eastern arctic other studies of erosion and transport of sediments by glaciers was undertaken by Drs. Shilts and Klassen on Bylot Island. Here modern glaciers situated on highly metamorphosed Precambrian terrains drain onto poorly consolidated Mesozoic sediments. The contrasts in terrain types enabled deductions to be made about the processes of glacial erosion and sedimentation.

In the early 1980's a prominent environmental concern was the effect on lakes and other terrain elements, particularly in the southern Canadian Shield, of acid rain arising from the precipitation of gaseous atmospheric pollutants. In an attempt to assess the distribution and magnitude of the acid rain problem some of the scientific staff of the

SMT Section undertook an extensive sampling of glacial drift over the Frontenac Arch, the southern part of the Canadian Shield that extends south-eastward from the Haliburton district of Ontario toward Kingston and the Thousand Islands. Chemical analysis of the sediments revealed that glacial dispersal of carbonate glacial debris provides for high buffering capacity of lakes in the eastern part of the region. It was also demonstrated that glacial dispersion of carbonate-derived drift had a significant effect in assisting non-carbonate bedrock terrain to moderate the effects of acid rain.

In addition to the work on terrain reaction to acid rain in the Frontenac Arch area chemical analysis of sediments revealed several regions of arsenic, mercury and base metal anomalies. These anomalies are of interest both as possible environmental contaminents and as mineral exploration targets. Further sampling of drift to determine its sensitivity to acid rain was extended to the Gatineau area of the southern Canadian Shield. These sampling programs provided the basis for development of a technique for estimating the Acid Neutralizing Capability (ANC) of till.

Throughout the mid 1980's and beyond both scientific staff of the SMT section and other scientists working under contract carried out mineral indicator tracing studies in central Keewatin, northern Manitoba, northern Ontario, Abitibi region of Ontario and Quebec, northern Quebec, Labrador and New Brunswick. Some of this work was carried out with support from various federal/provincial mineral development agreements designed to stimulate mineral exploration in various parts of the country.

Since the fundamental basis for mineral indicator tracing lay in understanding both glacial flow directions and glacial stratigraphy as well as identifying indicator minerals, it was inevitable that SMT scientific staff would become involved in various forms of regional mapping and stratigraphic studies. Thus, in various parts of the country the Section used air photos and Landsat imagery to aid in the determination of ice-flow directions and the pattern of dispersion of glacial erratics associated with various phases of ice flow. Sonar profiling of lakes and rivers, such as Lake Temiskaming and the Ottawa River, was also used to provide information on the stratigraphy of glacial and younger sediments. In some localities along the Ottawa River sonar profiling provided evidence of subaqueous landslides and faulting that may be indicative of previous seismic or neotectonic events.

Extensive knowledge of the glacial geology in the District of Keewatin enabled scientific staff of the Section to provide a realistic estimate of the amount of glacial erosion that had occurred over the Canadian Shield during the last glaciation. This estimate, one of particular interest for potential use of Canadian Shield terrain for subsurface placement and long-term management of spent nuclear fuel, was based on analysis of the glacial dispersal of material derived from distinctive red beds of the Dubawnt Group of rocks. Results of the analysis indicated that less than 10 m of rock had been removed from the source area by glaciation. The study also provided important information on the growth and decline of the major continental glacier that originated in the Keewatin region.

The work of SMT Section was primarily intended to provide techniques and guidelines to aid mineral exploration in glaciated terrain. These guidelines are contained in a number of publications by SMT both as Geological Survey publications and in scientific journals. A concise overview of the relation between glacial till and mineral exploration is provided by Dr. W.W. Shilts in his paper entitled “Glacial Till and Mineral Exploration” contained in Royal Society of Canada Special Publication No.12 (1976) edited by R.F. Legget .The Section also contributed significantly to mapping the glacial geology of the country and to the understanding of its glacial history. In this latter regard it complemented and supplemented the mapping activities of the Regional Projects Section but each Section operated essentially independent one from another and with some differences of opinion on the interpretation of events in the glacial history of the country.

Permafrost and Northern Terrain

The mandate of the Division for the conduct of Quaternary geological studies in all parts of Canada of necessity included northern and arctic regions of which extensive parts are characterized by the existence of either continuous or discontinuous permafrost. Permafrost is a thermal condition under which the ground remains frozen throughout the year except for the annual thaw of a near-surface zone extending in depth to a few tens of centimetres. As the name implies in continuous permafrost frozen ground extends everywhere throughout the region whereas in regions of discontinuous permafrost, mainly in more southerly regions, tracts of permanently frozen ground may be separated by areas of unfrozen ground. Within a permafrost regime there is the tendency for ice to accumulate within the soil as lenses or layers and for these to increase in size with time as moisture, either in liquid or vapour form, migrates toward a freezing front.

So long as permafrost terrain remains undisturbed the ground remains stable. If the ground is disturbed, however, by natural means such as coastal or river erosion or by artificial means such as excavation or vegetation removal, ground ice can be exposed to thermal degradation with consequent loss of soil stability. Thus, understanding of variations in soil texture and the distribution of ground ice is fundamental to the understanding of the potential behaviour of northern terrain.

Concern with permafrost and northern terrain was always an integral part of the scientific work of the Division but in the early 1970's the numbers of staff with expertise in this field were never sufficient to form a separate operational unit. Thus, those staff with expertise in permafrost were commonly assigned to the Engineering Geology or similar unit. In addition to its own limited permafrost expertise the Division provided modest amounts of annual field support to Prof. J. Ross Mackay, Department of Geography, University of British Columbia to assist in his research on permafrost phenomena in the Mackenzie delta and Yukon coastal plain. One of Prof. Mackay’s findings was the relationship between the development of pingos (ice-cored hillocks), that are common in the Mackenzie delta, and the draining of shallow lakes through coastal erosion.

As a complement to the extensive mapping program in the Mackenzie Valley related to oil and gas pipeline routing a major drilling and soil sampling program was undertaken in 1972. This program under the direction of Dr. R.M. Isaacs, a soils engineer, was designed to retrieve undisturbed cores of frozen soil for subsequent analysis and testing in the Ottawa laboratory. It was deemed essential to obtain, retain and to transfer the cores to the laboratory in Ottawa without altering the thermal condition of the frozen soil. A significant part of the terrain evaluation work in the Mackenzie Valley involved a drilling program to recover undisturbed cores of unconsolidated sediments for evaluation of the texture and ground ice content of these materials. In order to preserve the frozen state of the sediments during drilling a helicopter-transportable drilling fluid chiller was especially designed and built under contract. The chiller was shipped to the field for use during the drilling program which extended over both summer and winter months. The chiller was effective in maintaining the frozen state of the core samples which were initially retained in the field in electrically-operated chest freezers.

The core-laden freezers were subsequently shipped by air from Norman Wells to Ottawa. This shipment was somewhat unusual as the cores needed to be kept in their frozen state throughout the duration of the shipment. Not all commercial aircraft then available for cargo shipments were capable of providing a refrigerated cargo space. After some considerable investigation by the Division's administrative officer at the time, Mr. L.A. Jackson, it was determined that a charter airline company operating out of Winnipeg could adapt the airconditioning system of a twin- engined turboprop in its fleet such as to maintain appropriate freezing temperatures in the cargo bay of the aircraft. A contract for use of this aircraft was arranged and the cores were shipped to Ottawa with a refuelling stop in Winnipeg. During this short stop the freezer containers were connected to on-ground electrical power in order to maintain the frozen state of the cores. The cores arrived in good order in Ottawa late at night on the day of shipment from Norman Wells. Unfortunately, prior to transfer of the cores from the Ottawa airport to the Division's cold room laboratory the power cord to one of the freezer chests was inadvertently detached with some subsequent loss of core integrity. Not surprisingly the drilling and sampling operation and subsequent shipment of the cores was a particularly costly venture. The information obtained from the cores, however, was of particular value in evaluating terrain of the Mackenzie Valley for pipeline purposes. Further, the data obtained from the cores along with subsurface information obtained from other drilling programs in the area were subsequently assembled by Mr. D. E. Lawrence of the Division into a geotechnical data bank. This data bank has been and continues to be in use since its inception in the 1970's.

During the same period as work in the Mackenzie Valley oil and gas exploration activities in the Arctic Islands generated a demand by the Department of Northern Affairs for information on terrain sensitivity to assist in the development of land use regulations and environmental safeguards. The Division, with assistance from Arctic geologists from the Institute of Sedimentary and Petroleum Geology in Calgary, responded with the preparation of a 1:500,000 scale terrain sensitivity map series to meet the needs of the Northern Affairs Department.

Systematic terrain mapping of Bathurst, Cornwallis, Somerset and Prince of Wales Islands at a scale of 1:125,000 by D.M. Barnett and Dr. A.S. Dyke, along with previous terrain mapping by the Division in the Arctic Islands, District of Keewatin and northern Manitoba provided basic terrain information for over 80 per cent of the potential gas pipeline route extending south from Melville and Bathurst Islands to 54° N. Lat. The mapping was accompanied by specialized studies by Dr. S.A. Edlund of the botanical cover and of the geotechnical characteristics of terrain units to assist in the evaluation of terrain performance. This information was of value for both pipeline design considerations and to the Department of Indian Affairs and Northern Development for enhanced application of Arctic Land Use Regulations.

Throughout the remainder of the 1970's studies of the occurrence of permafrost in the Mackenzie Valley and high Arctic continued in relation to the effects on the terrain of petroleum exploration and pipeline construction Work on the acoustic properties of frozen ground in the Mackenzie valley and the application of field geophysical methods by Dr. P.J. Kurfurst demonstrated that geophysical surveys can be used to delineate the occurrence of ground ice thereby reducing the extent of drilling necessary to aid in the design of large construction projects.

By 1978 Mr. J.A. Heginbottom had returned to the Division following a two- year secondment to the Department of Indian and Northern Affairs for work related to northern pipelines. Upon his return he was appointed as Head of a newly-formed Geomorphic Processes Section which was tasked with studying the distribution, nature and rates of surface and near-surface processes that shape the Canadian landmass. This section operated as an independent unit for several years prior to its incorporation into a larger subdivision.

Work continued on the occurrence and performance of permafrost terrain in Northern Canada and on the effects of summertime operation of cross-country vehicles and diamond drilling operations in Keewatin. This work was aimed at improving the effectiveness of Territorial Land Use Regulations. Elsewhere in Keewatin during the early 1980's several different studies of northern terrain were in progress. Dr. L.D. Dyke continued a study of frost heaving in bedrock. It was determined that such heaving is pronounced where a relatively thick active layer occurs in an area of a near-surface water table. Also work on “mud-boil” patterned ground in Keewatin clearly indicated that soil stability is highly dependent upon retaining the integrity of the vegetation cover.

Work was also continued on the development of a system for recognition of terrain susceptibility to vehicle disturbance. It was intended that the system would enable vehicle operators to select alternate routes that are less susceptible to disturbance and thereby minimize the potential for erosion. It is not certain that the system ever proceeded to the operational stage.

By the mid 1980's consideration was being given to the construction of an oil pipeline from Norman Wells, N.W.T. to Zama Lake, Alta. The pipeline route would traverse the upper part of the Mackenzie and beyond and would thus be underlain by both continuous and discontinuous zone of permafrost. A project, under the leadership of Mr. D.E. Lawrence, was thus initiated to examine the potential environmental impact of construction of the pipeline. This work was supported in part by the Departmental Office of Energy Research and Development (OERD).

In 1985 Dr. D.R.Sharpe renewed investigations within the thermokarst terrain of the large glaciomarine fan northeast of Cambridge Bay, Victoria Island, (now part of Nunavut). This work was part of a continuing program to investigate the origin, modern processes and periglacial significance of active thermokarst erosion of the glaciomarine deposits. This work was another example of the manner in which field investigations commonly reflected the interest and capabilities of the individual scientist as opposed to the general responsibilities of an organizational unit. Permafrost and related geomorphic studies would normally be carried out by members of the Geomorphic Processes Section but, in this case, Sharpe undertook the investigation as part of his regional surficial geology mapping project on Victoria Island.

Also in 1985 a drilling program, in conjunction with the Department of Indian and Northern Affairs and supported in part by OERD, was undertaken on Richards Island, NWT. The aim of the drilling program was to provide information on the geotechnical and geocryological characteristics of the subsurface materials. This information was also used to assist in the evaluation of ground probing radar as a means for detecting ground ice in a permafrost environment. Work also continued on evaluating the geotechnical and geocryological conditions along the landward side of the coastal zone of the Beaufort Sea. This work was supported in part by funding from the OERD and the Northern Oil and Gas Action Program (NOGAP). Elsewhere in the arctic study of periglacial geomorphic processes was continued in the vicinity of Cambridge Bay, Victoria Island. This work, carried out by Mr. P.A. Egginton, included an examination of the distribution of ice in the active layer and its variation during the summer thaw season.

Early in 1986 major organizational changes occurred in the Geological Survey as the result of the amalgamation of the former Earth Physics Branch with the Geological Survey, elimination from the Survey of the former Resource Geophysics and Geochemistry (RGG) Division and transfer to the Survey of the Glaciology Section from the Polar Continental Shelf Project (PCSP). These changes were ostensibly to enhance operational efficiency within the Department. Attainment of the desired operational efficiency was a rather less certain event than was the consternation generated within the affected operational units of both Branches.

One of the impacts upon Terrain Sciences Division of these Branch-level organizational changes was a restructuring of the Division into subdivisions to accommodate The Terrain Geophysics Section from the RGG Division, Permafrost Research Group from the Earth Physics Branch and the Glaciology Section from PCSP. The Terrain Dynamics Subdivision formed to accommodate the newly-acquired units greatly enhanced the capability of Terrain Science Division to conduct permafrost and northern terrain research. The Subdivision also maintained its capability to deal with other terrain performance issues in southern regions of the country.

For the balance of the review period .most of the work of the Subdivision was directed to arctic regions in relation to oil and gas development and to environmental concerns arising therefrom.

A field study of periglacial processes was undertaken in the vicinity of Cambridge Bay, Victoria Island, N.W.T. including the installation of equipment to measure piezometric heads and water table elevations. This work complemented a study of tension cracks and thermokarst development. In addition both field and laboratory experiments were made to determine the effects of ice segregation on soil permeability.

In the Beaufort Sea coastal area and in the Mackenzie Delta the Northern Oil and Gas Action Program (NOGAP) provided support for evaluation of ground probing radar as a means for detecting massive ground ice bodies in permafrost regions. These trials, undertaken by Mr. J.A. Pilon, demonstrated that the radar system is capable of mapping ground ice masses and subsurface geology at depths up to 30 meters. Elsewhere along the Yukon coast, Richards Island, located on the northeastern flank of the Mackenzie Delta, and on the Tuktoyaktuk Peninsula geotechnical and ground temperature studies were undertaken to assist in assessment of rates of coastal retreat.

Studies of the growth of permafrost in drained lakes and of the growth of pingos continued in the Mackenzie Delta - Tuktoyaktuk Peninsula area. One of the leading workers in the permafrost regime of the Beaufort Sea coastal plain was Prof. J.R. Mackay, Department of Geography, University of British Columbia whose field work over many years was supported, in part, by the Division. Also, in the area off northern Richards Island, a locale of particularly thick permafrost, drilling and sampling of both frozen and unfrozen sediments was undertaken to aid in the geotechnical characterization of these materials. On the west side of Richards Island a program of temperature, uphole seismic, and thermal conductivity measurements in boreholes was undertaken to assess the characteristics of the terrain along the inshore part of a possible pipeline landfall.

Offshore in the Beaufort Sea over 200 line kilometers of seismic refraction records were obtained. These data were used to map the presence of ice-bonded sediments within 20m of the sea floor and to determine the seismic velocity of sediments at and near the sea floor. This information was of particular significance for the design and siting of offshore drilling platforms and/or pipelines.

An important part of the Arctic scientific program has been the installation of temperature cables in both offshore and onshore locations and the collection of temperature data by direct recording and by acoustic telemetry from remote locations. These temperature data from active recording locations along with archived data enable relationships to be established among such variables as climate, latitude, elevation, geological history and sediment type.

A topic attracting increasing international attention, particularly with respect to Arctic oil and gas exploration, is that of gas hydrates. Such bodies of frozen methane gas commonly found in Arctic offshore regions may be potential gas resources or possibly explosive hazards if encountered unexpectedly during exploration drilling. A number of exchange visits on the topic of gas hydrates took place under provisions of the (then) Canada/ USSR Arctic Exchange Program.

Natural Hazards

The principal terrain hazards within the purview of the Geological Survey were those of slope failures in unconsolidated materials or rocks and the instability of terrain associated with the degradation of permafrost. Scientific staff having an interest in such issues as well as other aspects of applied geology, of which I was one of a small number, were assigned to an Engineering Geology unit or similar organizational entity directed toward a number of applied geological activities.

Over the course of this review period the Engineering Geology unit varied with time and numbers of staff from a section to a subdivision (see Appendix II) and participated in a number of diverse activities of varying duration. Included among these activities were engineering geology field work in the Mackenzie Valley, urban geology, geoscience studies for the Mirabel airport, work on permafrost terrain, environmental geology of coal mining in the Cordillera, geological disposal of high level nuclear waste and study of landslides in various parts of the country. Many of these activities were of a limited time duration and are reported on as part of other programs included under Category A or as part of topical programs describe later under Category B. With respect to natural hazards *per se* the study of landslides in various terrains constituted the main ongoing work of the Engineering Geology unit but was pursued by only a small number of scientific staff at any given time.

In early May 1971, following a winter of exceptionally heavy snow fall and heavy spring rains through out the Ottawa-St. Lawrence lowlands, a particularly severe landslide occurred in the marine clays that lay beneath the village of Saint-Jean-Vianney, Quebec. The village, which now no longer exists, was located 2.4 km north of the Saguenay River and approximately10km west of Chicoutimi. The landslide occurred with little warning late in an evening and claimed 31 lives as well as the loss of 40 individual homes and property in the village. It was one of the worst natural disasters to have occurred in the province in many years. As then Head of the Engineering Geology and Geodynamics Section I was asked by the Department to join with several other geotechnical specialists from other departments of the federal government as part of an ad hoc committee to examine the site a few days after the event occurred. This examination was done by an overflight by a helicopter provided by Canadian Forces based in nearby Bagotville, Quebec. The site was also under investigation by agencies of the Government of Quebec which also provided assistance to the victims of the disaster. As I recall, the federal government ad hoc committee concluded that the Government of Quebec had the post-disaster situation well in hand and that the disaster relief provisions of the federal government were not required in this case. Subsequent investigations of the site by Quebec geotechnical specialists revealed that the landslide, actually an earthflow, had occurred within an area that had been subject to a much larger earthflow about 500 years earlier.

As a follow on to the St-Jean Vianney disaster a year later Dr. N.R. Gadd was assigned a project to delineate the extent of Champlain Sea deposits in the St. Lawrence lowlands to assist the Quebec Department of Natural Resources in evaluating the extent of the landslide hazard in the area. Dr. Gadd had extensive experience with Champlain Sea and other Quaternary deposits in the area and was thus able over the next year or so to compile the information required by the Quebec Department.

The study of slope failures in Champlain Sea clays was extended to the Ottawa River valley and continued for the next several years. This work included coring of the sediments for geological purposes and an evaluation of hydrogeological factors affecting slope stability. Results of investigations of the marine clay in the Ottawa area were released on Open File in 1976 as a series of 17 maps showing the distribution of the sensitive clays and of landslides..

In the fall of 1973 Dr. P.A. Carr, a hydrogeologist with previous experience with the Geological Survey, transferred from the Department of the Environment to assume responsibility as Head of the Engineering and Environmental Geology Section. One of the ongoing activities at that time was the study by Mr. J.A. Code of the stability of slopes along the Mackenzie River of significance to the potential routing of oil and gas pipelines in that area. Another investigation of slope stability, although not a natural hazard, was a study of the environmental impact of coal mining in the mountainous East Kootenay area of British Columbia. This work, undertaken by Dr. J.E. Harrison, was designed to evaluate the stability of spoil piles and to assess the potential for use of vegetation in the stabilization and reclamation of these slopes. Field work on this project was continued over the next several years. Dr. Harrison went on to assume other responsibilities within the Public Service and later with the Department which precluded him from completing his report on the coal mine reclamation work until 1985.

In December1975 Dr. Carr transferred to the National Energy Board. He was replaced as Head of the Engineering and Environmental Geology Section by Mr. E. B. Owen a long term employee of the Geological Survey with extensive experience in a variety of government-sponsored engineering projects. Apart from continuation and completion of the work on landslides in the Ottawa River valley over the next year or two the Engineering and Environmental Geology Section was reduced to about two scientific staff who devoted their time exclusively to the Nuclear Fuel Waste Management Program. The small size of the Engineering and Environmental Geology Section and the absence of work on natural hazards continued for the next several years, even following the retirement of Mr. Owen in September, 1980 after 34 years of service with the Geological Survey.

During this period of reduced capacity for work on natural hazards and other facets of applied geology attempts were made at Divisional level to recruit scientific staff trained at the graduate level in engineering geology. At that time, however, the supply of such individuals was low and the demand by industry for those available was relatively high thus the Survey was not able to attract engineering geologists.

By 1982, however, improvements were made in the Division with respect to work on natural hazards and related terrain performance issues. A Geomorphic Processes and Engineering Geology Section was created under the leadership of Mr. J.A. Heginbottom and in October of 1982 the Division was successful in recruiting Mr. S.G. Evans who was in the process of completing a doctorate from the University of Alberta based on landslide research. Evans eventually completed the requirements for his doctorate degree and continued with the Geological Survey beyond the period of this review in his examination of slope stability issues in a wide range of geological and geomorphic settings throughout the Cordilleran region. Some of these studies were undertaken jointly with Dr.J.J. Clague a distinguished Divisional scientist assigned to the Vancouver office of the Geological Survey. In addition to his work on Cordilleran landslides Dr. Evans undertook a compilation of the historical damage caused by landslides in Canada and participated in many domestic and foreign conferences on the subjects of landslides and slope stability.

By 1986 the Geomorphic Processes and Engineering Geology Section became part of the Terrain Dynamics Subdivision under J.A. Heginbottom. Study of the landslide hazard in the Canadian Cordillera was continued by Dr. Evans including field studies of relatively recent major landslides throughout the Cordillera and archival research to enable assembly of a catalogue of destructive landslides in the more populous regions of the southern Cordillera.

Also in 1986, following a previous request from Public Works Canada, Dr.Evans completed an investigation and report on geological conditions as they might affect and control deep-seated slope movements at the Parliament Hill promontory in Ottawa. The report concluded that the Parliament Buildings were not endangered by the slope movements that had been detected.

In 1987 work on natural hazards in the Atlantic Region was undertaken by Dr. D.R. Grant, a scientist with the Quaternary geology mapping unit of the Division. Dr. Grant's work revealed that postglacial sea-level recovery showed a widespread rapid rise linked to crustal subsidence and tidal change. A submergence rate of 20-50 cm per century was determined which is the fastest submergence rate in eastern North America and a principal cause of shoreline change. A further example of postglacial dynamic movement in eastern Canada was the discovery, through systematic Quaternary geological mapping in western Newfoundland, of large-scale, deep-seated gravitational creep of mountainsides which cause debris flows and landslides. One such event had recently occurred in Gros Morne National Park.

. B. TOPICAL PROGRAMS AND EVENTS

In addition to the ongoing scientific programs, which formed the primary basis for the organization of the operational scientific units of the Division, a number of additional responsibilities and activities contributed to the workload of the Division. Some of this additional work was of relatively brief duration while other activities continued for a number of years. A description of some of these programs and events follows in the order of the year in which the work began.

Flume Laboratory (1970 - 1983)

In 1968 the Geological Survey decided to proceed with plans and specifications for a flume facility that would have sufficient flexibility such that a wide variety of sedimentary environments could be studied experimentally. Initial requirements, specifications and plans were drawn up jointly by Dr. I. Banerjee and Dr. B.C. McDonald both of whom had specific research interests in fluvial processes and sedimentary structures. Final designs and specifications were drawn up by Dr. McDonald in concert with a contractor, Mr. F.H. Siemonsen, P.Eng., who later supervised construction and installation of the facility. Construction of the flume on the ground floor of a former garage attached to the building at 299 Carling Ave.(later to become better known as 401 Lebreton St.) began in March 1970 and was completed in November 1970. Upon completion the tilting-bed recirculating hydraulic flume was an impressive apparatus consisting of a glass-walled main channel approximately 18 m long, 0.75m wide and 0.60m deep with massive electric pumps capable of handling both water and sediment. Variables such as discharge, slope, depth, and sediment characteristics could be controlled during experimental work with the flume. It was intended that the facility be available to any Geological Survey staff member for experimental study of particular sedimentary structures or processes.

Upon completion of the facility it became an asset of the Engineering Geology and Geodynamics Section for which I had responsibility. I was not an employee of the Survey at the time the decision was taken to proceed with the design and construction of the flume. Upon returning to the Survey in 1969 I did have reservations over the decision to proceed with its construction. My reservations had nothing to do with the scientific merit of the facility which had the capability to examine an array of fluvial and related sedimentary processes and structures. My concern arose from the limited number of scientific staff in the Survey with an interest in such research but more importantly from the limited capacity of the Division to provide the necessary technical support to operate and maintain the facility.

Useful research was done on the flume in its early years by Dr. McDonald and a few university researchers. In September 1973, however, Dr. McDonald was selected for managerial training under the Career Assignment Program (CAP) operated by the Public Service Commission. Following completion of training in December 1973 he returned to the Geological Survey for an initial CAP assignment as Acting Head of the Geotechnical Subdivision in Terrain Sciences Division. Early in 1974 Dr. McDonald's duties were expanded by the Assistant Deputy Minister, Science and Technology to include those of Departmental Co-ordinator, Environmental-Social Program, Northern Pipelines and to serve on departmental and interdepartmental environmental committees.

The demands of these new assignments were such as to severely limit Dr. McDonald's opportunities for the conduct of research with the flume facility. This situation continued until his departure from the Geological Survey in 1975.

Experimental work with the flume was continued with the recruitment in July 1974 of Dr. T.J. Day from the Department of Geography, University of Canterbury, New Zealand. Dr. Day had an interest in fluvial processes and over the next several years he undertook, in conjunction with Dr. J-S Vincent a major field study of arctic rivers, particularly on Banks Island, to provide information relevant to environmental assessment. This work was continued until about 1978. In 1978 and part of 1979 Dr. Day spent a year at the Hydraulics Research Station, Wallingford, England undertaking research on fluvial processes. Upon his return to the Division in 1979 and until his resignation from the Geological Survey in August, 1980 to take a position with Environment Canada he was actively involved in work with the Flume Laboratory in concert with researchers from the University of Ottawa and Wilfred Laurier University. With the departure of Dr. Day no other scientific staff of the Division or the Branch expressed any interest in the facility which subsequently declined into disuse.

During the next several years the facility remained idle and attempts were made at Divisional level to have the facility donated to a university or other research institution that might make productive use of it. Any costs for dismantling and shipment of the facility were to be the responsibility of the recipient. After several years of continuing internal inactivity with the flume, and no indication of any external interest in it, the decision was made to declare the facility surplus and to turn it over to Crown Assets for disposal. By about 1985 the flume was dismantled and sold either for scrap metal or for the going market price for any of its functioning components.

Over the period of time that the flume was in active use, about 10 years, there is no doubt that it enabled some useful experimental work to be done but it may well remain an open question as to whether the work done justified the capital cost of the facility. I remain of the opinion that the acquisition of major capital equipment should be subject to a thorough review of the projected use of the equipment and its value to the immediate and continuing scientific objectives of the organization.

Montreal International Airport (Mirabel) (1970 -1973)

In 1971 the Department of Regional and Economic Expansion (DREE), in concert with the Quebec Department of Mines, requested assistance from the Geological Survey and provided financial resources to evaluate the soils at the site of the new Montreal International Airport (later to become known as Mirabel) and to assess local sources of gravel for this major project. Responsibility for this work was assigned to Dr. D.A. St-Onge who promptly assembled a team to undertake the work on a continuing basis at the site. The field crew, supported by drilling, sampling and geophysical surveying equipment, operated from a combined office and laboratory for geological and geotechnical analysis of samples. The field office and laboratory, under the direction of Mr. F. Morin, was established in a dwelling in the former village of St. Scholastique. This property was but one of a large number of properties within an area of prime agricultural land. that had been expropriated for the airport itself and for a much larger surrounding buffer zone. The area studied extended over approximately 1,300 km^2 which greatly exceeded the actual area required only for the airport. At the time this work was in progress the Department made the following statement in its annual report for 1971-72:

"Greater social and economic awareness is also evident in the work of such essentially scientific agencies as the Geological Survey of Canada. The much-debated development proposals for the Mackenzie Valley have prompted an intense effort aimed at understanding the peculiar terrain of that area, and its potential reaction to the various stresses that advancing civilization may place on it. But in the highly populated and industrialized southern parts of Canada, too, geological research has moved into the compilation and analysis of terrain data that will provide a better basis for urban and industrial planning."

The latter part of this statement is in direct reference to the work then being undertaken for the new Montreal airport but the entire statement was intended to convey the relevance of the work of the Geological Survey, and perhaps Terrain Sciences Division in particular, to the social and economic requirements of the country.

Field work on the project was carried out during 1971 and 1972. Data on the geology of the area and the geotechnical characteristics of the soils were subsequently used by Ms. M. Kugler-Gagnon as the basis for a doctoral thesis at the Department of Geography at the University of Ottawa. Parts of the thesis were subsequently published by the Geological Survey as Paper 76-26 entitled “The Geoscientific Information System for the North Montreal Region”. For its time the work done on data processing by Ms. Kugler-Gagnon using punch card technology and an adaptation of the then available SYMAP V program was a pioneering effort in the development of geoscience data banks and automated map production. This report is also accompanied by a surficial geology map of the site area at a scale of 1:100,000.

Mirabel's rather less than fully successful time of operation for international airline passenger flights came to an end in early November, 2004 after almost 30 years of operation. An account of the demise of the airport is contained in an article by Hubert Bauch reprinted from The Montreal Gazette by The Ottawa Citizen on October 30, 2004. The article claims that:
"What was to have been one of the world's great airports now stands as a monument to bad planning and worse execution - and a staggering waste of public funds" The article goes on to point out the lack of adequate land connections to the airport from urban Montreal, overly optimistic projections during the late 60's and early 70's of the volume of air passengers, the impact of the 1970's OPEC oil crisis on air transportation and excessive expropriation of land as a buffer against the noise of anticipated supersonic passenger aircraft (38,000 hectares of prime farm land were expropriated but fewer than 2,000 hectares were used for the facility, it may be noted that one hectare is equal to about 2.47 acres or is contained within a square of 100 metres to the side). These were but some of the missteps that befell the airport during its planning. construction and operation under multiple levels of government and a plethora of approving agencies.

Although applied to what was to become very much less than a successful enterprise the geoscientific work applied to the site to did aid in the geotechnical assessment of site conditons including location of granular materials for construction. In terms of efficiency of data gathering and the development electronic data banks and production of computer-generated maps Terrain Sciences Division's contribution to Mirabel could be fairly described as then state-of-the-art and totally unrelated to the ultimate fate of the airport.

Urban Geology (1971-1977)

Upon my return to the Geological Survey in 1969 following a two year period of service with a firm of consulting engineers I remained involved with the Science Council of Canada-sponsored study group that was examining the many facets of the solid earth sciences in Canada. My particular responsibility with the study group was to examine the contributions of Geotechnique to the earth sciences and to the economic development of Canada. The study group experience provided an appreciation of the role that geology could, and should, play in the development of urban areas. About the same time, engineers and planners in the National Capital Region expressed a need for geoscientific information to assist in their work. Thus, in 1970 I initiated within the Geological Survey a project entitled "Environmental Geology Prototype Study - Ottawa-Hull Region". This project, based on a compilation and interpretation of existing geological and geotechnical information for the region, was an attempt to provide planners, engineers and administrators with a geoscience information system to aid urban development. In contrast with previous urban geology work undertaken by the Geological Survey and by other organizations in Canada that I have described elsewhere[28] the Ottawa-Hull project was intended to be based upon a geoscience data and information system using computer technology that would enable the production of machine-drawn maps to meet specific information requirements. The use of computer technology was thus expected to transform previous atlas-type "static" data presentations into a more "dynamic" information system that could be updated incrementally through the addition of new information.

Within a year following initiation of the Ottawa-Hull project I assumed additional managerial responsibilities within the Division with work on the prototype study being transferred to others. A final report on the project was completed by Bélanger and Harrison[29]. This publication, now out of print, has been extensively used within the Ottawa-Hull area and contains a description of the Urban Geology Automated Information System (UGAIS) developed by Dr. J.R. Bélanger[30] which was used not only in the preparation of computer-drawn maps for the Ottawa-Hull study but also used extensively by Terrain Sciences Division in the production urban geology data banks.

Late in 1971 the Government of Canada made funds available to departments of government for projects that would provide employment to the public over the forthcoming winter months. The Division, through the initiative of its Director at the time, Dr. J.G. Fyles, responded to this opportunity by proposing programs for the collection of geological and geotechnical data for urban areas, conduct of shallow seismic surveys in urban areas to complement the geological/geotechnical data collection program and a program for the collection of mineralogical and geochemical data from bore hole samples of glacial drift covering areas of gold mineralization in northern Ontario and Quebec. These proposed programs were accepted by the government and were carried out over the winter months of 1971-72 by contractors working under supervision of Divisional staff. While the programs provided immediate benefits to those employed through them, Divisional scientific and administrative staff bore significant responsibilities for these programs in addition to their normal work loads

The urban geology data collection program, under the contracted supervision of Mr. B.V. Middleton, then an employee of the Toronto-based consulting firm of Derry, Michener and Booth, was the largest of these winter works programs. This program, using the UGAIS system noted above, involved the collection of geological and geotechnical data available from existing borehole records covering 27 major Canadian cities located in all of the provinces except Prince Edward Island. The work, done mainly under contract with consulting firms located in the various urban centres, provided almost 1,200 person-

---

[28] Scott, John S., 1998: Urban geology in Canada-a Perspective; *in* Karrow, P.F. and White, O.L. (eds.), Urban Geology of Canadian Cities; Geological Association of Canada, Special Paper 42, p. 1- 9 .

[29] Bélanger, J.R. and Harrison, J.E., 1980: Regional Geoscience Information: Ottawa - Hull; Geological Survey of Canada Paper 77-11

[30] Bélanger, J.R., 1975: UGAIS data record instruction manual: Geological Survey of Canada Open File 292

months of employment at a cost of approximately $750,000. Data files, produced for each of the cities, contained an aggregate total of 110,000 bore hole records.

Funding for the program was available only during the balance of the then current fiscal year which ended in March 1972. The rapid mobilization of the contractors and the completion of the data collection within the constrained time frame is a tribute to the concerted efforts of Mr. B.V. Middleton, the contracted supervisor.

The severe time constraints imposed by the winter works employment program created two particular difficulties for the long-term development of what might have become a continuing urban geology activity on a national basis. The first was that it was not possible to have any significant amount of consultation with municipal officials prior to implementation of the progrram and to thereby elicit their support for it. However, municipal officials in each of the cities selected for the program would have been aware of the involvement of local geotechnical consultants in the data collection process. The second difficulty arose from the massive amount of data collected during the program. These data were not in a form suitable for direct transmission to the municipalities.

In order to process the data in the form of computerized data banks with accompanying locator maps an Urban Projects Section under Dr. D.A. St-Onge was established within the Division in 1972 (see Appendix II). The work on data processing and compilation of computerized data banks by Dr. J.R. Bélanger was to continue for the next several years.

In 1973 Dr. D.A. St-Onge and I met individually with city engineers in Winnipeg, Calgary, Edmonton, Vancouver and Victoria to explain the work done in those cities under the winter works program and to seek support from the cities for the continuation of the work by the municipalities themselves. In each city we were cordially received and interest was expressed in the urban geology data banks being developed by the Geological Survey. Municipal officials were willing to accept the data banks but no commitment was forthcoming as to the local provision of support for the future continuation of their maintenance and development. The Geological Survey was willing to promote the development of urban geology data banks and to demonstrate their usefulness. It was never its intention, however, to be the perpetual custodian of the urban geology data banks nor to provide for their upgrading or to act as central repository for urban geology information. Our experience arising from the meetings with municipal officials was to have a significant impact upon the future of urban geology work by the Geological Survey. The Urban Projects Section continued to exist from 1972 until 1976 under a succession of Section Heads (Dr. D.A. St-Onge, Dr.N.W. Rutter, Dr. J.E. Harrison and Mr. E.B. Owen) occasioned by either the leader's reassignment or resignation. During this period and for a few years beyond work continued to complete the data banks initiated under the winter works program of 1971-72 and to transmit this information either to individual cities, or, in the case of cities in Ontario and Quebec, either to the Ontario Geological Survey or the Quebec Ministry of Natural Resources. By late 1977 work on the urban geology data banks had been completed as had work on limited mapping and data collection projects in Hamilton, Rivière-du-Loup and St. John. This essentially brought to a close active work by the Division on urban geology.

It is probable that future pressures upon the urban environment and the continuing development of data processing technology may combine to create a renewed interest in the development of urban geology information systems. It is also possible that the Geological Survey may once again become involved in any such renewed interest but only if the initiative and principal resources are forthcoming from the urban centres themselves.

Marine and Coastal Studies (1972 - 1978)

During its relatively brief period of existence the Marine and Coastal unit of the Division was an integral part of the operational scientific structure of the Division and could well have been included along with the other units described under the section on continuing programs of the Division. The fact that the unit existed within the Division for such a relatively short period of time, however, was such as to accord it greater affinity to the other Topical Programs and Events that are described in this section.

For a number of years following its original formation the Division had maintained a limited but active scientific interest in the Quaternary geology of lake sediments particularly through the work of Dr. C.F.M. Lewis who was stationed at the Canada Centre for Inland Waters at Burlington. In September 1972, Dr. Lewis was transferred to Ottawa to develop a Divisional program of marine and coastal activities. Lewis worked with Dr. Y.O. Fortier and Dr. J.O. Wheeler in writing a Departmental marine geoscience program for the Pacific region. Implementation of this plan at a later date was to have significant consequences for the Division.

Later in February 1973, Dr. Lewis was appointed as Head of a Marine and Coastal Geology Section within Terrain Sciences Division. This unit was to undergo modest expansion over the next few years and to undertake coastal and related studies in the Atlantic, Pacific and Arctic regions as well as in the Great Lakes. Formation of this unit further exemplified the manner in which Dr. J.G. Fyles, as Director of Terrain Sciences Division, endeavoured to establish a broadly-based, integrated scientific unit to deal with the Geological Survey's obligations to provide information on the Quaternary geology of Canada in both terrestrial and aquatic environments. The Section remained as an active scientific unit within the Division over the next five years.

During 1973 the newly formed section directed its efforts toward studies of the seafloor and coasts of the Pacific region, Great Lakes region and Arctic Island channels. A new program of environmental marine geology was launched in the Pacific region from the Vancouver office of the Geological Survey under Dr. J.L. Luternauer. He began work on Fraser Delta sedimentation and related processes designed to aid Environment Canada in their assessment of the relationship of sediments to the biological production of benthic fauna. Dr. Luternauer also began work on the Quaternary geology of the northern Strait of Georgia.

In the arctic, offshore work was coordinated with the Canadian Hydrographic Service operating from *CSS Parizeau* and *CSS Baffin*. This work provided new information on sediments, bedrock topography and Quaternary geology in Amunsden Gulf and Lancaster Sound. Compilation of previous work done in the Beaufort Sea area on sediment thickness, stratigraphy and ice scour was continued. Field studies of sedimentary and geomorphic processes in the coastal zone were initiated within arctic island channels on eastern Melville Island and northern Somerset Island. Studies involved experimentation with techniques for study of coastal ice movement and for providing information on sediment type, subsea permafrost, drift-ice phenomena and coastal stability of significance for potential gas pipeline routes.

In the Pacific Region during 1974 the program of environmental marine geology operated from the Vancouver office of the Geological Survey continued with studies of sedimentation in the Fraser River delta and Quaternary geology of the northern Strait of Georgia. Also studies of Great Lakes sediments were continued by Dr. T.W. Anderson operating from the Canada Centre for Inland Waters at Burlington, Ont. His work involved palynological investigations of sediment sequences and buried marsh zones.

In the western arctic Section staff participated in an industry-funded Beaufort Sea Environmental Studies Program operated under the project management of Environment Canada. Offshore work was conducted from survey vessels *M.V. Pandora, M.V. Pressure Ridge,* and submersible *Pisces.* These surveys provided information on the distribution of offshore permafrost and the extent of bottom scour by sea ice in the Beaufort Sea. Additional studies were made of the susceptibility of the Beaufort Sea coast to oil spills. In the eastern arctic studies, in cooperation with Atlantic Geoscience Centre scientists aboard *CSS Hudson,* were made to provide information on bottom sediments and bathymetry in northern Baffin Bay, Nares Strait, Parry Channel, Lancaster Sound and Barrow Strait. Palynological analysis of seabottom sediment cores from Maxwell Bay on southwestern Devon Island indicated the presence of Tertiary-Cretaceous sediments that were previously unknown in this area.

In Cunningham Inlet on northern Somerset Island new approaches to the study of arctic marine geology were implemented. These included the use of a 31-foot landing craft, transported to the area aboard *CSS Hudson,* and by use of SCUBA diving by Mr. P. McLaren to observe and sample bottom sediments off Melville Island. Information on coastal processes, permafrost, drift-ice phenomena and coastal stability obtained with the new approaches were pertinent to potential gas pipeline construction.

During 1975, one of the field parties evaluating coastal process and bottom sediments pertinent to arctic island pipeline crossings was unfortunately subject to one of the hazards of field work in the high Arctic. The party, led by Mr. R.B.Taylor, was attacked by a polar bear in their field camp at Cunningham Inlet on northern Somerset Island. Two of the personnel were severely injured and in order to prevent further injuries to personnel it was necessary to shoot the bear. Fortunately, with prompt administration of first aid and medical attention shortly thereafter both victims fully recovered from their injuries.

Elsewhere in the arctic coastal and marine geological studies were undertaken of coastal processes and to determine the occurrence and extent of ice scour in the offshore. This work was of particular relevance to evaluating the potential impact of oil spills and the siting of offshore drilling platforms.

In addition to the marine and coastal work done in the arctic, studies were undertaken of suspended sediment in the Fraser River delta - Strait of Georgia area and systematic mapping of surficial sediments was undertaken on the Pacific Continental Shelf southwest of Vancouver Island. This work, carried out aboard *CHS Vector,* identified the potential for gravel resources in the offshore region. Leadership for the Pacific coast offshore work was provided by Dr. J.D. Milliman, who served a brief period with the Geological Survey as an interlude in his work with Woods Hole Oceanographic Institute. During the time of his Pacific offshore geological work in 1975 I took the opportunity to spend a week aboard *CHS Vector* to obtain some insight into the operation of offshore geological surveys. *Vector* was not a particularly large ship but adequate for the task of towing a marine seismic array and maintaining station while obtaining grab samples from the sea-bottom. The ship seemed to me to be top heavy and tended to roll in any sort of sea thus it took a day or so for me to find my sea legs and to be able to retain the excellent food provided by the ship's cooks. I found working with the scientific staff on the watch-keeping basis of 4 hours on duty and 8 hours off over a 24 hour to be an interesting experience along with the extensive position-record keeping essential to marine geological surveying. This type of work had substantial appeal to those who chose to do it on a regular basis. I found, however, that my previous experience with onshore geological work with diverse materials, terrains and applications remained more to my preference than the pursuit of marine geology.

Studies of Beaufort Sea ice scour yielded information of particular interest for construction of offshore structures. It was found from repetitive mapping of the seafloor that ice scour tracks are preserved from year to year. It was also shown that up to 2% of the seabed is disturbed annually in the water depth zone of 15-20 m where winter pack ice impinges against land fast ice. It was also shown that ice scour generally occurs only in water depths up to 50±m. although ice scour may be found in water depths up to 80m. Scour at these grater depths, however, may have been caused during periods of lower sea level.

Scientists of the Section participated during 1976 in a major multidisciplinary research cruise into the Northwest Passage aboard *CSS Hudson*. The cruise had been planned for Barrow Strait and adjacent channels but the plan had to be altered when *Hudson* lost one of its two propellers near Prince Leopold Island (off the northeast tip of Somerset Island) while en route to Resolute. A program of lesser duration and extent was implemented in Lancaster Sound where open water conditions were generally prevalent. Coring, subbottom photography and high resolution seismic profiling conducted during the cruise indicated that much of Lancaster Sound seafloor is undergoing erosion due to strong bottom currents. This condition may have persisted for thousands of years since glacier ice blocked Barrow Strait to the west.

A reconnaissance of selected coastal environments in Lancaster Sound was completed by Mr. P. McLaren from one of *Hudson's* launches with the use of diving gear. This work was useful in planning a more comprehensive regional study of Lancaster Sound coasts with respect to the impact of oil spills that may occur in future. Further side scan sonar work in the area revealed ice scour tracks in the area at depths of more than 150m clearly indicative of drifting ice bergs that could pose a hazard to sea bed pipelines.

Work on the coastal studies of northern Somerset Island, southeast Bathurst Island and adjacent islands in Barrow Strait relevant to possible gas pipeline crossings was completed with the information documented in preliminary manuscripts. An additional report was prepared on multi-year observations of bottom scour in the Beaufort Sea area and work continued on coastal processes along the Yukon coast which are also of relevance to pipeline routing in the area.

In the Pacific region marine geological work continued in the Fraser delta area to provide information about sediment dispersal in estuaries, distributary channels and the delta front as well as to contribute to the interpretation of the depositional history of the delta.

The historical record for the Division for 1976-77 indicates that the limited expertise available for work on fluvial processes either in the field or in the flume laboratory had been incorporated in the Marine and Coastal Section. The principal areas of field work on fluvial processes was in the Babbage River delta of the Yukon and on Banks Island. This work was designed to aid in the environmental assessment of pipeline and related engineering work in arctic regions.

In the early spring of 1977 S.M. Blasco of the Section participated in a joint venture industry and government test of a new technique for ice platform investigations of the sea floor. The technique involved the use of a Tethered Remotely Operated Vehicle (TROV) fitted with a variety of geophysical, side-scan sonar and sampling equipment. Deployment of the TROV through the ice off Drake Point on Melville Island indicated significant potential for the device in future arctic marine geology studies.

Throughout 1977 scientific staff of the Marine and Coastal Section, under the leadership of Dr. C.F.M. Lewis, continued to provide coastal and offshore geological information for parts of the Pacific, Arctic and Atlantic regions. A major compilation of coastal information was undertaken to provide background information for the possible location of marine terminals and pipeline crossings pertaining to arctic gas development. Previous work on the Pacific coast enabled scientific staff to undertake a technical review of a proposal to establish an oil tanker port and pipeline terminal at Kitimat, B.C. During the year a reconnaissance of the coastal morphology and processes of the Labrador coast was completed using a combination of diving and ship-borne geophysical techniques for data acquisition at representative sites. This work was aimed at assisting in planning for oil spill countermeasures.

Results of sea bed ice scouring in the Beaufort Sea were published. This work enabled the Department of Indian and Northern Affairs to specify “burial” depths for the protection of well heads from the hazard of ice keel impacts. Elsewhere in the arctic the study of beach morphology and geomorphic processes in the Barrow Strait region was essentially completed with a report on the work in progress. This work is of particular significance for the evaluation of potential pipeline crossings and for the development of contingency plans for potential oil spills.

The Marine and Coastal Section tended to operate somewhat independently of other sections of the Division. Work of the Section, however, did serve to emphasize the continuity of Quaternary geology from onshore to offshore areas and did facilitate the coordination of national Quaternary geological work within the Division. Such coordination in Quaternary geology was seldom established with other marine geological units of the Survey through their conduct of marine surveys, whether offshore or in coastal regions.

During 1977 a decision was taken at Branch level to remove the Marine and Coastal Section from Terrain Sciences Division and to relocate its personnel to the Cordilleran Division in Vancouver and to the Atlantic Geoscience Centre in Dartmouth, N.S. This action was taken without much, if any, prior discussion with Terrain Sciences Division. It is assumed that this organizational change was in response to the earlier development within the Department of a marine geology program for the Pacific region and that the time for implementation of the program had arrived.

There was certainly need for a significant marine geology program on the west coast and it was logical to expand the capability of the Atlantic Geoscience Centre to deal with Atlantic and Arctic offshore and coastal matters. Given the decision by the Branch to enhance the marine geology activities of the western and eastern coastal offices through transfer of Divisional staff the demise of the Marine and Coastal Section of Terrain Sciences Division was inevitable. No provision was made by the Branch for continuation of support for the work that the Division had been doing in the Great Lakes. The Division endeavoured, however, to provide for some continuation of this work and other studies of Quaternary and Recent sediments in rivers and lakes.

The scientific staff of the Marine and Coastal Section, to their great credit, accepted the transfers without complaint and continued to serve the Geological Survey in a creditable manner. It never became clear to me, however, that work on coastal and marine geology per se or its relationship with continental Quaternary geology was ever significantly enhanced by the transfers. Others, of course, may have a different view of this event.

Terrain Sciences link with marine geology remained through Dr. B.R. Pelletier, a sedimentologist/stratigrapher with extensive marine geological experience, who transferred from the Atlantic Geoscience Centre to the Division in 1975. Dr. Pelletier was initially assigned to a Special Projects unit of the Division consisting of a number of senior scientists engaged in a variety of scientific compilation-type projects. Over a number of years, in addition to serving in scientific leadership roles within the Division, Dr. Pelletier worked as editor and compiler of a Marine Science Atlas of the Beaufort Sea. This major work involving a large number of contributors was to consist of a number of folio-type publications each dealing with a specific attribute of the Beaufort Sea. The first of these publications, dealing with sediments, was published in 1984 by the Geological Survey of Canada as Miscellaneous Report 38.

International Congresses (1972 and 1987)

Periodic scientific meetings that are international in terms of participation and location are common scientific activities, and throughout its history various scientific components of the Geological Survey have been participants in such events. For the most part these international meetings are held in countries other than Canada, thus attendance at them by scientific staff of the Geological Survey tended to be limited due to the relatively high costs for travel. On occasions when Canada was the host country for such conferences, however, participation in them by Geological Survey staff, as might be expected, was considerably higher.

In1972 two international congresses were held in Montreal during August both of which involved participation by staff of Terrain Sciences Division. The first of these meetings was the International Geographical Congress that, from the record of Geological Survey participation, was limited to about four staff members from Terrain Sciences Division..

The second meeting, held in late August and early September, was the 24th International Geological Congress (IGC), for which the Geological Survey acted as the principal Canadian agent for the planning and organizing of the event. This responsibility, of necessity, required considerable effort on the part of those involved for several years prior to as well as during the actual meeting. The overall extent of Geological Survey involvement is indicated by the fact that 14 Survey officers acted as conveners for technical sessions, 22 chaired technical sessions and 56 were among the 205 leaders and co-workers who organized the 64 major geological field excursions. Also, three continuing employees of the Survey served as Secretary-General, Assistant Secretary-General and Organizing Secretary of the Congress while others served on the National Organizing Committee and the Executive Committee. All of this effort contributed to the success of an event, held once every four years, that on this occasion attracted over 3,900 attendees.

Approximately 20 staff members of Terrain Sciences Division were heavily involved in the 24th International Geological Congress in various capacities. Dr. J.G.Fyles and Dr. A.M. Stalker of the Division, along with Dr. W.O. Kupsch, University of Saskatchewan were conveners of the Section on Quaternary Geology. I, along with

Mr. C.B. Crawford, Division of Building Research, National Research Council, were conveners of the Section on Engineering Geology. Fifteen officers of the Division were leaders or co-leaders of field excursions and one of the staff members, Ms. T.A. De-Vreeze, attended the Congress in the capacity of an interpreter for both French and Russian visitors.

In my case preparation for participation in the 24th IGC fortuitously began in 1970 through my attendance in September at an International Congress of the International Association of Engineering Geologists held in Paris. This meeting provided an opportunity to make contact with engineering geologists from a number of European countries including France, Belgium, Germany and the Soviet Union. One direct result of attendance at the Paris Congress was receipt of an invitation in 1971 from the Academy of Sciences of the U.S.S.R. to attend a symposium on the Engineering Geology of Clays sponsored by the International Association of Engineering Geologists to be held in Moscow in September. The symposium was rather ordinary from a scientific point of view but it did provide a further opportunity to expand my circle of contacts in the international field of engineering geology.

During the year prior to the 24th Congress I spent a considerable amount of time on two main tasks related to the Section on Engineering Geology. The first of these was to review all of the papers submitted, select those considered to be suitable for presentation and subsequent publication as part of the Congress proceedings..

The official languages for the Congress were English and French and most of the submissions from countries beyond North America were in English and, not uncommonly or surprisingly, in need of considerable editing and revision. Thus, I spent time in both editing and rewriting submissions as there was insufficient time to return copies to authors for correction and resubmission. A total of 35 papers were selected for presentation and publication.

The second task was to select co-chairmen for each of the sessions within the Engineering Geology Section. There were four separate sequential sessions in the Section on Engineering Geology with each session requiring two co-chairmen who would be able to respond to questions from the audience in either English or French. As a result of the contacts in engineering geology that I had previously established I was readily able to select Congress delegates from a number of different countries to serve as co-chairmen for the sessions.

My recollection of the meeting is that all of its activities both scientific and social were well organized and well attended resulting in an overall consensus that it was a very successful event.

After an interval of 15 years scientific staff of the Division once again became involved in organizing and participating in a Canadian-hosted international meeting. This event was the XIIth International Congress of the International Union for Quaternary Research (INQUA) that was held in Ottawa from 31 July to 9 August 1987. In the preceding year a number scientific staff of the Division were involved in various committees for the organization of the Congress and in the planning and preparation of guide books for 9 of the 23 associated field trips. During the Congress itself about 19 members of the Division participated either through presentation of scientific papers, as session chairmen or as leaders of field trips. The Congress attracted about 1,000 attendees and was considered to be an unqualified success.

In recognition of the INQUA Congress the journal Géographie physique et Quaternaire prepared a special issue (Vol.XLI, No.2) on the Inception, Growth and Decay of the Laurentide Ice Sheet. Dr. R.J. Fulton, Terrain Sciences Division, and Dr. J.T. Andrews, University of Colorado, were editors for the issue and over half of the text was written by seven scientific staff of the Division. Included as part of the special issue was the excellent series of maps by Drs. A.S. Dyke and V.K. Prest portraying the recession of the Laurentide Ice Sheet. These maps were published by the Geological Survey as Map 1702A (scale 1: 5,000,000) and Map 1703A (scale 1:12,500,000). This special volume with the accompanying maps constitutes a major milestone in the synthesis of Canadian Quaternary geology and is no doubt destined to become a classic reference for many years to come.

Given the lead time required for the submission of papers and the substantial amount of effort required for the planning and organizing of a major international conference it is perhaps appropriate to offer some comment on the value of these events. The conference presentations and subsequent published proceedings can provide an overview of the state-of-the-art for the particular aspect of science covered by any conference Section. Some of these published overviews will have lasting value but many will soon become outdated and lag behind material contained in current scientific publications. The various scientific sessions and social events always provide an opportunity for exchange of ideas and the useful expansion of contact networks. The value derived therefrom is entirely dependent upon the amount of personal effort expended to benefit from the opportunity. Field excursions associated with geological meetings, whether international or local, always provide the opportunity to expand one's exposure to, and experience with, geological materials, environments and processes of benefit to professional development.

Nuclear Fuel Waste Management Program (NFWMP) (1973 - 1987)

Late in 1972 the Department of Energy Mines and Resources (EMR) received a request by telephone from Atomic Energy Canada Ltd. (AECL), Whiteshell Nuclear Research Establishment (WNRE) located at Pinawa, Manitoba for advice on the concept of geological disposal of nuclear fuel waste. The request arose from AECL's continuing responsibility for, and research in, all aspects of nuclear waste management.

The topic of nuclear waste management, along with other matters pertaining to energy and uranium supply, was discussed at a meeting[27] on 18 December, 1972 of the

[27] Minutes of the Science Management Committee meetings of 18 Dec. 1972 and 9 Jan. 1973 are contained in Geological Survey of Canada File GS6330-1, V.1

Departmental Science Management Committee chaired by Dr. C.H. Smith, then Assistant Deputy Minister, Science and Technology, EMR. At that meeting the Geological Survey was tasked with identifying an individual to act as a focal point for liaison with the Energy Sector of the Department regarding the disposal of nuclear waste in geological structures. At the subsequent meeting of the Science Management Committee on 9 January 1973 Dr. S.C. Robinson, Geological Survey, advised the Committee that I had been identified as the required liaison individual.

The substantive response by the Department to the request from AECL took place in February, 1973 at EMR headquarters in Ottawa through a meeting of representatives from EMR and AECL As the designated Geological Survey liaison individual for nuclear waste matters, I was invited by Dr. C.H. Smith, to attend the meeting. Through our previous association on the Science Council of Canada sponsored study of the earth sciences in Canada Dr. Smith was aware of my background in engineering geology. He perceived such a background to be a prerequisite for the development of a program of geological disposal.

At the time of the initial meeting EMR was specifically requested by AECL to: a) identify factors for consideration in the concept of geological disposal of high-level radioactive waste; b) evaluate the proposal of the United States for high-level radioactive waste storage in salt (then the preferred rock type in the United States) in relation to geological criteria; c) determine the extent to which Canadian salt deposits meet the geological criteria; and d) examine the suitability of other geological formations in Canada for disposal of radioactive wastes. The last task was considered to be the largest and one of particular significance as a complement to the extensive developmental work done on salt in the United States and elsewhere. As a matter of historical interest the suggestion that hard rock of the Canadian Shield be considered as an alternate to salt for radioactive waste disposal purposes was raised by Mr. R.A. Simpson, Mineral Policy Sector, EMR who was in attendance at the initial meeting between AECL and EMR.

In order to respond to the request from AECL a committee was formed with members from the scientific branches of the Department, Geological Survey (GSC), Earth Physics Branch (EPB) and Canada Centre for Mineral and Energy Technology (CANMET). I was asked to chair this committee whose initial work evolved with time into a full-fledged multidisciplinary scientific program for which I had responsibility as Program Director in addition to full time responsibility as Director, Terrain Sciences Division.

Throughout 1973 and 1974 the committee members exchanged information with AECL on both an informal and formal basis. Information provided by the committee to AECL included a preliminary list of factors for consideration in the selection of a rock type and repository site. These factors were grouped[28] into three categories; A. Site and Environmental, B. Legal and Political and C. Rock Mass and Rock Substance

[28] Scott, J.S., 1979: EMR Program for Geological Disposal of High-Level Radioactive Wastes *in* Barnes, C.R. (ed.): Disposal of high-level radioactive waste: The Canadian Geoscience Program; prepared by Canadian Geoscience Council: Geological Survey of Canada Paper 79-10, p.13-20

Characteristics. Also provided to AECL was a review of American reports on salt and an initial assessment of the potential within Canada for disposal in rock types other than salt. It was recognized that the diversity of Canadian geology, physiography and demography provided for a wide range in the choice of rock types as an alternative to salt. The choice of alternative rock types, however, was also influenced by the fact that the Province of Ontario was then, and was anticipated to be, the major area for growth of nuclear power in Canada. Further, it was not possible to simultaneously study all possible alternative rock types. Thus, the decision was taken to direct the geoscience activities to the study of igneous rock types prevalent within the extensive Canadian Shield in Ontario and to examine further the potential within various regions of Canada for salt as a disposal medium. During the early stages in the development of the Geoscience component of the program a number of igneous rock types were identified for consideration. Included among the rock types were granite, gabbro, anorthosite and syenite. Given the distribution of these rock types throughout the Canadian Shield in Ontario, however, it was apparent that granite and gabbro were of greatest abundance among the intrusive igneous rock of interest.. Thus granite and gabbro became of primary interest and, as the program evolved; gneisses were also included for field study.

Stage I of the Geoscience Program

Early in 1975 scientific staff of EMR prepared proposals and budgets for geoscientific activities to be included in what may now be considered as Stage I of the AECL program of nuclear fuel waste management. The major part of the geoscience program, directed toward the evaluation of igneous rocks, was subdivided into three main activities viz. Geology, Geophysics and Rock Properties, with each activity consisting of a number of distinct tasks. Responsibility for these activities was assigned respectively to GSC, EPB and CANMET. The Geological Activity was concerned with literature reviews, field mapping, drilling and core logging. This work was complemented by a variety of airborne, surface and subsurface geophysical techniques that were tasks of the Geophysics Activity designed to evaluate the mass characteristics and structural integrity of rock masses. Evaluation of the physical, mechanical, electrical and thermal properties of rocks as well as evaluation of methods for bore hole and shaft sealing constituted tasks within the Rock Properties Activity.

A separate manager for each of these activities was drawn from one of each of the participating branches of the Department. The Geological Activity was initially managed by Mr. B.V. Sanford, followed by Dr. I.F. Ermanovics and then Dr. P.A. Brown who was initially employed by AECL and seconded to EMR. The Geophysics Acitivity was initially managed by Mr. M.R. Dence followed by Dr. J.G. Tanner, both of whom were from Earth Physics Branch. The Rock Properties Activity was managed throughout the duration of the program by Mr.G.E. Larocque from CANMET. During the association of EMR with AECL/WNRE in the nuclear waste management program over the next 15 years or more the principal contact at Whiteshell was the Director of the Waste Management Division. The position of Director was occupied by a succession of individuals over the course of the program as were the positions of other senior managers at AECL/WNRE.

In parallel with the work on igneous rocks the Geological Survey also undertook a major review of the occurrence of salt in Canada. This work was primarily the responsibility of Mr. B.V. Sanford, Continental Geoscience Division, aided by colleagues from the Atlantic Geoscience Centre (AGC), Dartmouth, Nova Scotia. Scientific staff from AGC also maintained a watching brief on international developments in the use of seabed as a site for nuclear waste disposal.

Work on various tasks within each of the three Activities began in 1975 managed as noted above in close collaboration with AECL and supported by resources from both AECL and EMR. As field and laboratory geoscience work progressed throughout Stage I of the program, however, financial support and scientific staff, through secondment, were increasingly provided by AECL to EMR.

This funding arrangement, while effective, presented something of a continuing problem of an administrative nature. Specifically, the Financial Administration Act (FAA) did not permit the transfer of funds from a Schedule C Crown Corporation, such as AECL, to a line Department such as EMR as these funds would be in excess of the authorized parliamentary appropriation to the Department. In spite of the limitations of the FAA and observations by the Internal Audit Branch of EMR[29] on the irregularity of the fiscal arrangement, and even the lack of a legal base for carrying out geoscience research for AECL, funding for the program continued to be provided by AECL to EMR on an annual basis for the duration of the joint involvement of the two agencies in the program. I do not recall that the issue of funding irregularity between AECL and EMR was ever resolved but funds continued to be provided by AECL to EMR for program activities by means of purchase orders or other arrangements. The administrative officer of Terrain Sciences Division provided the accounting requirements for the funds provided by AECL to EMR. This service was a significant addition to the accounting responsibilities of the Division. It did, however, assist in ensuring that these funds were used solely for the purposes of the Nuclear Fuel Waste Management Program

Initial field work on igneous rocks during the field season of 1975 included studies of granitic rocks in the White Lake and Marmora areas of Ontario to the west of Ottawa. This work, as well as subsequent field studies of igneous rocks in other locations, was intended solely to evaluate surface and subsurface exploration methodologies and techniques and to obtain basic information on the structural and petrological character of the rocks. None of the localities selected for field study was ever intended to become the site of a nuclear fuel waste repository.

[29] Memorandum, ADM, Earth Sciences (W.W. Hutchison) to ADM Finance and Administration (S. Mensforth), 15 May 1984, Internal Audit of the GSC: Geological Survey of Canada File No. GS-6330-1, V.4.

Early in 1976 field work continued at selected localities in Ontario for the purpose of evaluating exploration methodologies and obtaining information on various attributes of igneous rock masses. By mid year the work by the Geological Survey on salt in Canada had been completed and both AECL and EMR had issued press releases describing the scope and purpose of the geoscience program for the field and laboratory study of igneous rocks. By the fall of 1976, however, public concern was expressed over the field work being undertaken in the area around White Lake. Later, in the spring of 1977, even greater public opposition to the field work being undertaken in the Marmora area was voiced at a public meeting held at Madoc, Ontario.

During the period September, 1976 to August, 1977 I was in full time attendance on the course at the National Defence College in Kingston, Ontario and thus not on hand to provide support for the program. During my absence Mr. M. Gyenge from CANMET carried the responsibilities of Geoscience Program manager on an interim basis and served the program well during a difficult period.

The increasing public concern over the geological field work for the NFWMP resulted in the decision by AECL to suspend geological and related field operations planned for Ontario during 1977. Throughout the balance of that year geoscience activities were confined to office and laboratory studies and to minor field work on gneissic rocks underlying the AECL facility at Chalk River, Ontario.

The suspension of major field work during 1977 was an event of particular significance for the NFWMP and the public concern that brought about the suspension had a major impact upon the future of the program. In contrast with public concerns over nuclear waste disposal, a report[30] by Aikin et al.(1977) commissioned by the Energy Policy Sector, EMR, endorsed the concept of geological disposal and recommended acceleration of the program. The report went further to suggest that an operating nuclear waste disposal facility using the geological concept could be in place by the year 2000. Such a target date clearly implied that the authors felt a period of about 20 years following publication of their report was adequate for any pre-operational research, design and construction considerations for the repository. The optimism over the relatively brief period of time required for development of a waste management facility and the apparent assumption of public support for any disposal concept that met scientific and technical approval were weaknesses associated with activities during Stage I of the NFWMP. Although no specific event marks the occasion it may be considered, for convenience, that Stage I of the program terminated at the end of 1977.

[30] Aikin, A.M, Harrison, J.M. and Hare, F.K. (Chairman), 1977: The Management of Canada's Nuclear Wastes; Energy, Mines and Resources Canada, Report EP 77-6.

Stage II of the Geoscience Program

The restriction on field work in Ontario continued into 1978 but a number of events[31] occurred during the year that were instrumental in reshaping the future of the program. The first of these events occurred in February, 1978 with organizational restructuring at WNRE to reflect increased emphasis on fuel cycle waste management. As part of this restructuring a new public affairs group was established specifically to handle public information aspects of nuclear waste management. This action was undoubtedly motivated by the adverse public reaction to the geological field work that had been undertaken as part of the program. In March 1978 Dr. J.D. Keys, then Assistant Deputy Minister, Science and Technology, EMR, issued a memorandum to the Directors General of Branches participating in the program confirming the establishment of a Program Management Committee for which I had responsibility as Director. As with the previous less formal program committee arrangement close collaboration with AECL remained an ongoing requirement. Formalization of the Program Management Committee within the Department was of assistance to me as Director in obtaining participation as required of scientific staff from other Divisions of the Geological Survey and from other Branches of the Department.

One of the major advances in the development of the NFWMP occurred in early June, 1978 with the joint announcement by the governments of Canada and Ontario to cooperate in developing technologies for the safe, permanent disposal of Canada's nuclear fuel wastes. This agreement was the result of some prior months of discussion among representatives from the two levels of government. Under the agreement AECL had responsibility for research and development on the immobilization of fuel wastes and their safe disposal. Both EMR and Environment Canada agreed to assist AECL with the geoscience aspects of fuel waste disposal. Ontario Hydro was the principal provincial participant in the agreement and had responsibility for development of technologies for interim storage and transportation of irradiated fuel. In documents concerning the NFWMP produced by AECL subsequent to the Canada/Ontario agreement (e.g. Lyon et al.,1981)[32] the beginning of the program is commonly identified as June 1978 with little reference being made to events prior to that time. It may be noted, however, that the document by Lyon et al.(1981,p.9) in reference to a paper presented by Scott and Charlwood[33] noted the following:

[31] Geological Survey of Canada File No. GS-6330-10, Radwaste Program - Event Summary

[32] Lyon, R.B., Rossinger, E.L.J., Wright, J.H. and Gillespie, P., 1981: Guide to the Canadian Nuclear Fuel Waste Management Program, Atomic Energy Canada Limited, Whiteshell Nuclear Research Establishment, Pinawa, Mainitoba.

[33] Scott, J.S. and Charlwood, R.G.. 1979:Canadian Geoscience Research and Design Concepts for Disposal of High-Level Waste in Igneous Rocks *in* International Symposium on the Underground Disposal of Radioactive Wastes, sponsored by IAEA/OECD/NEA, Otaneimi, Finland: IAEA-AM 243/168.

“Work by the Geological Survey of Canada (GSC) in the early seventies led to the recommendation that an appropriate geological host medium for deep disposal might be large igneous intrusions of crystalline rock, known as plutons, found in the Canadian Shield”

For convenience and the purposes of this account June 1978 is thus designated as the beginning of Stage II of the program. Within Stage II provisions of the Canada/Ontario agreement eventually led to the resumption of field work.

From the standpoint of geoscience research for the NFWMP the major significant event of 1978 was the forum “Disposal of high-level radioactive waste: The Canadian Geoscience Program”. This event, sponsored by the Canadian Geoscience Council, was held in Toronto during October on the occasion of joint annual meetings of the Geological Association of Canada, Mineralogical Association of Canada and the Geological Society of America. It was the first time that the program had been subject to a review by professional peers and the fact that the forum attracted 600 attendees was indicative of widespread interest by the geoscience community in the issue of nuclear waste management.

The published record[34] of the forum including prepared commentary, presented papers and edited discussion highlighted a number of issues that were to have a significant influence on the future directions of the program. Among these issues were strong pressure from the academic community for their greater involvement in independent research pertaining to the program, increased peer review of research by government agencies involved in the program and the need for some form of independent external advisory group to provide oversight for the program. Also, at the time of the forum the proposed schedule for the program consisted of four phases each of which was of relatively short duration. Phase I was concerned with verification of the concept of geological disposal during the period 1978-1981; Phase II with site selection from 1979-1986; Phase III with construction and operation of a demonstration repository from 1984-1999; and Phase IV- a full scale repository around the year 2000 presumably developed from the demonstration facility. This overall schedule was perhaps optimistic but similar to that suggested by Aikin et al. in their 1977 report.

Throughout most of 1979 field work remained restricted to igneous rocks underlying AECL properties at Chalk River, Ontario and Pinawa, Manitoba and resumption of limited field work in the White Lake area of Ontario was authorized through provisions of the Canada/Ontario agreement.

A major advance in providing external oversight for the program occurred in June 1979 with the establishment of an independent Technical Advisory Committee (TAC). This committee was formed by AECL as the result of recommendations in previous program review reports and suggestions from parts of the scientific community. The resources necessary for the operation of TAC, including those for the acquisition as

[34] Barnes, C.R. (ed.), 1979: Disposal of high-level radioactive waste: The Canadian Geoscience Program; prepared by Canadian Geoscience Council: Geological Survey of Canada Paper 79-10.

required of specialist advice, were provided by AECL. Membership on the Committee comprised twelve or more members each of whom has been selected from a list of nominees provided by major Canadian scientific and engineering societies which covered all of the scientific and technical disciplines involved in the NFWMP. Members of the committee were initially appointed for a term of three years with the term of appointment being subject to renewal. Prof. L.W. Shemilt, Department of Chemical Engineering, McMaster University served in a most effective manner as chairman of TAC from its inception in 1979 until the conclusion of its work in 1996

In each of its almost 17 years of operation, with the exception of 1994, TAC produced a publically-available annual report in both official languages. These reports contain reviews and critical commentary on all aspects of the NFWMP and were thus of inestimable value in providing independent guidance for the program and support for it from the scientific community. Throughout its existence, TAC endorsed the concept of geological disposal of nuclear fuel waste and provided the essential degree of independent scientific oversight necessary to establish credibility for the concept.

From the earliest years of the program the results of scientific and technical work by program participants, including the Geological Survey, had been recorded on an ongoing basis in an AECL report series known as “Technical Records”(TRs). Each of these documents was assigned a number prefixed by the designation “TR” and identified further by title and author(s). Throughout the course of the program the number of Technical Records produced extended well into the hundreds and possibly beyond that range and covered all aspects of the program. For the most part, these reports contained accounts of work in progress including data and conclusions from both field and laboratory studies. While neither subject to peer review nor widely distributed, the TRs were readily available to the public through AECL/WNRE and collectively constituted both a record of scientific and technical work done for the program and a convenient source of reference material.

Other accounts of scientific or other work relating to the program were periodic contributions to local, national and international meetings and conferences concerning nuclear waste disposal and, on occasion, as contributions to scientific or technical publications.

One of the common criticisms directed toward the program, particularly from the scientific community, was the general lack of publication of research undertaken for the program in refereed scientific journals. With respect to the geoscience work done for the program, particularly that within EMR, the main source of criticism over non-refereed publication arose from a few academic members of the Geological Association of Canada (GAC) visiting committee that was established by GSC to review its scientific programs. During the spring of 1980 a small subcommittee of the GAC visiting committee was established to review the published work (mainly in the AECL TR series) undertaken by the Geological Survey for the program. The recorded outcome of this initiative by GAC is not readily evident but it is probable that it became integrated with the work of TAC.

In its first three annual reports (TAC-1, 1980; TAC-2. 1981; and TAC-3, 1982) the Technical Advisory Committee addressed the issue of the publication in the scientific literature and affirmed its advantages regarding research work emanating from the program. In its report for 1983 (TAC-4)[35] reaffirmed its position of previous years regarding publication in the scientific literature and repeated (p.75) a statement on the matter of scientific publication from its report of the previous year as follows:

"The question of such publication can present a problem for a mission-oriented organization. Frequently the result of a project may have been established with a degree of certainty sufficient to make possible the next step towards the mission goal, and yet not have the form or context suitable for a refereed scientific journal. TAC appreciates the managerial dilemma of whether, in any particular case, to devote more staff time and effort to achieving a publication in the open scientific literature rather to just recording the result in a TR report and proceeding more rapidly and directly towrds the mission goal. It also acknowledges that much of the work in this extensive and complex program is not readily suited to scientific publication, in part since it involves specialized application of known scientific methods and principles."

TAC went on to note that contributions to the scientific literature by participants in the program was on the increase and encouraged the continuation of this trend. The committee also correctly pointed out that a body of refereed scientific and technical literature pertaining to the program would facilitate the task of obtaining widespread support for the concept of geological disposal.

While the value of records of work done for the program that are contained in refereed scientific journals cannot be disputed it remains a fact, as noted above in TAC-4, that much of the work done was not suited for outside publication. Further, if refereed journals were the only medium for publication much of the work done would never be published and that which was would be dispersed over a number of publications, thereby rendering any sort of overview a difficult task.

In my view the AECL Technical Record series provided a convenient single source of information pertaining to the program to which publications in conference proceedings and scientific journals contributed a valuable supplement. Also, the series of annual reports (TAC 1-15) published by the Technical Advisory Committee constitute a particularly concise and accurate single source of authoritative information and commentary on the NFWMP.

Throughout 1980 geological field work on igneous rocks remained limited to the White Lake area in Ontario and to the rocks underlying AECL properties at Chalk River, Ont and Pinawa, Man. Increased interest was developing in the intrusive granitic rocks of the Lac du Bonnet batholith that underlie the Whiteshell facility and a substantial part of

[35] Shemilt, L.W. (Chairman), 1983: Fourth Annual Report of the Technical Advisory Committee on the Nuclear Waste Management Program, TAC-4, *submitted to* Atomic Energy of Canada Limited.

the surrounding area. At this point in the program consideration was being given to the development of an underground research laboratory (URL) somewhere within the vicinity of WNRE. In order to further the development of the URL AECL obtained from the Government of Manitoba a lease for 975 acres of land near the community of Lac du Bonnet. The lease was valid for a period of 21 years and contained the stipulation that no radioactive materials were to be placed anywhere within the lease boundaries.

A Surface Evaluation Subcommittee, co-chaired by Dr. P.J. Kurfurst, Terrain Sciences Division, was active during 1980 in field work within the lease to determine the most favourable location for the URL. During the coming years work involving the URL was to assume increasing importance as a part of the NFWMP.

In 1981 provisions of the Canada/Ontario agreement enabled several new areas to become available for geoscience research. Included among these new area were the gabbroic intrusive complex at East Bull Lake east of Elliot Lake and north of Massey, Ont, the Eye-Dashwa Lake granitic pluton northwest of Atikokan, Ont. and the Overflow/Denmark Lake gabbroic intrusive southeast of Kenora, Ont. These new research areas, in addition to those already under investigation at White Lake, Chalk River and WNRE, completed the list of field areas that were investigated under the geoscience component of the program.

The period from 1981 to about 1986 constitutes the time of most intensive geoscience activity during the program as work was ongoing at all of the research areas as well as at the URL at which construction began in 1984. An indication of the level of geoscience effort by EMR during this period is given by Pedersen (1983)[36] which lists a total of 61 individuals. The distribution of these individuals was as follows: from various Divisions of the Geological Survey - 16; Earth Physics Branch - 18; Canmet - 7; EMR Headquarters - 2; AECL term employees seconded to the Geological Survey - 18.

During 1985 AECL/WNRE underwent major organizational changes resulting in the placement of waste management activities under a Program Responsibility Centre managed by a Vice-President. The NFWMP thus became organized into two main divisions, one for geological and environmental science and one for geochemistry and waste immobilization. Each of these divisions had a number of appropriate branches. Among the changes brought about by the reorganization was the development of WNRE as a major location for geoscience work related to the program and a reduction of the direct involvement of EMR in program activities.

Thus, early in 1986 a number of the AECL term employees that had been seconded to EMR were relocated to AECL/WNRE, Pinawa, Man. to complete the work on the various field research areas and to focus increasing attention on detailed studies of the URL and its surrounding area. Over the next year or so the remaining AECL seconded staff were relocated to Pinawa to participate in geoscience work in the Whiteshell Research Area.

[36] Pedersen, L.S. (compiler), 1983: Who's Who of the Canadian Nuclear Waste Management Program, Atomic Energy Canada Limited, Whiteshell Nuclear Research Establishment, Technical Record TR-209-1.

Also during !986, AECL was anticipating a forthcoming environmental review of the concept of geological disposal of high level nuclear waste and thus began the intensive preparation for a formal concept assessment document or FCAD as the planned document became known. During the next several years, as the actual timing of an environmental assessment became better established, the term “FCAD” for the documentation to be presented became replaced by the more familiar “environmental impact statement” or EIS. This period, during which the focus of geoscience work was at WNRE and particular attention was being given to the preparation of environmental assessment documents, is designated herein as the end of Stage II, of the program and the beginning of Stage III, the final stage of the program.

Stage III of the Geoscience Program

The internal annual report of the Geological Survey for fiscal year 1986-87 is the last report in which any reference is made to the involvement of Terrain Sciences Division in the NFWMP. No specific details of the Division’s involvement are given in the report but it is probable that the main contribution was the continuing involvement of Dr. P.J. Kurfurst in work at the URL.

Neither annual reports nor files of the Geological Survey provide any documentation regarding formal conclusion or withdrawal of EMR involvement with AECL in the NFWMP. It seems probable that with completion in 1986 of transfer to Pinawa of AECL term staff previously seconded to Ottawa any continuing geoscience work was conducted and supervised from WNRE. Also, the geoscience documentation required for the environmental impact statement was provided by AECL staff. Throughout most of 1986 and on into the fall of 1987 when I left Terrain Sciences Dvision to assume responsibilities at Branch level I had no significant involvement with the NFWMP.

Post Script for the NFWMP

The final report[37] of the Technical Advisory Committee contains a concise summary of events leading to the environmental assessment and review of AECL’s concept of geological disposal of nuclear waste. The process began in 1988 with a decision by the Canadian government that the concept be subject to the federal Environmental Assessment Review Process (EARP) an activity administered by Environment Canada. In order to proceed with the process an Environmental Assessment Panel was established about one year later under the chairmanship of Blair Seaborn which gave rise, henceforth, to its designation as the Seaborn Panel. In 1992 the Panel issued a set of guidelines to AECL for the content of the Environmental Impact Statement (EIS) that the company was required to submit for review by the Panel. In October 1994 AECL issued its EIS which

[37] Shemilt, L.W. (Chairman), 1996: Fifteenth Annual Report of the Technical Advisory Committee on the Nuclear Waste Management Program, TAC-15, *submitted to* Atomic Energy of Canada Limited.

contained the general requirements for a disposal concept and listed the technical objectives required to develop and demonstrate the technology for the siting, construction, operation and decomissioning of a disposal facility. The EIS also contained material to support demonstration of a methodology to evaluate the safety of a disposal system and to determine whether technically suitable disposal sites are available in Canada.

After a number of years of Panel deliberations, public hearings and specialist interventions the Panel published in February, 1998 its report entitled Report of the Nuclear Fuel Waste Management and Disposal Concept Environmental Panel. Among the conclusions drawn by the Panel were two of particular significance for the future of the disposal of nuclear fuel wastes. The first conclusion was that from a technical perspective the safety of the AECL concept has been on balance adequately demonstrated for a conceptual stage of development but from a social perspective it has not. A second conclusion of the Panel was that as it stands the AECL concept for deep geological disposal has not been demonstrated to have broad public support.

Both of these conclusions were no doubt amply substantiated by the documentation provided in support of the concept of geological disposal and by the comments, submissions and other information obtained during the course of the hearings. Given the amount of scientific and technical effort that went into developing support for the concept and the extent of external scientific review accorded the concept, both nationally and internationally, it is not surprising that the Panel found the concept to have been adequately demonstrated. Also given the widespread apprehension by the public over almost any nuclear issue, a general lack of interest in becoming informed about nuclear issues, and, with respect to the management of any kind of waste, public preference is commonly for a location remote from their own regardless of the source of the waste. Thus, absence of broad public support for the concept of geological disposal is not surprising.

From political and social points of view it is clearly desirable that a nuclear waste disposal facility have broad public support. In the absence of some sort of widely perceived critical event concerning the disposal of nuclear waste, however, broad public support for a disposal concept may not be attainable.

The conclusions of the Seaborn Panel brought about a cessation of any immediate further effort toward the implementation of a nuclear waste facility. Recommendations by the Panel, however, provided a framework for action by the Government of Canada that would facilitate the future development of such a facility. In 1996, possibly prompted by the then ongoing deliberations of the Seaborn Panel, the Government of Canada issued a statement enunciating a Policy Framework for Radioactive Waste. The policy statement identified producers of nuclear fuel waste as owners of that waste. It further required owners of the waste to establish a waste management organization (WMO) to deal with all aspects of long term management of the waste and to establish trust funds with annual contributions to finance the long term management of the waste.

As an outcome of the policy statement the Government of Canada in 2002 enacted the Nuclear Fuel Waste Act (NFWA) with the purpose of providing a framework that would enable the Government to make a decision, based on proposals from a waste management organization, for the management of nuclear fuel waste that would provide a comprehensive, integrated and economically sound approach for Canada.

The organization specified in the Nuclear Fuel Waste Act to deal with the matter of nuclear fuel waste disposal was established late in 2002 as the Nuclear Waste Management Organization (NWMO). It is located in Toronto, Ontario with a board of directors drawn from the waste owners who have appointed Ms Elizabeth Dowdeswell as president of the organization. The NWMO, as required by the NFWA, is also served by an independent Advisory Council whose role is to comment on the process, report and recommendations of the NWMO.

The NFWA placed rather stringent restrictions upon the NWMO by requiring that after three years of coming into force of the NFWA (i.e. Nov. 2005) the organization shall submit to the Minister (Natural Resources Canada) the results of a study setting out its proposed approaches for the management of nuclear fuel waste and the comments of the Advisory Council on those approaches.

The Act also required, inter alia, that each of the following methods must be the sole basis of at least one approach: deep geological disposal in the Canadian Shield based on the AECL concept described in its EIS; storage at nuclear reactor sites; and, centralized storage either above or below ground.

After considerable effort involving commissioned studies, public hearings, review of submissions, development of an extensive web site and publication of several interim reports the NWMO duly submitted on schedule its required report to the Government of Canada in November, 2005.

The report entitled “Choosing a Way Forward: The Future Management of Canada’s Used Nuclear Fuel” recommended that the Government of Canada adopt an approach described as “Adaptive Phased Management” In essence, this approach comprises centralized containment and isolation of used fuel in a deep geological repository in suitable rock of the Canadian Shield or Ordovician sedimentary strata, provision for an optional step of shallow underground storage at the central site and potential for retrievability for an extended period until such time as a future society makes a decision for closure and postclosure monitoring. The implementation process would be accompanied by continuous monitoring of the used fuel as well as continuing research and development on safety issues.

Although the matter of site selection was stipulated in the NFWA, the NWMO did not address this issue with respect to the selection of a specific site. It did, however, make reference to the process of site selection including the commitment of the organization to the search for an informed, willing community to host the long-term management facility. It is to be hoped that this search, whenever it gets underway, will be more successful than that of the Siting Task Force sponsored by EMR during the early 1990's which attempted, but failed, to find a community willing to host a repository for the low-level radioactive refinery wastes from Port Hope, Ontario and surrounding area.

The submission of the NWMO report to the Government of Canada in November, 2005 did not receive much, if any, response from the press. Further, well over a year later in the early spring of 2007, there has been no indication of any action taken by the Government of Canada to further pursue the matter of nuclear fuel waste disposal. Since November, 2005, however, a federal election was held in January, 2006 resulting in the election of a minority Conservative government. Regardless of its political persuasion, a minority government is not one likely to give the issue of nuclear fuel waste management a place of prominence on its agenda.

For the immediate future, and perhaps for even a much longer period of time, used nuclear fuel will remain at the reactor sites either in the spent fuel bays or in storage canisters on surface.

Coldstream Ranch Well (1979 - 82)

The connection between the Geological Survey and a water well on the property of the Coldstream Ranch in the Okanagan Valley of British Columbia arises from the activities of a Quaternary geology field party operating in the area during the mid 1960's. Specifically, during the field season of 1965 Dr. R.J. Fulton and his party were involved in Quaternary geological mapping in the Vernon area of British Columbia. Stratigraphic studies, involving drilling and sampling were an integral part of the field program. One of the sites selected for drilling was on the Coldstream Ranch property located approximately 7.2 km southeast of Vernon near the junction of Highway 6, Canadian National Railway crossing and the Kalmalka Lake road.

The surface elevation at the site is 470 m asl with mountains rising to 1,400 m within 6.4 km of the valley. The valley in which the ranch is located contains a perennial stream, Coldstream Creek, which drains west into Kalmalka Lake located at the northern end of the Okanagan Valley. In retrospect, the site for the drill hole, although within a relatively arid part of the interior of British Columbia, possessed most of the topographic and hydrological characteristics necessary for the occurrence of an artesian aquifer.

An uncased 16.5 cm diameter hole was drilled at the site with the use of a rotary drill. At a depth of about 60 m, in the somewhat understated account by Fulton[38] the drill: "encountered a previously unknown high pressure artesian aquifer at a depth of about 200 feet"

[38] Fulton, R.J., 1966: Quaternary studies, Vernon (West Half) map-area; *in* Jenness, S.E. (ed.) Report of Activities, May to October, 1965, Geol. Surv. Canada, Paper 66-1, p. 56 - 57

Indeed it did as the initial flow was estimated to be of the order of 500 Imperial gallons per minute with a surface pressure between 30 and 50 p.s.i. sufficient to eject water and entrained gravel and cobbles to the height of the drill mast - a distance of about 9 m. This mishap was soon to become known as "The Coldstream Ranch Well".

The high volume of flow from an uncased drill hole was such that it could not be controlled by the drillers best efforts to do so with the use of weighted drilling mud and the flow soon assumed an uncontrolled state. The high volume of flow from the hole brought with it quantities of unconsolidated sediments and soon reduced the surface around the hole to an unstable state. Fortunately it was possible to remove the drill stem from the hole and the drill rig from the site just prior to the development of a crater around the drill hole due to sediment removal. The crater was soon backfilled with gravel and an attempt made to grout off the flow through the injection of a cement slurry through two 5 cm diameter pipes that had been jetted to a depth of about 45 m near the centre of the crater. This attempt had little effect in reducing the volume of flow. A second attempt at flow control was made by constructing a timber platform over the cratered area to provide access for a drill rig and then inserting a 15 cm diameter casing into the original hole to a depth of 52 m. Grout was then pumped through the casing but it too had little effect in diminishing the flow which was by now mainly outside the casing and continuing to cause removal of sediment from the zone of flow.

By July 1965, following the inability of previous attempts at grouting to bring the flow under control, it was apparent that a more concerted effort would be required. At that time I was involved in surficial geological mapping of the Suffield Experimental Station in southern Alberta when I was instructed by my Division Director, Dr. S.C. Robinson to go to the site of the flowing borehole to assess the situation and to formulate a plan of action to bring the flow under control.

For the purpose of this account it is sufficient to note that an account[39] of the remedial work done exists and that the work extended, on an intermittent basis, from the summer of 1965 until the spring of 1967 at a substantial financial cost as well as a significant amount of my time. In spite of the best efforts of oil field cementing specialists, grouting consultant, consumption of tons of portland cement as grout, and the installation of an 80 cm diameter heavy-wall casing to a depth of 45 m, the best that could be accomplished was to stabilize the ground around the flow zone and to bring the flow under control. Even with all of this effort and the flow now confined to the 80 cm casing, the ground around the flow zone was not sufficiently stable nor the artesian zone adequately contained to enable the flow through the casing to be mechanically shut off, although this had been the original intent of the remedial work. It was hoped that with the flow confined to the 80 cm casing the discharge would be confined therein on a long term basis and that the flow could be used for irrigation or other beneficial purpose.

[39] Scott, J.S., 1968 (See Footnote 2, p.3)

In April 1979, however, the period of controlled flow came to an end with the notification to the Department by mail from the general manager of the Coldstream Ranch that seepage of groundwater was occurring around the housing for the 80 cm well casing. Such an occurrence could only be caused by some restriction of flow within the casing and its diversion outside the casing by hydrostatic pressure within the aquifer. This was a clear indication of the development of an unstable situation that would only further deteriorate with time. Since the manager of the ranch had never agreed to absolve the Department of further responsibility for the well once the original remedial work had been completed, the Department had no choice other than to examine the situation and to undertake such further work as may be required.

Given my previous involvement with the remedial work on the Coldstream Ranch well it was not surprising that this latest development should be brought to my attention. At that time my duties as Division Director were demanding of most of my time and the Geological Survey did not then have another staff member with a hydrogeological background who could investigate this latest occurrence. With the assistance of the Vancouver office of the Geological Survey and the cooperation of the Department of the Environment (DoE) we were able to obtain the services of a Vancouver-based DoE hydrogeologist, Mr. Hugh Liebscher, for a site visit and to provide us with recommendations for remedial work to be done.

From his visit to the site in May 1979 Mr. Liebscher concluded that an attempt should be made to increase the flow from the 80 cm casing and that additional grouting might be required to reduce seepage around the casing. In view of the possible requirement for additional grouting the Division entered into contract with the original grouting consultant, Mr. L.A. York to oversee work at the site. In early June 1979 Mssrs. Liebscher, York and I visited the site to prepare a work plan and to advise the Ranch manager of the work to be done. During the summer of 1979 the main work done at the well was airlift pumping from the bottom of the 80 cm casing in an attempt to remove accumulated sediment and thereby improve flow from the well. This work was apparently not successful in either improving flow from the casing or in reducing seepage around the casing. No grouting was done at the site and no further work was done over the winter of 1979-80.

During the summer and fall of 1980 improvement in the flow from the 80 cm casing was achieved by the emplacement of sections of well screens at depths well below the base of the 80 cm casing. This work greatly improved the flow rate and eliminated the external seepage. Additional work at the well included improvements to the well housing, discharge line and installation of flow control and measuring devices.

My last visit to the site was in the spring of 1982 at which time the well was under control and being used for irrigation purposes. In addition other wells were being drilled on ranch property to supply irrigation water. In spite of the additional work done to improve the original well and the development of additional wells that would provide aquifer pressure relief management of the ranch remained unwilling to absolve the Department of any further responsibility for the original well.

The issue of Departmental responsibility was resolved in the mid 1990's when it was determined that ownership of the ranch had changed hands which, in the view of the Department, would place any obligation for any previous liabilities upon the new owners. It is presumed that now, about 40 years after the initial artesian flow, the discharge continues, hopefully for beneficial use. and that it no longer is a matter of Departmental concern.

Decade of North American Geology (DNAG) (1981 - 1987)

.

In 1980 Branch involvement with the Geological Society of America (GSA) Centennial project - Decade of North American Geology (DNAG) was accelerated. This major project of the Society, a compendium of continental geology involving a large part of the North American geoscience community, was intended to be published in 1988 to commemorate the centennial of the founding of GSA in 1888. Motivation for involvement of the Geological Survey in the project.was provided by the then Director General of the Geological Survey, Dr. D.J. McLaren, who had previously served as president of the Geological Society of America. Further, the project provided the opportunity for the preparation by the Survey of a major publication as replacement for Geology and Economic Minerals of Canada - 5th edition previously published in 1970. It was also recognized that a significant lead time would be required if a major compilation of Canadian geology was to be produced in time for the centennial. Nine volumes were planned for the geology of Canada to be prepared and published by the Geological Survey. Dr. J.O. Wheeler was assigned as overall project coordinator for this new edition.

As it transpired, in December 1980 Dr. D.J. McLaren stepped down as Director General of the Geological Survey and was appointed as Assistant Deputy Minister (Science and Technology). He was replaced as Director General in January 1981 by Dr. W.W. Hutchison who served in that capacity until August 1981 when he was promoted as Assistant Deputy Minister and replaced as Director General of the Geological Survey by Dr. R.A. Price. These organizational changes may have contributed, however unintentionally, to some degree of loss of Branch priority that had been previously accorded the DNAG project.

Responsibility for compilation of the Quaternary geology of Canada was assigned to Terrain Sciences Division and it was determined from the outset that this work would constitute one of the volumes to be produced by the Geological Survey. It was apparent to me as Division Director that we were faced with a demanding challenge by this project. If the Division was to have any hope of getting the job done by any time close to the centennial date it would require a dedicated project leader and that Divisional participants, as well as other contributors, would have to accord priority to the work and be responsible for adhering to schedules and deadlines.

In 1981 Dr. R.J. Fulton, then Head of the Quaternary Projects Section, was assigned responsibility for coordinating the preparation of the Canadian Quaternary geology volume. During that year an outline for the volume was prepared and authors were assigned responsibility for each chapter of the volume although actual writing of the material had yet to begin. In the following year Dr. Fulton was relieved of his responsibilities as Section Head in order to devote more time to coordinating the Divisional and national efforts in the preparation of the Quaternary geology volume. He was assisted in this task by Mr. J.A. Heginbottom who was assigned as coordinator for the part of the volume dealing with applied Quaternary geology. It was to this part of the volume that I, in concert with colleagues from Manitoba, Saskatchewan and Alberta, contributed to a section dealing with "Engineering geology and land use planning in the prairie region of Canada". I also made an additional contribution to the GSA Centennial volume series through publication of "The role and development of engineering geology in the Geological Survey of Canada" as part of Chapter 3, Research efforts, governments of North America in Centennial Special Volume 3, 1991, "The heritage of engineering geology; the first hundred years" edited by the late George A. Kiersch.

With respect to the Quaternary geology volume approximately 25 members of Terrain Science Division were contributors as were about an equal number of Quaternary geoscientists from other organizations across the country. Most of the writing for the volume was done during the period 1984 - 1986 with a following sustained period of compilation and editing that preceded publication. In the absence of such priority assignment it is most likely that publication of the Quaternary geology volume would have encountered the delays experienced by other volumes produced by the Geological Survey.

Among the Canadian volumes scheduled for production the first to be completed and published (1989) was "Quaternary Geology of Canada and Greenland" coordinated and edited by R.J. Fulton. Other Canadian volumes in the DNAG series produced by the Geological Survey were published between 1990 and 1998. The relatively early completion of the Quaternary Geology volume was due in large measure to the organizational skills and concerted efforts of the volume editor and coordinator of Part 1- Regional Quaternary Geology of Canada, Dr.R.J. Fulton, to Mr. J.A. Heginbottom, coordinator of Part 2 - Applied Quaternary Geology in Canada and to Dr. S. Funder, coordinator of Part 3 - Quaternary Geology of Greenland. The cooperation and concerted efforts of the many contributors to the volume both within and beyond Terrain Sciences Division who so effectively responded to the priority assigned to this project further enabled timely completion of the volume.

In addition to his major work in the preparation of the Quaternary Geology volume Dr. R.J. Fulton was also substantially involved in the compilation of a 1:5M scale Quaternary materials map for Canada. This major work of compilation was originally intended to accompany the Quaternary Geology volume. The magnitude of the task, however, was such that the work could not be completed in time to meet the publication schedule for the Quaternary Geology volume. The Quaternary materials map was subsequently completed by Dr. Fulton and published in 1995 by the Geological Survey of Canada as Map 1880A.

Publication of the Quaternary Geology of Canada and Greenland volume with its accompanying maps and the subsequent publication of Map 1880A constitutes one of the major achievements of the Division. Given the increasing trend toward electronic forms of publication it seems quite probable that the DNAG volumes published by the Geological Survey may well be the last hard copy compilations of Canadian geology to be produced.

Geological Survey of Canada Futures Conference (1981)

The Geological Survey held a futures conference at Glen House Lodge, Gananoque, Ontario from December 1 - 4, 1981. The purpose of the conference was to identify the challenges and opportunities anticipated over the next decade and to assess the Survey's ability to respond effectively to them. For the most part, the initiative for the conference was provided by the late Dr. W.W. Hutchison, then Assistant Deputy Minister, Earth Sciences Sector, in response to the implementation of a new Policy and Expenditure Management System - one of a series of such systems to find its way into the Public Service.

Attendees at the conference comprised managers from Branch and Sector level, invited guests from other Branches of the Department and 59 members of the Geological Survey representative of both management and scientific staff. A total of 5 staff from Terrain Sciences Division attended the conference.

The record of the conference[40] notes that I served on several ad hoc committees and chaired the one concerned with Pleistocene Glaciations, Paleoclimatology and the Engineering Behaviour of Geological Materials. In addition representatives from Terrain Sciences Division gave a three part presentation covering a.) Historical and General aspects of Divisional activities (J.S. Scott); b.) Environmental Issues (W.W. Shilts); and c.) Quaternary Geoscience work (R.J. Fulton).

The following points arising from these presentations are recorded in the report on the conference:

Part a.)

1. Quaternary geology has been a part of Geological Survey of Canada activity since 1842 but over the years it has been subject to erratic administrative fluctuations.
2. Quaternary geology activities have had Division or Section status since 1950.
3. Since 1967 levels of A-Base resource allocations to the Division have been essentially static but externally-funded programs have contributed from time to time both funds and person-years.
4. For the future growth restraints will arise from a general environment of moderate growth.
5. Internal restraints arise from an undesirable age distribution among scientific staff - a bimodal age distribution of young staff ($\leq$40 yrs.) and significant numbers of older staff ($\geq$55 yrs.) with too few in the intermediate age range. The problem is further compounded by a lack of properly-trained university graduates to fill the few vacancies that become available.
6. On the positive side new opportunities were envisaged through increasing needs for terrain information for environmental protection, waste disposal, resource development, particularly in northern and offshore environments, and in the assessment of terrain hazards. Future developments in remote sensing and data processing techniques were also viewed as future opportunities.

Part b.)

1. Glacial debris contains materials that may release toxic elements into the environment or which may serve as indicators in mineral exploration. Thus a more consistent policy of sampling and sample analysis in the course of surficial geology mapping is required.

---

[40] Findlay, D.C. (Compiler/editor), 1982: Geological Survey of Canada Futures Conference, Dec. 1 - 4, 1981, Geological Survey of Canada, internal report.

2. Quaternary geology studies have been traditionally neglected or underemphasized by Canadian universities. Thus, Terrain Sciences Division has a role to play in furthering the development of Canadian Quaternary geology expertise through supporting promising students by providing summer employment and thesis support.
3. Future emphasis in work by the Division will likely include environmental geochemistry, geophysical techniques to aid in overburden mapping, drift prospecting applications and investigations of surface processes, particularly in arctic regions. This work would be done in coordination with surficial geology mapping.

Part c.)

1. At the time of the conference about 20 per cent of Canada's surface area remained unexamined even on a reconnaissance basis and Quaternary geology mapping at "inventory" scales is less than 50 per cent complete.
2. For the future some principal needs are:
   a.) Establishment of basic written map standards such as density of data points and measurement parameters.
   b.) Maintain a continuing supply of qualified staff through close association with student training and universities.
   c.) Greater use of contracting-out for labour intensive aspects of the Division's work.
   d.) Greater use of remote sensing techniques particularly in northern areas.
   e.) Develop new ways of cooperative work with the provinces to assist in Terrain Sciences Division's national synthesis role.

The extent to which the conference specifically influenced program directions within Terrain Sciences Division, or elsewhere in the Geological Survey, may be difficult to determine at this time so long after the event. The main benefits of the conference, however, were manifest at the time of the event through the interaction of ideas and concerns among management and scientific staff, interdivisional participation in workshops and on subcommittees and in a common recognition of the conflicts that commonly arise among the internal and external priorities faced bt the Survey in the formulation of its programs.

It is further evident from a review of Divisional activities that occurred over the years following the conference that a number of issues or concerns raised at that event such as advances in remote sensing techniques, environmental concerns, cooperation with provincial agencies and regional geological syntheses were addressed as part of the Division's scientific program.

Canadian Geoscience Council Report (1986)

In 1983 a Canadian Geoscience Council advisory group for the Geological Survey of Canada, chaired by Mr. J.A. Coope, produced a report (GSC Paper 82-6) on the outputs of the Geological Survey with commentary as to the extent to which these outputs met the needs of user groups. The report recognized that the subject of Quaternary and engineering geology was of particular importance to Canada and recommended that a review be undertaken of the work of the Geological Survey on this subject including an evaluation of the outputs of the Geological Survey pertaining thereto. Within the Geological Survey such a review would be focused almost entirely upon the work and outputs of Terrain Sciences Division. Consequently during the same year, an advisory group consisting of Prof. M.A. Church, University of British Columbia, (Chairman),Dr. J-Y Chagnon, Quebec Department of Natural Resources, Dr. E.A. Christiansen, Consulting Geologist, Saskatoon, Prof. S.B. McCann, McMaster University, Mr. H.W. Naismith, Consultant, Victoria and Mr. G.C. Topp, Department of Agriculture was formed to carry out the study. This was the first time that the outputs of Terrain Sciences Division had been placed under external scrutiny.

Over the next several years the group conducted its review of Geological Survey outputs in Quaternary and engineering geology. The initial part of the study was through the use of questionnaires sent to both general and specialized user groups to obtain their opinions. The group also interviewed a wide representation of users of these outputs as part of its evaluation exercise. This work, in addition to personal opinions of the group members formed the basis for their report. A preliminary version of the Committee's findings, conclusions and recommendations was received in September 1985 with the final report delivered in the spring of 1986.

The report contained a total of 21 recommendations grouped according to the principal terms of reference for the study viz.:

- Identification of the present and future (10 yr.) requirements of various users with respect to geographic region and application

- Accuracy standards and format of data presentation

- Relative priorities of data and information requirements among specific user groups

- Changes or modifications to outputs that would improve their usefulness to users

- Identify problems relating to mobilization of external expertise and data resources under contract or through co-operative programs to improve the national information and data base in Quaternary and engineering geology within anticipated resource limits.

As was customary within the Geological Survey following receipt of such review reports, the Director of the Division to which the report was principally addressed was responsible for preparing or having prepared a commentary to be included with the published version of the report. As I was still Director of Terrain Sciences at the time the report was submitted to the Geological Survey I prepared the commentary which is contained in Part 1 of the report. Both the report and the commentary thereon are contained in Geological Survey of Canada Paper 87-25 "Mapping the Landscape".

It is noted in the commentary that just prior to receipt of the report Terrain Sciences Division underwent a significant reorganization through acquisition of scientific units that formerly operated within Earth Physics Branch (permafrost), Polar Continental Shelf Project (glaciology) and elsewhere within the Geological Survey (terrain geophysics). These organizational changes did not in any way invalidate either the report or its recommendations. Integration of the new units into the structure of the Division, however, did tend to divert attention from the report and the implementation of some of its recommendations. Within about a year following receipt of the report I had assumed responsibilities at the Branch level and implementation of recommendations were transferred to Dr. D.A. St-Onge, my successor as Director, Terrain Sciences Division. The report did provide constructive and useful recommendations for program directions and product enhancement by the Division.

In the internal annual report of the Geological Survey for 1987 - 88 the new director of Terrain Sciences Division records changes to the structure of the Quaternary Geology Subdivision that, along with other initiatives, would enable the Division to respond to many of the recommendations contained in the Canadian Geoscience Council report on outputs in Quaternary and engineering geology. To the extent possible, and within the resource constraints applicable to the Division, most of the recommendations of the Advisory Committee were implemented in subsequent years from which it may be concluded that external reviews of Geological Survey programs and products are an effective means for bringing about positive changes and improvements.

Mineral Development Agreements (1984 - 1987)

Early in 1984 the office of the Director General was expanded to include a Mineral Development Programs office under Dr. W.H. Poole to deal with the various Federal and Provincial Mineral Development Agreements. These agreements, established between various provincial governments and the federal government, were intended to promote mineral exploration in the provinces on a shared cost basis. For the most part the agreements were initiated in 1984 and remained in force until 1989. Among the various scientific divisions of the Geological Survey, Mineral Resources Division was perhaps the principal participant in the Mineral Development Agreement (MDA) Program. It was thus logical that Geological Survey coordinators for the various provinces that would serve in the Mineral Development Agreements Program office were drawn from Mineral Resources Division. Terrain Sciences Division, however, through its development of drift prospecting techniques to aid mineral exploration in the drift covered regions of the country and its program of systematic mapping of Quaternary geology became an active participant in the program. Thus, scientific staff from two sections of the Division, Sedimentology and Mineral Tracing and Regional Projects, as well as outside contractors, became involved over the next several years in MDA - supported projects.

During 1984 field work by the Division supported by the MDA program was conducted in a number of regions of Canada including Quebec, central Labrador, Nova Scotia, New Brunswick and northern Manitoba. In the Lac Matapédia area of the Gaspé region of Quebec Dr. G. Prichonnet of the University of Quebec at Montreal (UQAM), under contract, examined the distribution of erratics and determined ice-flow directions from bedrock indicators. He also collected till samples throughout the area and had them analysed for ten trace elements. Elsewhere in the country the work under the MDA program consisted mainly of reconnaissance drift geochemical sampling and airphoto mapping for the purpose of delineating patterns of major glacial features including ice flow directions.

Over the next two years scientific staff of the Division were particularly active in a number of projects in several provinces that were supported under the MDA program. In the Central Mineral Belt of Labrador studies of drift composition and glacial history of the area by Dr. R.A. Klassen were continued. This work indicated a complex history of ice flow related to previously unknown dispersal centres within the Laurentide Ice Sheet. Patterns of glacial dispersal associated with the various phases of the ice flow were established by examination of indicator erratics, geochemical analysis of till and interpretation of dispersal trains at both regional (100's of km) and detailed (100's of m) scales. This work provided a basis for the use of drift prospecting techniques for mineral exploration.

In northern New Brunswick detailed surficial geological studies were undertaken by Dr. M. Lamothe to determine the relationship of the widespread preglacial regolith (i.e. in situ weathered bedrock) to the overlying glacial deposits. The close similarity of the glacial till to the regolith was found to be particular problem for the use of drift prospecting techniques in the area. It was also discovered that a significant and long-lived ice cap centred on New Brunswick interacted in complex ways at various time with Laurentide glaciers that flowed southward from the Canadian Shield. Clarification of these interactions was essential to efficient interpretation of drift prospecting data.

Within the framework of the Lower St. Lawrence and Gaspé MDA mapping of the surficial geology of the Gaspé Peninsula at a scale of 1:50,000 was completed in 1985 by Divisional staff with assistance from a contractor. Other contracted work in the Gaspé area was also supported by the MDA. This work included a detailed study by Prof. P.P. David (Université de Montréal) of the McGerrigle boulder train and associated deposits with emphasis on glacial transport conditions, till stratigraphy and geochemistry and completion of the work begun the previous year by Dr. G. Prichonnet of UQAM.

Work under the Manitoba MDA provided support for compilation of a surficial geology map by Dr. R.N.W. DiLabio and Ms. C.A. Kaszycki for northeastern Manitoba which served as a basis for an extensive reconnaissance drift geochemical sampling program. Some of the till samples from northern Manitoba that were submitted for geochemical analysis yielded relatively high gold concentrations in the fine fraction of the till matrix. From previous work in regional mapping and interpretation of directions and distance of glacial transport it was possible to identify the probable source rocks for the gold.

In 1986 the Division continued to participate in surficial geology and drift prospecting studies supported by MDA's in Labrador, New Brunswick and initiated several surficial geology and drift prospecting studies in Northern Ontario, particularly by Dr. L.H. Thorliefson, under provisions of a 5 year Ontario that first came into force in 1985.

The extent to which MDA's achieved their intended purpose of stimulating mineral exploration in the provinces is a matter for analysis and comment well beyond the scope of this account. From the standpoint of the objectives of Terrain Sciences Division, however, the MDA program was instrumental in accelerating systematic Quaternary geological mapping in the participating provinces and in furthering the development of drift prospecting techniques.

Multi-Agency Group for Neotectonics in Eastern Canada (MAGNEC) 1986-1992

In 1986 interest in and concern over the occurrence of neotectonic events extended well beyond the interest of Terrain Sciences Division. During that year a rather informal organization with the acronym MAGNEC - a contraction of Multi-Agency Group for Neotectonics in Eastern Canada - was formed by representatives from various government agencies, universities and private sector organizations. The concept for MAGNEC was originally proposed in about 1985 by John Bowlby, then a geologist with Ontario Hydro and by Earle Taylor, an engineer and former Manager of Geotechnical Engineering at Ontario Hydro both of whom were interested in developing a forum for full and open discussion of geological issues related to seismic hazard evaluation particularly for critical structures such as nuclear power plants and underground gas storage facilities. In parallel with the interests and concerns of the geoscientists at Ontario Hydro were the investigations of Dr. J.E. Adams, Geophysics Division, Geological Survey and others of a variety of displacements of geological materials that might be attributable to seismic events or some other form of release of geological stresses

While the concept for some form of study group arose within Ontario Hydro the development of an informal group to examine the issue of neotectonics was due largely to the efforts of J.L. Wallach then a geologist with Atomic Energy Control Board in Ottawa. All of these early proponents of the MAGNEC organization were concerned that the seismic hazard evaluation for critical structures was apparently being made without full recognition and inclusion of geological data and opinion to complement the seismic data and information prescribed by the National Building Code for seismic hazard evaluation.

Given the interest of Terrain Sciences Division in the Quaternary geology of Canada including post glacial events it was logical that scientific staff of the Division would become involved in a program that endeavoured to meet the practical needs of a major public utility and the information requirements of a regulatory agency responsible for nuclear power plants. Thus, in 1986 representatives from the several interested organizations got together to create a program with a self-mandated statement of:

"Integrated geologic and seismotectonic studies for the improved assessment of seismic hazard in Eastern Canada".

In Canada the period of record for such seismic data and information is confined to a couple of hundred years of reported "felt events" and a much lesser period of seismograph records. Thus, an attempt to complement the existing seismic record with evidence of seismic activity that had affected Pleistocene and younger sediments could lead to improvement in the assessment of seismic hazard for critical facilities.

Dr. J.E. Adams, then with Earth Physics Branch of the Department, was appointed as chairman for the MAGNEC program, a capacity in which he served from 1986 to 1988. I served as chairman of the program from 1989 until 1991 at which time overall interest in the program began to decline.

Throughout its rather brief period of existence, however, MAGNEC did achieve a number of accomplishments including the convening of at least 12 meetings between January, 1987 and November, 1991 that were held at various locations in Ontario, Quebec, Newfoundland and New Brunswick for the purpose of discussing a number of field investigations that had been initiated by the program.

It was realized that a comprehensive seismotectonic analysis of the whole of eastern Canada would be a major undertaking and one that would be beyond the capacity of the MAGNEC group. Thus, it was decided to select several smaller areas as test localities within the larger region. The localities chosen were Prince Edward County, a projection of land into Lake Ontario south of Belleville, Ontario; Charlevoix County in Quebec located on the north shore of the St. Lawrence River between Quebec City and the Saguenay River; and Passamaquoddy Bay located in the southwest corner of New Brunswick adjacent to the Bay of Fundy. Each of these localities has a different tectonic setting and seismic history.

Prince Edward County is relatively aseismic but is located along a projection of the Clarendon-Linden fault zone, an active seismic source, that cuts New York State. Charlevoix County is the most seismically active region in eastern Canada and has a lengthy recorded history of seismic activity. The region also contains evidence of the disturbance of glacial and younger sediments by seismic activity and thus serves as a source to assist in the identification of such features. Passamaqoddy Bay is an area of moderate seismic activity but the presence or location of active structures is not known. Thus identification of such structures and verification of possible rapid crustal submergence as the cause of seismicity in the area were the focus of investigations.

Although the MAGNEC program was of relatively short duration and never became an integral part of the scientific program of the Geological Survey or, apparently, of any other scientific organization it did leave a published record of its meetings, discussions and other activities. The following list of reports pertaining to MAGNEC is unlikely complete but it will serve to assist in locating reference to most of the work done under the program:

MAGNEC '88	Annual Report	Geological Survey of Canada Open File 1991
MAGNEC '89	Annual Report	Geological Survey of Canada Open File 2275
MAGNEC '90	Annual Report	Geological Survey of Canada Open File 2453

The most comprehensive document pertaining to the program is the report prepared under contract by Dr. M.E. Grier, Kingston, Ontario entitled "MAGNEC 1987-1992 Five-Year Report" published by the Geological Survey of Canada in 1993 as Open File 2728. Contained in this report is information on seismic hazard evaluation, work undertaken under the MAGNEC program, recommendations for future work and minutes and proceedings of MAGNEC meetings.

The activities of MAGNEC and the documentation pertaining thereto may well have stimulated interest in neotectonic activity in eastern Canada and the possible hazard to critical structures in that region that may arise from seismic events. With respect to any revisions to aseismic provisions of the National Building Code, however, there is no indication that MAGNEC has had any effect.

EPILOGUE

It is recognized that the foregoing review of the origins of Quaternary geology in the Geological Survey and the evolution of that activity into an operational entity of one of Canada's foremost scientific organizations will no doubt contain both errors and omissions for which the author bears sole responsibility. Regardless of such shortcomings, the assembly of the material for this account and the recollection of many past events and personal associations that occurred over the years has given me cause to reflect upon what a remarkable organization, known world wide as the Geological Survey of Canada, I had the privilege to serve.

As a geologist I had the opportunity to experience professional practise in both domestic and foreign commercial assignments all of which were satisfying and beneficial to career development. The greatest satisfaction from a career standpoint, however, came from my employment with the Geological Survey and the reasons for this are several. The first is the stature of the organization which derives only in part from its venerable age, having been founded in 1842, but more from its continuing record of relevance and service to Canada. A second reason derives from the exceptional group of people comprising scientists, managers and various categories of support staff that collectively provided a collegial and invigorating environment in which to work. I was privileged, as were many others, to be able to associate with many senior members of the scientific staff who had lengthy distinguished careers and who provided both a living link to past achievements of the Survey and an inspiration for the future. A further reason is the national mandate of the organization and its linkages to the global geoscience community. These attributes of the Survey were such as to provide me with the opportunity to either work in, or to visit in some professional capacity, every province and territory of Canada and to participate in scientific meetings or conferences at various locations in Canada, the United States, England, France, Germany, Finland and Russia.

Throughout its history the Geological Survey has been subject to many and varied changes each reflecting some manifestation of economic and political circumstances and it is certain that changes of some sort will continue to impact the organization in the future. It is to be hoped, however, that future federal governments will continue to exercise stewardship over the natural resources endowment of the country and that the Geological Survey of Canada will continue to be a principal agent for providing the knowledge necessary for the exercise of that stewardship.

Appendix I TERRAIN SCIENCES DIVISION - LIST OF CONTINUING STAFF 1968 - 1987					
Surname	**Initials**	**Title**	**Function**	**Service Dates with TSD**	
				From	**To**
Achard	R.A.	Dr.	Geologist	Pre1968	1970
Adshead	J.D.	Dr.	Mineralogist	1976	Post 1987
Allen	V.A.	Mr.	Lab.Tech	1987	Post 1987
Alt	B.	Ms.	Climatologist	1987	Post 1987
Anderson	T.W.	Dr.	Palynologist	1972	Post 1987
Armstrong	J.E.	Dr.	Geologist	1973	1976
Aylsworth	J.M.	Mrs.	Geologist	1984	Post 1987
Bannerjee	I.	Dr.	Geologist	Pre1968	1969
Barnett	D.M	Dr.	Geographer	Pre1968	1977
Bélanger	J.R.	Dr.	Geologist	1974	Post 1987
Bélec	E.G.	Mr.	Draftsman	1979	1981
Bik	M.J.J.	Dr.	Geomorphol.	Pre 1968	1973
Bisson	J.G.	Mr.	Gphys.Tech.	1970	Post 1987
Blake	W., Jr.	Dr.	Geologist	Pre1968	Post 1987
Blasco	S.M.	Mr.	Geologist	1976	1978
Bornhold	B.D.	Dr.	Geologist	1975	1977
Bourgeois	J.	Ms.	Palynologist	1987	Post 1987
Boydell	A.N.	Dr.	Geologist	1973	1975
Buckley	J.T	Mrs.	Geographer	Pre1968	1969
Burgess	M.M.	Ms.	Geophys.	1987	Post 1987
Burns	R.A.	Mr.	Geophy.Tech	1987	Post 1987
Cade	M.R.	Mrs.	Admin.Clerk	1972	1977
Campbell	D.M.	Ms	Lab. Tech.	1973	1974
Carr	P.A.	Dr.	Geologist	1973	1975
Casey	A.J.	Mr.	Admin.Off.	1979	Post 1987
Chartrand	S.M.	Mrs.	Lab. Tech.	1973	1977
Clague	J.J.	Dr.	Geologist	1974	Post 1987
Claude	Y.	Mr.	Admin.Off.	1978	1979
Code	J.A.	Mr.	Geologist	1970	1972
Coulthart	I.A.	Mr.	Draftsman	Pre1968	1969
Cox	J.	Ms.	Secretary	1977	1979
Craig	B.G.	Dr.	Geologist	Pre1968	1981
Dallimore	S.R.	Dr.	Geologist	1986	Post 1987
Davey	P.	Ms	Admin. Clerk	Pre1968	1970
Day	T.J.	Dr.	Geographer	1974	1980
De-Vreeze	T.A.	Ms	Editor	1972	1973
DiLabio	R.N.W.	Dr.	Geologist	1976	Post 1987
Dredge	L.A.	Dr.	Geologist	1977	Post 1987

Dubey	R.J	Mr.	Lab. Tech.	1987	Post 1987
Duk-Rodkin	A.	Ms.	Geologist	1987	Post 1987
Dumych	H.	Ms	Editor	1972	Post 1987
Dyke	L.D.	Dr.	Geologist	1978	1981
Dyke	A.S.	Dr.	Geologist	1978	Post 1987
Edlund	S.A.	Dr..	Botanist	1976	Post 1987
Egan	D.J.	Mr.	Draftsman	1973	1977
Egginton	P.A.	Mr.	Geologist	1977	Post 1987
Evans	S.G.	Dr.	Geologist	1982	Post 1987
Federovich	S.	Dr.	Palynologist	1971	Post 1987
Field	D.E.	Mr.	Lab. Tech.	Pre1968	1979
Fransham	P.B.	Dr.	Geologist	1976	1978
Fulton	R.J.	Dr.	Geologist	Pre1968	Post 1987
Fyles	J.G.	Dr.	Div. Director	Pre 1968	1974
Gadd	N.R.	Dr.	Geologist	Pre1968	Post 1987
Gagne	R.M.	Mr.	Geophy.Tech	1987	Post 1987
Gale	J.E.	Dr.	Geologist	1975	1977
Gerrard	T.	Ms.	Draftsperson	1983	Post 1987
Gibbs	T.L.	Ms	Lab. Tech	1980	1981
Good	R.L.	Mr.	Geophy.Tech	1987	Post 1987
Grainger	B.J.	Ms.	Secretary	1979	Post 1987
Grant	D.R.	Dr.	Geologist	Pre1968	Post 1987
Harrison	J.E.	Dr.	Geologist	1971	1977
Harry	D.G.	Dr.	Geologist	1983	Post 1987
Heginbottom	J.A.	Mr.	Geographer	Pre1968	Post 1987
Henderson	E.P.	Dr.	Geologist	Pre1968	1974
Henderson	P.	Mrs	Lab. Tech.	1981	1985
Higgins	P.J.	Mrs.	Lab. Tech.	1977	Post 1987
Hodge	R.A.	Mr.	Lab. Tech	Pre1968	1970
Hodgson	D.A.	Mr.	Geographer	Pre1968	Post 1987
Hughes	O.L.	Dr.	Geologist	Pre1968	Post 1987
Hunter	J.A.M.	Dr.	Geophys.	1987	Post 1987
Isaacs	R.M.	Dr.	Soils Eng.	1970	1974
Jackson	L.A.	Mr.	Admin. Off.	1968	1978
Jackson	L.E.	Dr.	Geologist	1978	Post 1987
Jetté	H.	Ms.	Lab. Tech.	1984	Post 1987
Judge	A.S.	Dr.	Geophys.	1987	Post 1987
Kelley	R.G.	Mr.	Lab. Tech	Pre1968	Post 1987
Kettles	I.	Ms.	Geologist	1982	Post 1987
Klassen	R.A.	Dr.	Geologist	1975	Post 1987
Klassen	R.W.	Dr.	Geologist	Pre1968	Post 1987
Koerner	R.M.	Dr.	Glaciologist	1987	Post 1987
Kurfurst	P.J.	Dr.	Geologist	1973	Post 1987
Lardner	M.	Mrs.	Editor	Pre1968	1969
Lawrence	D.E.	Mr.	Geologist	1970	1975

Lee	H.A.	Dr.	Geologist	Pre1968	1969
Lewis	C.F.M.	Dr.	Geologist	Pre1968	1978
Lewis	C.P.	Dr.	Geologist	1973	1977
Lisle	A.E.	Mrs.	Admin.Clerk	1978	1985
Lowdon	J.A.	Mr.	Chemist	Pre1968	Post 1987
Luscombe	J.R.	Mr.	Lab. Tech.	1978	1984
Luternauer	J.L.	Dr.	Geologist	1973	1977
Mahony	G.I	Mrs.	Secretary	1980	1981
Matthews, Jr.	J.V.	Dr.	Entomologist	1973	Post 1987
McDonald	B.C.	Dr.	Geologist	Pre1968	1975
McFarlane	C.D.	Ms.	Lab. Tech.	1974	Post 1987
McLaren	P.	Mr.	Geologist	1974	1978
McLeish	P.A.	Mrs.	Admin.Clerk	1977	1985
McNeely	R.N.	Dr.	Limnologist	1981	Post 1987
Meehan	H.M.	Ms	Admin.Clerk	1970	1972
Meheden	D.M.	Mrs.	Secretary	1974	1977
Miller	D.E.	Ms	Typist	Pre1968	1981
Milliman	J.D.	Dr.	Geologist	1975	1976
Minning	G.V.	Ms	Geologist	Pre1968	1973
Mizerovsky	G.	Mrs.	Tech.Support	Pre1968	1978
Morel	D.M.	Mr.	Lab. Tech.	1970	1975
Morency	L.S.	Ms	Secretary	Pre 1968	Post 1987
Morin	F.M.	Dr.	Geologist	1975	1979
Mott	R.J.	Mr.	Palynologist	Pre1968	Post 1987
Netterville	J.A.	Dr.	Geologist	1974	1977
Nixon	M.F.	Mr.	Field Tech.	1977	Post 1987
Overton	A.	Mr.	Geophys.	1987	Post 1987
Owen	E.B.	Mr.	Geologist	Pre1968	1980
Parker	M.L.	Dr.	Dendrochron	1968	1970
Parnandi	M.	Mr.	Lab. Tech.	1987	Post 1987
Pelletier	B.R.	Dr.	Geologist	1975	Post 1987
Pilon	J.A.	Mr.	Geologist	1987	Post 1987
Podolak	W.E.	Mr.	Lab. Tech.	1975	1980
Prest	V.K.	Dr.	Geologist	Pre 1968	1977
Proudfoot	D.A.	Mr.	Data Mgr.	1974	1978
Pullen	S.E.	Ms.	Geophys.	1987	Post 1987
Rampton	V.N.	Dr.	Geologist	1969	1974
Richard	S.H.	Mr.	Geographer	Pre1968	1987
Richardson	R.J.	Mr.	Geologist	1976	1981
Rivoire	B.A.	Mrs.	Lab. Tech.	1980	1987
Robertson	I.M.	Mr.	Lab. Tech.	Pre1968	Post 1987
Rutter	N.W.	Dr.	Geologist	Pre1968	1974
Scott	J.S.	Dr.	Geologist	1969	1974
Scott	J.S.	Dr.	Div. Dir.	1974	1987
Sharpe	D.R.	Dr.	Geologist	1982	Post 1987

Shearer	J.M.	Mr.	Geophysicist	1970	1973
Sherman	B.E.	Ms.	Admin.Clerk	1985	Post 1987
Shilts	W.W.	Dr.	Geologist	1969	Post 1987
Shimizu	K.	Mr.	Statistician	Pre1968	1976
Skinner	R.G.	Dr.	Geologist	1970	1974
Slegr	M.	Mrs	Typist	1981	Post 1987
St-Amour	P.	Mr.	Draftsman	1981	1983
St-Onge	D.A.	Dr.	Geographer	Pre 1968	1973
St-Onge	D.A.	Dr.	Geographer	1984	Post 1987
Stalker	A.M.	Dr.	Geologist	Pre1968	1987
Taylor	A.E.	Mr.	Lab. Tech.	1987	Post 1987
Taylor	R.B.	Mr.	Geographer	1973	1978
Telka	A.M.	Ms	Lab. Tech.	1982	Post 1987
Thomas	R.D.	Mr.	Geologist	1976	1980
Thorleifson	L.H.	Dr.	Geologist	1987	Post 1987
Veillette	J.J.	Mr.	Geologist	1974	Post 1987
Vilonyay	A.G.	Mr.	Lab. Tech.	Pre1968	1974
Vincent	J-S	Dr.	Geologist	1974	Post 1987
Wilkinson	A.	Mr.	Lab. Tech.	1987	Post 1987
Wilson	L.	Mrs.	Lab. Tech.	1969	1984
Wyder	J.E.	Dr.	Geophysicist	Pre1968	1971
Wygergangs	M.H.M.	Ms.	Lab. Tech.	1987	Post 1987

Appendix II

TERRAIN SCIENCES DIVISION - ORGANIZATION HISTORY SUMMARY

(Note: See Appendix III for list of abbreviations and acronyms)

1968 - 1969			1969-1970			1970 - 1971		
QRG Div.	**Subdiv.**	**Section**	**QRG Div.**	**Subdiv**	**Section**	**QRG Div.**	**Subdiv.**	**Section**
Hq.		R&S	Hq.		R&S	Hq.		R&S
Sp. Proj		S&G	Sp.Proj.		EG&G	Sp. Proj.		EG&G
Ad/Fin		P&G	Ad/Fin		P&G	Ad/Fin		P&G
Sci.Serv		E&I	Sci.Serv			SciServ		
		RadC						
1971 - 1972			**1972 - 1973**			**1973 - 1974**		
TerSci Div	**Subdiv**	**Section**	**TerSci Div**	**Subdiv**	**Section**	**TerSci Div**	**Subdiv**	**Section**
Hq.		R&S	Hq	Geotech	S&MT	Hq	Geotech	S&MT
Sp. Proj.		EG&G	Clr/Scy		E&EG	Clr/Scy		E&EG
Ad/Fin		P&G	Ad/Fin		UrbProj	Ad/Fin		UrbProj
SciServ			TechServ		SedLab	TechServ		SedLab
			ESP,NP	Quatern	RegProj	Sp. Proj	Quatern	RegProj
					P&G			P&G
					M&C			M&C
					PaleoLab			PaleoLab
					RadC			RadC
1974 - 1975			**1975 - 1976**			**1976 - 1977**		
TerSciDiv	**Subdiv**	**Section**	**TerSciDiv**	**Subdiv**	**Section**	**TerSciDiv**	**Subdiv**	**Section**
Hq		S&MT	Hq		S&MT	Hq		S&MT
Clr/Scy		E&EG	Clr/Scy		E&EG	Clr/Scy		E&EG
Ad/Fin		UrbProj	Ad/Fin		UrbProj	Ad/Fin		SdEnLab
TechServ		SedLab	TechServ		SdEnLab	TechServ		RegProj
Sp. Proj		RegProj	Sp. Proj		RegProj	Sp. Proj		P&G
		P&G			P&G			M&C
		M&C			M&C			PaleoLab
		PaleoLab			PaleoLab			RadC
		RadC			RadC			

1977 - 1978			1978 - 1979			1979 - 1980		
TerSciDiv	**Subdiv**	**Section**	**TerSciDiv**	**Subdiv**	**Section**	**TerSciDiv**	**Subdiv**	**Section**
Hq		S&MT	Hq		S&MT	Hq		S&MT
Clr/Scy		EngGeol	Clr/Scy		EngGeol	Clr/Scy		EngGeol
Ad/Fin		SdEnLab	Ad/Fin		SdEnLab	Ad/Fin		SdEnLab
TechServ		RegProj	TechServ		RegProj	TechServ		RegProj
StaffSci		P&G	StaffSci		P&G	StaffSci		P&G
		M&C			PaleoLab			PaleoLab
		PaleoLab			RadC			RadC
		RadC			GmrProc			GmrProc
		GmrProc						

1980 - 1981			1981 - 1982			1982 - 1983		
TerSciDiv	**Subdiv**	**Section**	**TerSciDiv**	**Subdiv**	**Section**	**TerSciDiv**	**Subdiv**	**Section**
Hq		S&MT	Hq		S&MT	Hq		S&MT
Clr/Scy		EngGeol	Clr/Scy		EngGeol	Clr/Scy		GP&EG
Ad/Fin		SdEnLab	Ad/Fin		SdEnLab	Ad/Fin		SdEnLab
TechServ		RegProj	TechServ		RegProj	TechServ		RegProj
StaffSci		P&G	StaffSci		P&G	StaffSci		P&G
		PaleoLab			PaleoLab			PaleoLab
		RadC			RadC			RadC
		GmrProc			GmrProc			

1983 - 1984			1984 - 1985			1985 - 1986		
TerSciDiv	**Subdiv**	**Section**	**TerSciDiv**	**Subdiv**	**Section**	**TerSciDiv**	**Subdiv**	**Section**
Hq		S&MT	Hq		S&MT	Hq		S&MT
Clr/Scy		GP&EG	Clr/Scy		GP&EG	Clr/Scy		GP&EG
Ad/Fin		SdEnLab	Ad/Fin		SdEnLab	Ad/Fin		SdEnLab
TechServ		RegProj	TechServ		RegProj	TechServ		RegProj
StaffSci		P&G	StaffSci		WRegPrj	StaffSci		WRegPrj
		PaleoLab			P&G			P&G
		RadC			PaleoLab			PaleoLab
					RadC			RadC

1986 - 1987			Apr. 1987 - Oct. 1987			Nov. 1987 - Mar. 1988		
TerSciDiv	**Subdiv**	**Section**	**TerSciDiv**	**Subdiv**	**Section**	**TerSciDiv**	**Subdiv**	**Section**
Hq	QuatGeol	WestReg	Hq	QuatGeol	WestReg	Hq	QuatGeol	WestReg
Clr/Scy		NorthReg	Clr/Scy		NorthReg	Clr/Scy		NorthReg
Ad/Fin		EastReg	Ad/Fin		EastReg	Ad/Fin		EastReg
TechServ		MinExM	TechServ		MinExM	TechServ		MinExM
StaffSci		RadC	StaffSci		RadC	StaffSci		RadC
	QuatEnvr	Palecol		QuatEnvr	Palecol		QuatEnvr	Palecol
		Glaciol			Glaciol			Glaciol
		SedLab			SedLab			SedLab
	TerrDyn	GP&EG		TerrDyn	GP&EG		TerrDyn	GP&EG
		TrGeoph			TrGeoph			TrGeoph
		PfrRes			PfrRes			PfrRes
		SedRes			SedRes			SedRes

Appendix III

TERRAIN SCIENCES DIVISION
Organizational Abbreviations

Ad/Fin	Administration and Finance
Clr/Sc	Clerical and Secretarial
E&EG	Environmental and Engineering Geology
E&I	Engineering and Indicator Geology
EastReg	Eastern Region
EngGeol	Engineering Geology
ESP,NP	Environmental Social Program, Northern Pipelines
Geotech	Geotechnical
Glaciol	Glaciology
GmrProc	Geomorphic Processes
GP&EG	Geomorphic Processes and Engineering Geology
Hq	Headquarters
M&C	Marine and Coastal
MinExM	Mineral Exploration Methods
NorthReg	Northern Region
P&G	Paleoecology and Geochronology
Palecol	Paleoecology
PaleoLab	Paleoecology Laboratory
PfrRes	Permafrost ResearchQRG Div. Quaternary Research and Geomorphology Division
QuatEnvr	Quaternary Environments
Quatern	Quaternary
QuatGeol	Quaternary Geology
R&S	Regional and Stratigraphic Projects
RadC	Radiocarbon Laboratory
RegProj	Regional Projects
S&G	Sedimentology and Geomorphic Processes
S&MT	Sedimentology and Mineral Tracing
SciServ	Scientific and Technical Services
SdEnLab	Sedimentology and Engineering Geology Laboratory
SedLab	Sedimentology Laboratory
SedRes	Sedimentology Research
Sp. Proj	Special Projects
StaffSci	Staff Scientists
TechServ	Technical Services
TerrDyn	Terrain Dynamics
TerSciDiv	Terrain Sciences Division
TrGeoph	Terrain Geophysics
UrbProj	Urban Projects
WRegPrj	Western Region Projects