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MAPPING THE LANDSCAPE

REPORT OF THE CANADIAN GEOSCIENCE COUNCIL ADVISORY COMMITTEE TO THE GEOLOGICAL SURVEY OF CANADA ON OUTPUTS IN QUATERNARY AND ENGINEERING GEOLOGY

by the
ADVISORY COMMITTEE
Chairman: M. Church
Members: J.-Y. Chagnon, E.A. Christiansen,
S.B. McCann, H.W. Nasmith, G.C. Topp

Canada

GEOLOGICAL SURVEY OF CANADA
PAPER 87-25

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Prepared by the
CANADIAN GEOSCIENCE COUNCIL

Advisory Committee

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PART 1

PREFACE

For some years the Geological Survey of Canada has followed a policy of having external peer reviews of aspects of its scientific operations. This has been coupled with mandatory ongoing operational audits and reviews conducted by internal departmental (Energy, Mines and Resources) or interdepartmental teams. These processes have provided a series of checks and balances against which the scientific and administrative procedures in use at the Geological Survey could be judged in terms of the efficiency and effectiveness of the use by the Branch of its allotted financial and manpower resources, and of the relevance and timeliness of its scientific output.

The principal vehicle of external peer review has been the Canadian Geoscience Council. From time to time, Advisory or Review Committees nominated by the Council and composed of representatives from the Geological Survey's main 'client' sectors (industry, academia, other federal and provincial government agencies) have evaluated and reported on aspects of the Branch's activities in particular fields of research.

This report is the result of a review by one such Advisory Committee and was prompted by specific recommendations contained in an earlier report on the output of the Geological Survey of Canada published in 1983 by the Canadian Geoscience Council. The subject of Quaternary and engineering geology is one of particular importance to Canada and, thus, to the Geological Survey. Over 95 per cent of the Canadian land mass has been subject to continental or alpine glaciations. These events of recent geological time, which are still continuing in northern latitudes and mountainous regions, have provided Canada with an extensive cover of unconsolidated geological materials upon which most of our urban centres are founded and our agricultural crops and forests depend. Knowledge of these materials, the processes that formed them, their properties, and behaviour under contemporary geological processes are essential to informed decisions on land use management in all parts of the nation. Study of the unconsolidated sediments or "surficial geology" and the application of this information to engineering works has been an integral activity of the Geological Survey almost from the time of its inception. Our outputs from these studies serve not only the traditional clients of the Geological Survey in the mineral and petroleum industries but also a diversity of clients with such interests as land use planning and geotechnical engineering. It is therefore timely and appropriate that this review has been undertaken to complement recent reviews of other aspects of the Geological Survey's program and outputs.

Contained here is the *Report of the Canadian Geoscience Council Advisory Committee to the Geological Survey of Canada on Outputs in Quaternary and Engineering Geology* entitled *Mapping the Landscape* and a *Commentary* on that report prepared by the Geological Survey. The purpose of the Commentary is to place on record the initial response of the Geological Survey to the recommendations contained in the Report rather than to provide an extensive discussion of the Committee's findings and recommendations. It will be evident from both the Report and the Commentary that all of the recommendations are constructive and deserving of consideration; however, they are not all amenable to the same degree of acceptance or feasibility for implementation.

Previous reports of Canadian Geoscience Council advisory committees to the Geological Survey have been published for the Council by the Geological Survey. Through agreement with the Canadian Geoscience Council similar publication through the GSC Paper series is accorded this report. The accepted manuscript for this report was forwarded in April 1987 to Geosciences Information Division of the Geological Survey for publication in English and French editions.

The Geological Survey records here its appreciation to the Canadian Geoscience Council for its continuing assistance in reviews of Geological Survey operations and products and, in particular, to Professor M. Church (Chairman) and members of his Committee for the conscientious and thorough manner in which they conducted their review. The Report and the recommendations arising from it are of great benefit to the Geological Survey. It is our resolve that this benefit will accrue to our clients through improved operations and products discussed in this Report.

SUMMARY: TERMS OF REFERENCE AND RECOMMENDATIONS

1. *To identify the present and future (10-year) requirements of various users (geologists, geographers, engineers, planners, other federal government departments or agencies, and others) for specific Quaternary and engineering geological data and information from the Geological Survey of Canada in terms of:*

(a) geographic region and/or application (e.g. mineral exploration, frontier hydrocarbon development, urban areas, transportation corridors, etc.);

(b) appropriate accuracy standards and format of data presentation.

Recommendations

(1.1) The Geological Survey should continue to regard the regional geological mapping programme – and attendant interpreta-tion of Quaternary history – as its major and most important activity. However, mapping scales should reflect the level of economic activity in the regions of Canada. Final selection of appropriate scales, as large as 1:25 000 in Census Metropolitan Areas, should be made following studies of information standards in maps.

(1.2) Increased attention should be given to coastal and inshore marine mapping with the objective of producing integrated maps of onshore and marine surficial geology and coastal features. Geophysical, remote sensing, and small boat techniques should be developed to improve field technique.

(1.3) Enquiries should be made into the possibility for increased co-ordination between Quaternary geology and soil mapping activities at the regional scale. Initially, this could take the form of consultations between the Geological Survey and the Soil Survey of Canada.

(1.4) Investigations of the geochemistry of surficial materials should be integrated into the regional mapping programme. By reviewing current experience, an analysis should be made of what information and what procedures for data collection, analysis, and reporting are apt to be of most general use in the next 15 years, bearing in mind applications both in mineral exploration and in environmental management.

(1.5) The Geological Survey should encourage a substantial increase in the study of Holocene environments in Canada.

(1.6) The Geological Survey should encourage the study of regional, mappable elements of environmental hazards related to bedrock and surficial geology, and should give emphasis to sensitive soils and permafrost occurrence in regional mapping.

(1.7) The Geological Survey should consider reemphasizing regional appraisal of groundwater conditions in its regional mapping programme, particularly in the Prairie Provinces.

(1.8) The Geological Survey of Canada should establish a working group to study opportunities and impacts of new systems for data acquisition and manipulation in the conduct of the programme in Quaternary and engineering geology, and to make recommendations to the Branch to implement effective measures.

(1.9) The Geological Survey of Canada should convene a national workshop meeting to discuss standards for surficial mapping, and for map legends, formats and presentation of surficial geological data.

2. *To consider the relative priorities of these data and information requirements among specific user groups.*

Recommendations

(2.1) The Geological Survey should give relatively increased attention to mapping in the settled regions of the country, including compilation of updated maps near the major centres of population.

3. *To recommend to the Geological Survey changes or modifications to Branch outputs in Quaternary and engineering geology that would improve their usefulness to users. Such changes or modifications as may be recommended are to be consistent with Branch mandates regarding Quaternary and engineering geology and with resources available to the Branch for Quaternary and engineering geology studies.*

Recommendations

(3.1) The Survey should give deliberate consideration to reemphasizing its definitive publications (A-maps, Memoirs, Bulletins, Papers) as the repository of its main conventional reports and maps, using contemporary production technology to promote timely publication.

(3.2) The Open File series should be used deliberately for releasing nonconventional material, data sets, certain consultant reports, and other products that will not fit the thematic or physical constraints of the definitive publications.

(3.3) Current Research should be abolished in favour of proper use of outside journals and establishment of a user selective project awareness service.

(3.4) General conferences and Open House should be abandoned as means of communicating with the user community.

(3.5) The Geological Survey should instead initiate user targeted seminars in regional centres, in collaboration with provincial and other local specialists, to update users on the results of Survey and other pertinent research and inventory activities.

(3.6) The Geological Survey should assign members of the Regional Projects staff to have a long term commitment to one or another of the settled regions of Canada and should station them at offices in the regions.

(3.7) The Geological Survey should establish a programme to inform the general public about its projects and results, in which substantial emphasis should be placed upon Quaternary geology and its applications.

4. *To 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, and to recommend methods to overcome them within the limitations of present and anticipated resource levels.*

Recommendations

(4.1) Terrain Sciences Division should alter the balance of its personnel to increase the technical complement relative to research officers.

(4.2) Contracts for mapping, by the private or public sector, should always be written to require a standard of performance sufficient for incorporation of results into the basic mapping programme. Provincial mapping should be incorporated into the formal national mapping programme when agreed standards are reached.

(4.3) The Geological Survey should explore the possibility to institute innovative arrangements for formally retaining scientific staff on an honorific or part-time basis.

(4.4) The Geological Survey should seek more extensive collaboration with the universities in several areas which could serve the mandate of the Survey very well.

COMMENTARY ON THE REPORT OF THE CANADIAN GEOSCIENCE COUNCIL ADVISORY COMMITTEE TO THE GEOLOGICAL SURVEY OF CANADA ON OUTPUTS IN QUATERNARY AND ENGINEERING GEOLOGY

INTRODUCTION

The *Report of the Canadian Geoscience Council Advisory Committee to the Geological Survey on Outputs in Quaternary and Engineering Geology* forms part of the formal process for program evaluation within the Department of Energy, Mines and Resources. This Report was commissioned by the Director General, Geological Survey of Canada in direct response to the conclusion, contained in a previous report by the Canadian Geoscience Council (Coope et al., 1983) on outputs of the Geological Survey of Canada Branch as a whole, that "Engineers and planners consider basic terrain science data produced by the Geological Survey of Canada to be vital for land use studies. However, coverage and rate of production of maps is not meeting present demands."

In addition to assisting the Branch in the ongoing and important critique of its programs and outputs, the present Advisory Committee had the task, among other things, as specified in its Terms of Reference, of identifying various users of outputs in Quaternary and engineering geology and their specific information requirements anticipated over the next decade. In view of the increasing application of Quaternary and engineering geological information to land management and environmental issues, as well as to mineral exploration in the glaciated terrains of Canada, a contemporary overview of Branch "clients" and their information requirements is fundamental to the proper discharge of the responsibilities of the Geological Survey.

During the course of preparation of the Report by the Advisory Committee, the Geological Survey underwent a major organizational change, effective 1 April 1986, whereby the former Geological Survey of Canada and Earth Physics branches were amalgamated to form a single administrative unit. Following the reorganization, Terrain Sciences Division, the principal focus for Quaternary and engineering geology within the Branch, was assigned scientific units concerned with permafrost, glaciology, and terrain geophysics that were previously administered within pre-existing units of Earth Physics Branch, Polar Continental Shelf Project, or Geological Survey. These organizational changes, while enhancing the Geological Survey's capability to address Quaternary and engineering geological problems on a national basis, did not substantially alter the value and relevance of the

Advisory Committee's Report to the Geological Survey.

The Advisory Committee has entitled its report *Mapping the Landscape* – a succinct reflection of a recurrent theme by Geological Survey clients as reported by the Advisory Committee (Section 3.2) that "to provide sound regional mapping and an interpretation of the geological history, is the most important product." Accordingly, the Advisory Committee has focused its attention upon the Quaternary geological mapping program of the Geological Survey for terrestrial and coastal areas. This attention includes consideration of appropriate map scales, information content, map data acquisition and access – all within the context of requirements as expressed by users in their responses to the questionnaires distributed by the Advisory Committee to representative clients across Canada. It is understood, however, that "Quaternary mapping" has been used as a shorthand means of referring to the broad range of process, stratigraphic, and paleoecological studies that must be included in proper evaluations of Quaternary geology on a regional basis.

The Advisory Committee has faithfully adhered to its Terms of Reference and provides 21 recommendations that collectively address each of the specific terms of reference. These recommendations, which are directed specifically to the management of the Geological Survey of Canada, form the principal basis for the commentary that follows. Both the report and the commentary, however, should be viewed in the context of the objectives of the Geological Survey for the conduct of Quaternary and engineering geological studies and the continually evolving capacity and capability for conduct of these studies by provincial government agencies, universities, and the private sector.

The objectives of the Geological Survey, as they pertain to Quaternary and engineering geology, are to ensure the availability of comprehensive knowledge, technology, and expertise concerning the Canadian land mass and adjacent coastal areas and conditions therein affecting land use, public safety and security, and formulation of policies. While these objectives are clearly national in scope, as befits an agency of the federal government, their attainment and, hence, the availability of appropriate outputs to users can only be achieved through co-operative and complementary activities among the Geological Survey, provincial government agencies, and other contributors to Canadian Quaternary geoscience. Accordingly, the Report of the Advisory Committee, although addressed specifically to the Geological Survey of Canada, contains an assessment of user requirements for Quaternary and engineering geology data and information that will be of value and interest throughout the Quaternary geoscience community.

The Geological Survey wishes to express its thanks and appreciation to the Chairman and members of the Advisory Committee for the thorough and competent manner in which the Committee undertook its study and produced its Report. Further, the Committee is deserving of the thanks of the broader Quaternary geoscience community in Canada for its incisive analysis and thoughtful commentary upon the complex relationship between outputs in Quaternary and engineering geology and user requirements.

QUATERNARY AND ENGINEERING GEOLOGICAL MAPPING – PROCESSES, PRODUCTS, AND PRIORITIES

In his monograph on the logic of geological maps, Varnes (1974) stated: "A map is a spatial classification that transmits information about features at or near the earth's surface for a defined purpose. Transmission is effective only if map maker, map and map user are so co-ordinated that the maker's concept is transferred to the user's mind without significant alteration."

The purpose of the Quaternary geological mapping program of the Geological Survey of Canada is to provide basic information on the character, distribution, origin, and spatial relationships of surficial geological materials and landforms. Thus, the maps and their legends produced by the Geological Survey reflect their intent to portray the geological framework of the country in a manner that permits interpretation and application of this information by a wide variety of users. It is not, however, the primary role of the Geological Survey to provide interpretations of regional geology to meet specific information requirements of a particular user group such as land use planners. This interpretive service can best be provided by the private sector. Both user groups and the Advisory Committee recognize the importance of the regional mapping program and recommend (1.1) its continuation but at scales deemed appropriate to the level of economic activity in the various regions of Canada.

The Geological Survey accepts the principle of recommendation 1.1 as a basis for improvement in the knowledge base of regional Quaternary geology in Canada and for improvement in the delivery to users of information more specifically designed to their needs. Implementation of the recommendation, however, is an activity that will involve other agencies in addition to the Geological Survey. Since the settled regions of Canada, for which the Advisory Committee recommends mapping scales larger than 1:250 000 (Section 5.2) are, for the most part, within the provinces, discussions between provincial agencies and the Geological Survey regarding complementary or co-operative mapping programs will be essential.

The requirement for detailed Quaternary geological information (scale 1:25 000 or larger) and for various derivatives of this information to meet the specific needs of planners and engineers in urban environments (recommendation 2.1) is a clear message transmitted by the Advisory Committee from user groups. Perhaps this information requirement is more acute now than it was in 1971-1972 when the Geological Survey undertook, by contract, an inventory of urban geology data for twenty-one major Canadian municipalities. This project resulted in the establishment of geological/geotechnical data banks and software to enable updating of the data base, and the production of a variety of parametric maps designed to meet the needs of planners and engineers. The intent of this program was to enable municipalities to acquire and operate their own information systems. Few, if any of the municipalities for which inventories were supplied have maintained the data banks. Although the Geological Survey remains convinced of the need for and value of urban geological information, the initiative for urban geology studies must come from municipal and provincial government agencies.

As part of its task, the Advisory Committee examined the work of the Geological Survey, as carried out by Atlantic Geoscience Centre (AGC), in the coastal zone only, rather than in the broader context of marine geology for which AGC has responsibility. The Committee recommends (1.2) that increased attention be given to coastal and inshore mapping resulting in maps that integrate onshore and marine surficial geology and coastal features. The Geological Survey supports this recommendation based on the need for information pertinent to mineral and aggregate resources, identification of coastal hazards, and general development of coastal regions. Both the Advisory Committee and the Geological Survey recognize that implementation of this recommendation will require a substantial influx of new resources to provide both the personnel and equipment required for the specialized requirements of operations in a highly dynamic, shallow water environment. While it is unlikely that the resources required for a major coastal mapping program could be obtained through reallocation among the several federal government departments with interests in the coastal environment, the identification by the Committee of a program priority is of value to the Geological Survey. In spite of limited capacity to address problems of the coastal zone, the Geological Survey can and will ensure that its existing capabilities, including co-operative work with universities and contractors, are used to maximum advantage.

The Geological Survey recognizes the close relationship between Quaternary geology and soil mapping and the value of co-ordination of both of these activities as expressed in recommendation 1.3. Previous and present co-ordination of activities have been effected between scientists of Terrain Sciences Division and those of Land Resource Research Centre, Agriculture Canada (LRRC) as mutual needs and opportunities have arisen. The Geological Survey will continue consultations with staff of the LRRC and would welcome similar consultations initiated by pedologists and soil scientists elsewhere.

The Advisory Committee has identified geochemistry of surficial materials (recommendation 1.4) as possibly representing the most significant emerging problem for Quaternary and engineering geology in the Survey over the next 15 years. Regardless of the relative priority that future events may dictate for this issue, we concur that it will remain one of importance. As recognized by the Advisory Committee, the Geological Survey has underway several programs in geochemistry of surficial materials and lake bottom sediments directed towards mineral exploration imperatives. These programs have provided background data that have been applied to assessment of terrain reaction to acid rain and the possible relationship between soil geochemistry and maple die-back particularly in the Eastern Townships of Quebec. The Geological Survey recognizes the importance of environmental geochemistry and has the nucleus of expertise in place to serve as a basis for implementation of the Committee's specific recommendations on environmental geochemistry.

In Sections 5.5 and 5.6 of its Report, the Advisory Committee provides timely commentary upon the relevance of the Holocene geological record for paleoclimatic interpretations and upon contemporary geological processes that pose hazards, particularly to the settled parts of Canada. From this commentary arises recommendation 1.5 for a substantial increase in the study of Holocene environments in Canada. The present organization of Terrain Sciences Division, which contains Quaternary Environments and Terrain Dynamics subdivisions, could be viewed as having anticipated this recommendation. Scientific staff in glaciology, formerly with Polar Continental Shelf Project, complement the paleoecology group within Terrain Sciences Division. These scientists, in concert with their colleagues elsewhere in the Geological Survey, are responding to the challenges and opportunities expected to be forthcoming from national and international involvement in the Global Change Program presently being formulated under the aegis of the Royal Society of Canada. These responses are less new initiatives than they are extensions of paleoecological, palynological, and paleoclimatic research that has been an integral part of the Division's scientific program for more than 20 years. Thus, the Geological Survey is well placed to effectively use any new resources that may be forthcoming for paleoclimatic and paleoenvironmental studies.

The Geological Survey recognizes the hazard to life and property posed by unstable slopes particularly in the Cordillera. Accordingly, study of slope failure phenomena of various kinds is underway and will be continued to the extent that resources permit. With respect to permafrost terrain and its attendant geomorphic problems occasioned by the behaviour of ground ice, the inclusion within Terrain Sciences Division of expertise in arctic geomorphology, terrain geophysics, and geothermal studies has enabled the Division to devote a significant part of its scientific program to northern terrain problems. This work has been accelerated, both within Terrain Sciences Division and under contract, through resources allocated to Energy, Mines and Resources for development of northern hydrocarbon resources and through co-operative programs with the Department of Indian and Northern Affairs. The recent development of ground probing radar equipment under contract and in-house development of geophysical techniques for evaluation of seabed permafrost in the shallow marine environment are significant contributions to enhancement of capability for characterization of permafrost. Accordingly, the Geological Survey is not only in agreement with the Advisory Committee's assessment of the importance of mapping of ground ice, sensitive soils, and terrain hazards (recommendation 1.6), but is actively involved in addressing these problems.

The Geological Survey is fully aware of the inextricable linkage between geology and hydrogeology, regardless of the character of the geological medium in which groundwater may occur. We are also aware of the importance of groundwater as a renewable resource not only in the Prairie Provinces, but elsewhere across Canada where alternative sources of water are not available. Studies of groundwater resources, however, are not within the present mandate of the Geological Survey. We do add to the general knowledge of groundwater through studies that provide an understanding of the dynamics and chemistry of subsurface fluids and the rôle of these fluids as they affect such phenomena as hydrocarbon accumulation, mineral deposits, or geomorphic processes. These concerns are clearly related to hydrogeology but are somewhat remote from "re-emphasizing regional appraisal of groundwater conditions in its regional mapping program, particularly in the prairie provinces" which forms the substance of the Advisory Committee's recommendation 1.7. The Committee notes the requirement for interdepartmental transfer of resources that would be entailed by action on this recommendation. The Geological Survey is not optimistic that action on recommendation 1.7 within the foreseeable future could extend beyond consideration of the implications within the Branch and further communication with colleagues in Environment Canada over concerns raised by respondents to the Committee's questionnaire.

MAPPING STANDARDS AND ACCESS TO DATA

The Advisory Committee discusses at length in Section 6 of its Report the widespread demand within the user community for direct access, preferably by microcomputer, to the basic field data and observational commentary that form the raw material for preparation of a Quaternary geological map. Consideration of this expressed user demand led to the corollary of the requirement for standardization of data formats and guidelines for "survey intensity" linked to map scale (Table 9). As a means for addressing these user requirements, the Advisory Committee recommends (1.8) establishment of a working group to study opportunities and impacts of new systems for data acquisition and manipulation. The Committee further recommends (1.9) that establishment of the working group be preceded by the convening of a national workshop to discuss standards for surficial mapping, map legends, and formats for presentation of surficial geological data. These recommendations are extended by recommendation (4.2) regarding establishment of performance standards for mapping done under contract and the incorporation of both contract and Provincial government map products as part of the national mapping program.

The Geological Survey acknowledges the need for evaluation and adoption of new systems for data acquisition and manipulation. This need arises not only from user requirements identified by the Advisory Committee but also from requirements of the Access to Information Act which establishes particular obligations for the management of unpublished scientific data. Therefore, we place priority upon the establishment of a working group within the Branch to deal with the important issues of data acquisition, manipulation, management, and accessibility. We also attach importance to the establishment of mapping standards as they apply to products produced within or for the Geological Survey. Our approach to addressing the issue of mapping standards will be to first examine it within the Branch. This examination will be facilitated by the thoughtful analysis of user requirements, examples of data formats, and summary of experience with pedological mapping systems that has been provided by the Advisory Committee. We agree that a national workshop on mapping standards (recommendation 1.9) has merit; however, we do not agree that such a workshop should be a precursor to an examination within the Branch of mapping standards and related matters as noted above. We will, therefore, defer consideration of a national workshop on mapping standards until completion of the in-house examination.

PUBLICATIONS AND COMMUNICATIONS

Examination of outputs in Quaternary and engineering geology constituted a major task which the Advisory Committee discharged with characteristic thoroughness as evidenced by the output summaries contained in Tables 3 to 8 and the commentary contained in Section 4 of the Committee's report. This commentary and the recommendations arising therefrom are directed specifically to outputs in Quaternary and engineering geology. Those outputs, however, as listed in Tables 3 and 4, with the exception of outside publications, are contained in publication series or formats established by the Geological Survey as vehicles for publication of results arising from the entire scientific program of the Branch. Thus, the critique directed by the user community in Quaternary and engineering geology towards a specific report series or publication medium is not necessarily consistent with views expressed about the same publication series or medium by other groups within the broader geoscience community. The Advisory Committee, in its introduction to recommendations on publications (Section 4.5) fully recognizes the broader implications these have for Geological Survey publications.

Emphasis upon the importance of definitive publications of the Geological Survey (recommendation 3.1) is a message that the Geological Survey has received from previous advisory committees and it reflects a position that the Geological Survey has continuously endeavoured to adopt. A measure of this importance can be found in the more than 5000 pages of formal reports published by the Geological Survey in 1985-86. This volume of publication has been accomplished through use of current technology and, as advances therein are made, we would anticipate their adoption to further ensure timely publication.

We concur with the Committee's recommendation 3.2 on the use of Open Files for release of nonconventional material. Open Files, however, also afford the means for rapid release of "conventional" information to an audience that may well be of limited numbers; with such an information release, only the needed copies are produced rather than the minimum of 600-700 copies required for formal publications to meet publication contracts and exchange agreements. Further, Open File titles are included in the GEOSCAN bibliographic database and thus can be retrieved as part of the record of Branch outputs.

The Committee's recommendation 3.3 to abolish Current Research is rather more extreme than views on this publication series expressed elsewhere in the geoscience community. The Geological Survey is in the process of restricting Current Research to a single issue per year composed of parts reflecting regional interests. It is expected that the limitation of publication of Current Research will be accompanied by an increase in submissions by scientific staff to outside publications.

General conferences and Open Houses sponsored by the Geological Survey in Ottawa and at the locations of regional divisions in Dartmouth, Nova Scotia, Calgary, Alberta, and Vancouver, British Columbia have been designed primarily for the interest of specialist rather than nonspecialist elements of the geoscience community. These functions have been successful in meeting their intended purpose of informing the broader geoscience community of the Geological Survey's scientific programs. Thus, we are of the opinion that such functions should be continued. The thrust of the Advisory Committee's recommendations 3.4 and 3.5, however, is directed towards those elements of the user community with specific interests in outputs in Quaternary and engineering geology, particularly in the more populous regions of Canada. Implementation of these recommendations is deserving of attention and will be addressed by the Geological Survey as part of its review of program activities in the urbanized regions of Canada.

Recommendation 3.7 for a program to inform the general public on scientific projects and results, with emphasis on Quaternary geology and its applications, is a useful complement to previous recommendations designed to enhance interaction between the Geological Survey and users of its products. Within the Department of Energy, Mines and Resources the responsibility for provision of information to the general public resides with the Communications Branch of the Department. Therefore, we will consult with the Communications Branch on the possibilities for an enhanced public awareness program in Quaternary and engineering geology that would be consistent with similar requirements for other aspects of the scientific program of the Geological Survey.

HUMAN RESOURCES

The Advisory Committee provides four recommendations (3.6, 4.1, 4.3, and 4.4) that derive both from its Terms of Reference and as corollary to its analysis of product design, priorities, and user requirements.

The first part of recommendation 3.6 – assignment of scientific staff to a long-term commitment to one or another of the settled regions of Canada – parallels the existing designation within Terrain Sciences Division of staff with responsibilities for expertise in each of the six major Quaternary geological regions of Canada. These regions include the settled areas of Canada. In those parts of Canada, including settled areas, for which Terrain Sciences staff do not have specific expertise, it is the responsibility of these staff to be current on the work of their colleagues in other agencies. Thus, long-term regional commitment of staff is in existence within the Geological Survey.

The second part of the recommendation – relocation of scientific staff to offices in the various urban regions – requires careful examination of its impact upon Terrain Sciences Division as well as consultation with provincial colleagues prior to assessment of its feasibility of implementation. This examination will be undertaken, but in the absence of additional resources it is unlikely that such staff relocation can be effected.

The Advisory Committee has devoted a substantial part of its Report (Section 7) to concepts of Quaternary geological mapping to meet specific user requirements. This analysis of mapping style, geological information structure, and balance between descriptive and interpretive levels of information is demanding of thorough analysis within Terrain Sciences Division. This analysis will form a part of the task of the working group that will be established to examine mapping standards and data formats.

In Section 7.4 the Committee states its view that "In the early stages of developing geological knowledge about a region, the work is mostly of a research nature. However, the production of descriptive maps is largely a technical task." This view appears to underlie recommendation 4.1 for an increase in the ratio of technical personnel to research personnel.

The Geological Survey is not persuaded that the compilation of a geological map as part of a systematic regional map series, regardless of scale, is "largely a technical task." In our view compilation of a geological map is a scientific exercise involving synthesis of spatially distributed attributes of the terrain in the context of concepts of their origin. Thus, geological map compilation closely parallels the preparation of a scientific report. Technical assistance can accelerate certain aspects of both map compilation and report preparation activities but cannot substitute for the involvement of professional scientific staff in either activity. Therefore we do not accept recommendation 4.1 in the context offered but prefer to examine the balance between technical and professional staff in the light of our analysis of mapping standards and related matters as noted above.

The final two recommendations (4.3, 4.4) reflect the desire expressed by client groups for increased collaboration with the Geological Survey. This desire is one that is shared by the Survey as evidenced by a variety of arrangements that have been made to foster interaction between staff of the Geological Survey and the broader geoscience community. These include assignment of Geological Survey staff to other institutions on a change of work stations basis, acceptance of university research staff on sabbatical leave, direct contracts to both industry and universities for research, research agreements, as well as numerous less formal arrangements between Survey staff and their colleagues in academic and industry for collaboration in research. All of these arrangements have been made within the guidelines established for operations of the federal Public Service and within the inevitable constraints imposed by availability of resources.

The Committee has identified a number of areas of scientific interest in Quaternary geology and geomorphology within which the Geological Survey could benefit from external expertise. In view of the increasing trend, not only within the Geological Survey but also many other scientific institutions, towards participation in projects that are either national or global in scope, the need for scientific collaboration becomes increasingly important. Thus, the suggestions of the Advisory Committee on collaboration are both timely and pertinent.

PART 2
MAPPING THE LANDSCAPE

REPORT OF THE CANADIAN GEOSCIENCE COUNCIL ADVISORY COMMITTEE TO THE GEOLOGICAL SURVEY OF CANADA ON OUTPUTS IN QUATERNARY AND ENGINEERING GEOLOGY

1. INTRODUCTION

1.1 Terms of reference

The following terms of reference were established for this study by the Director General of the Geological Survey of Canada:

1. To identify the present and future (10-year) requirements of various users (geologists, geographers, engineers, planners, other federal government departments or agencies, and others) for specific Quaternary and engineering geological data and information from the Geological Survey of Canada (GSC) in terms of:
   (a) geographic region and/or application (e.g. mineral exploration, frontier hydrocarbon development, urban areas, transportation corridors, etc.);
   (b) appropriate accuracy standards and format of data presentation.

   This identification to be carried out on the basis of a questionnaire and/or interviews with users.
2. To consider the relative priorities of these data and information requirements among specific user groups.
3. To recommend to the Geological Survey changes or modifications to Branch outputs in Quaternary and engineering geology that would improve their usefulness to users. Such changes or modifications as may be recommended are to be consistent with Branch mandates regarding Quaternary and engineering geology and with resources available to the Branch for Quaternary and engineering geology studies.
4. To 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, and to recommend methods to overcome them within the limitations of present and anticipated resource levels.
5. To report the findings of the study in writing to the Director General, Geological Survey of Canada, on or before 31 March 1985.

Background to this study

In a prior study of the outputs of the entire Geological Survey of Canada, a Canadian Geoscience Council Committee under the chairmanship of J. Alan Coope concluded (February 1982) that:

(C.30) Engineers and planners consider basic terrain science data produced by the Geological Survey of Canada to be vital for land use studies. However, coverage and rate of production of maps is not meeting present demands.

On the basis of this and other conclusions contained in their report the Visiting Committee recommended (Coope et al., 1983) that:

(R.1) The Geological Survey of Canada should continue to strongly emphasize its core program of mapping and related research designed to improve and expand the knowledge of the geological data base as it relates to the Canadian land mass. This is a reaffirmation of one of the principal recommendations of the previous Advisory Committee (Weir et al., 1979);

(R.3) The Geological Survey of Canada and the management of the Department of Energy, Mines and Resources should place greater importance on increasing the public's awareness of GSC activities and on the dissemination of significant results from geoscientific studies regarding resources, natural environments, geological hazards, and other topics of national importance;

(R.10) The Geological Survey of Canada should continue to encourage co-operative activity and the development of programmes with provincial surveys, universities, and with industry in order to make the most effective use both of available funds and of the pool of geoscience talent in Canada;

(R.13) Through the established National Geological Surveys Committee, the Geological Survey should explore the potential benefits of liaison with other established associations representing the mineral resource industries and geotechnical groups.

These conclusions and recommendations were noted in an evaluation by the Department of Energy, Mines and Resources of the scientific programme and operations of the Geological Survey (December 1982) with the recommendation that "...GSC management should review this conclusion (C.30) and assess the potential of expanding the program of terrain studies." The evaluation team recommended further that:

> GSC should review anticipated needs by engineers and planners for terrain science information over the next ten years and assess whether the Division's resources are adequate for these needs;
>
> GSC management should assess the priorities for completion of the country by 1:250 000 geoscientific mapping.

The requirements for information noted above are reflected in the terms of reference of the present Advisory Committee.

1.2 Activities of the Committee

The Committee met initially on April 1, 1984 with the relevant senior managers at the Geological Survey of Canada in order to be certain that the terms of reference were clearly understood. The Committee then determined that it would conduct a two-part questionnaire survey to fulfill its instructions.

In part 1 of the questionnaire we asked geological organizations active in Quaternary and engineering work (principally government agencies) to identify a number of individual clients in their regions whom we could address concerning GSC activities and products (Appendix 1). In part 2, the Committee selected about 125 users of geological information to contact. We concerned ourselves with regional and institutional balance and with obtaining views from a range of professions, not all traditional users of earth science information. We obtained 90 full replies from 123 enquiries that reached the intended respondents. Four of the contacts gave cordial reasons why they could not complete the questionnaire. The greatest interest was evinced in western Canada; 29 of the lost contacts were east of Manitoba and the rate of reply declined to 50% in the Maritime provinces.

The user questionnaire is in Appendix 2. We deliberately eschewed a 'statistical' sample. It is our observation that previous exercises of that sort in the earth science community have not enjoyed a high rate of return and we are sceptical that representative results can be gained thereby. We made personal contact to encourage returns and to follow up on replies. These arrangements allowed us to ask more complex questions and to obtain more nuanced opinions from users. The interpretation of the returns is, accordingly, more subjective as well. The Committee's own collective view has provided the organizing framework for presenting the results.

We regard our return rate (73%) as high and forming an adequate basis for framing conclusions. The group of respondents includes foresters, soil scientists, archaeologists, and fishery biologists, as well as civil and geotechnical engineers and earth scientists. We were least successful in raising the interest of regional planners, which presumably reflects their level of appreciation of earth science information.

The part 1 questionnaire was administered during May to July 1984, and the part 2 questionnaire during September to November. In December 1984 the Committee reconvened in Ottawa to collate questionnaire findings and to interview GSC scientists – in many respects best placed to answer some of our questions about emerging earth science information requirements. Committee members have also visited the other principal offices of the Survey to interview scientists and have interviewed officers of some other divisions in Ottawa. The information gathering activity was completed by March 1985.

The subsequent gestation period for this report has been long and may have affected the currency of some pieces of information in it. It has, however, allowed us to develop a clear conceptual structure for geological information, which is an important basis upon which to place our practical recommendations.

1.3 Organization of the Report

This Report is divided into nine sections. Following this introduction there is a brief discussion of the history and contemporary position of Quaternary studies in the Geological Survey, designed to provide a context for the present review. The subject is insufficiently appreciated in the country.

Section 3 describes the range of contemporary users of information about Quaternary geology. It is much broader than the traditional group of engineers, economic geologists, and advanced (mainly university) teachers and students. Land management disciplines increasingly use such information, although in many respects their real needs remain ill-defined. As well, the information requirements of the traditional, geologically trained users are rapidly becoming more sophisticated as automated data manipulation becomes convenient.

In order to provide a basis for addressing terms (1) and (3) – to identify present and future requirements of users and to recommend modifications to Branch products to meet these requirements – it is necessary to review recent results and their use. Section 4 reviews the products of the last 12 years in Quaternary and engineering geology and appraises the value of these products to users. Questionnaire results provide the information for this appraisal. The traditional final reports of the Survey retain greatest authority, but there is widespread recognition that a change in format for presentation is occurring.

The forecasting of information requirements and priorities (terms (1) and (2)) supposes that we can foresee, to some degree, major environmental problems that will require geological information, and regions of the country where significant development activities will occur during the next several years. We addressed these matters through our user questionnaire and by interviews with GSC and other geologists; Section 5 reports our findings. We were surprised to find that, in substantial measure, individuals' views are limited by what they are now doing; not surprisingly, they are also delimited regionally. The committee has, in the end, relied considerably upon its own judgment to order and elaborate the substantial range of suggestions received.

Section 6 addresses the appropriate formats for data presentation. Accordingly, it synthesizes conclusions drawn from considering the range of users (Section 3) and the character of the problems that must be faced (Section 5). It appears that traditional users of geological information desire details of field observations not, heretofore, formally released by survey agencies; nontraditional – and geologically nonexpert – users will require a degree of synthesis and interpretation of geological results not normally offered.

The outcome of these somewhat competing claims for geologists' attention is to realize that the approach to handling geological information should be changed. Technology for acquiring and manipulating information is encouraging change in any case. In order to ensure that these changes properly serve the requirements for geological information and interpretation identified in Sections 3 to 6, it is imperative to have a coherent concept of geological knowledge. The outline of a "geological knowledge structure" is given in Section 7. It becomes the basis for our main recommendations about Branch products in Quaternary and engineering geology. The section is designed to initiate discussion: we caution that this matter will require much more consideration. It ultimately will impinge upon the organization and operation of the entire Survey.

Section 8 addresses the fourth term of reference: how to co-ordinate more systematically the considerable expertise in the country outside the Geological Survey, so that national interests are best served by the entire community of Quaternary and engineering geologists.

Section 9 is a summary of the conclusions and recommendations of the study.

2. A PERSPECTIVE ON QUATERNARY STUDIES

2.1 The practical significance of Quaternary studies

Insofar as they purport to illustrate the geology of the earth's surface, most geological maps are a fraud. The map usually depicts the distribution of bedrock formations, yet over about 70% of the terrestrial surface of the earth, bedrock is covered by unconsolidated deposits – soil, in the broad sense (Goldberg et al., 1965). In Canada, the soil is universally of Quaternary age, and mostly of glacial origin. About 75% consists of till (Legget, 1982) – that is, direct glacial deposits. In most of Canada, Quaternary deposits are of the order of only one to a few metres in depth, although hundreds of metres may be encountered at valley sites. In the broad sweep of geological time this is an insignificant accumulation; but in terms of human activity, these materials are as significant as the rest of the rock column altogether.

Quaternary deposits constitute the basis for pedological "soil" – the real resource that underlies agriculture and forestry. All engineering structures must contend with these deposits and most actually are founded in them. They provide the source materials for the largest volume (and probably most secure) sector of the mineral industry – that is, industrial minerals. Nearly the entire manageable water supply passes through these materials and, in parts of the country, is recovered as groundwater from them. Perhaps most important of all, these earth surface materials form part of the daily environment of people and of all terrestrial organisms, the modifiable chemistry of which represents – increasingly obviously – the most critical of all environmental management problems.

Quaternary materials preserve a uniquely detailed record of recent earth history and of subcontemporary geophysical processes at the surface of the earth. With increasing technique, the record is being used to interpret climate and environmental change, and hazards to human activities. Records of significant slope failures, floods, earthquakes, and environmental changes are available from Quaternary deposits that far outstrip our instrument and documentary records.

The nature of the connection between Quaternary geology and engineering works is worth special note in this report. Dr. Robert F. Legget – founding Director of the National Research Council of Canada Division of Building Research and perhaps the world's leading student of the influence of geology upon engineering works – emphasized the following points (Legget, 1979):

- that before site investigations begin, the regional geology (Quaternary and bedrock) must be properly understood, so that the range of possible conditions on site may be anticipated;
- that borehole programmes to develop site information will be cost-effective only if planned and executed in the light of local and regional geology; and
- that conclusions about site conditions must be tested for conformity with local and regional geology before they can be accepted as a sound basis for engineering planning.

Dr. Legget also emphasized the remarkable variability of glacial deposits and the special problems to which they give rise. Of till, he remarked (1979, p. 358): "the varying characteristics of till .... have probably created more trouble than any other cause, possibly than all other soil problems combined, at least in the northern hemisphere." He noted (1979, 1982) that failure to reckon with the properties of tills (they were geologically well known) in the Welland and St. Lawrence Seaway canal works led to the ruin of several major contractors.

It is probable that, when we have more experience of their behaviour, we shall accord organic terrain and ice-rich soils similar reputations. The surface of Canada is largely a palimpsest of these three classes of materials.

The history of civil engineering is littered with misadventures like those associated with the seaway canal works. The first requirement to change this history definitively is a continuously improving and effectively applied knowledge of the regional geology.

In some parts of Canada a yet more critical issue is emerging that links geology with engineering. Increasing land values and increasingly close settlement are pushing buildings – including houses – and engineering structures onto sites subject to contemporary geological processes, including landslides, debris flows, unusual floods and, in a few cases, glacial activity (cf. Eisbacher and Clague 1984). These phenomena must be understood and anticipated in order to permit rational land use planning and sound engineering.

Appreciation of the essential connection between "parent material" and the fertility, drainage, and propensity for erosion of pedological soils has developed steadily during this century (cf. Chesworth, 1982). In Canada, with tens of millions of hectares of agricultural and forest soils to be managed, this connection increasingly is relied upon to shift soil mapping and appraisal onto a regionally viable basis by mapping, first, evident geological materials and landforms. The management of Canadian soils also begins, then, from knowledge of Quaternary materials and history.

In this review, we are considering a factor vital for the well-being of the Canadian economy.

2.2 Quaternary studies and the Geological Survey

In 1840 the notion of a former Ice Age on the surface of the earth was not well known and not at all accepted. In 1841 the Swiss scientist Louis Agassiz published the benchmark paper that began a definitive turn of scientific opinion. In 1842 the Geological Survey of Canada was founded. The Survey grew up with the development of modern glacial geology.

Whilst the theory was not there, the soils certainly were. During its first century, the Survey was continually pushing into unknown terrain; it was perforce a topographical and resource survey as well as a geological survey. The charge upon Sir William Logan in 1842 was to make an accurate and complete geological survey of the Province of Canada, and a full and scientific description of its rocks, soils, and minerals. In the Annual Reports and Reports of Progress there is frequent mention of soils, and a steady growth in appreciation of their glacial history. According to Legget (1982), about 10 per cent of the early maps were concerned with surficial materials. As early as 1845, Logan was recording evidently glacial materials in central Canada. In 1865 the Survey published a summary map of "superficial deposits" in the Canadas, compiled by Robert Bell. Between the 1870s and 1890s, G.M. Dawson developed the concept of the Cordilleran glaciation in the western mountains, and in the 1890s J.B. Tyrrell made a major contribution to the appreciation of continental glaciation after his epic journeys across the Keewatin barrens. W.A. Johnston, in his studies of the development of the modern Fraser River delta (1905-1920, prompted by the suspicion that petroleum might be found) made a remarkable early contribution to studies of the Holocene Epoch and of geological processes. On the whole, however, the Survey's major goals through this century were the mapping and explanation of Canada's bedrock geology in support of the growing mineral industries; soil resources were underappreciated and surficial geology was not emphasized.

There has been a section or division of the Geological Survey with various responsibilities for Pleistocene geology, engineering geology, or groundwater ever since the demise of the old Department of the Interior in the early 1930s. Groundwater development in the prairies was the principal focus of interest. A more general emphasis on Quaternary studies began to emerge only after World War II, when a Pleistocene and Engineering Geology Division was established by Director W.A. Bell. This group was able, for the first time, to establish a continuing programme to map "Pleistocene geology" in southern Canada and made notable investigations in the Arctic in co-operation with bedrock mapping parties. However, the group experienced several administrative reassignments in the following years, and only since the major reorganization of federal environmental science in the period 1966-68 has there been a stable administrative structure for Quaternary studies. At that time, responsibility for groundwater studies was lost to the new Department of Environment and a number of geomorphologists and projects were gained from the disbanded Geographical Branch. It is perhaps significant that these scientists were strongly oriented towards the Arctic, for the new Terrain Sciences Division that was formed was now strongly placed to play a prominent role in the rush of northern resource development and environmental assessment studies that came in the following decade.

Throughout its existence, Terrain Sciences Division has had to manage both its systematic programme of mapping and study of Quaternary deposits – its contribution to the basic task of the Geological Survey – and a range of special purpose, mainly northern environmental assessment and resource mapping exercises. These include mapping for a sequence of arctic pipeline and northern transportation corridors, frontier resource development studies, and federal-provincial mineral development agreements. Each of these tasks has, to some degree, required that mapping and reporting methods be adjusted to suit the purpose. In 1986, 80 per cent of the operating budget for the Terrain Sciences Division derived from special purpose programmes funded from outside the budget of the Geological Survey. Experience and results from the basic programme and from special studies reinforce each other to good effect in the Division's overall achievement. A number of issues facing the Survey, however, with respect to the conduct of Quaternary studies and presentation of results derive from the superposition of special purpose programmes onto the basic activity of the Terrain Sciences Division.

Three aspects of this history are of interest to us. The programme and traditions of Quaternary mapping are not yet long established in the Survey by comparison with many aspects of bedrock studies. To the degree that the mapping and presentation methods have followed those of classical geological activities, it has not necessarily been because long experience has shown that these are assuredly the most appropriate methods for the task. Second, the relatively brief history of deliberate effort in Quaternary studies means that a major programme is still underway to complete initial reconnaissance mapping of the country. Third, the superimposition of a significant corpus of northern environmental studies upon the more traditional geological activities of the old Pleistocene and Engineering Geology Division has left within the Division some fairly obvious contrasts in approach between various projects. These reflect problems faced by the entire discipline. We will pick up this thread in Section 7.

2.3 A Note of Definition

Engineering geology is defined by the American Geological Institute (1962) as the application of the geological sciences to engineering practice for the purpose of assuring that the geological factors affecting the location, design, construction, operation, and maintenance of engineering works are recognized and adequately provided for. Most text books in the topic quote a synopsis of this definition: for example, "the application of geology to engineering practice" (Bell, 1983, preface). These definitions are accepted for this report.

The publications of the Geological Survey, with their regional and systematic orientations, do not constitute 'engineering geology' in the narrow sense of direct application of geology towards the definition of engineering problems on specific sites. The Survey, however, makes direct contributions to geotechnique through general studies of the physical performance of earth materials (e.g., Kurfurst, 1977; Kurfurst and Veillette, 1977) and supports engineering studies of major projects of national interest by producing regional terrain and geological maps, derivative maps of terrain performance, and interpretations of regional history (e.g., Rutter et al., 1973; Hughes et al., 1973; Monroe, 1974). Further support is given to engineering by the contribution of regional geological hazard assessments (e.g., Eisbacher and Clague, 1984). In the broad sense of providing the regional geological context for engineering investigations these remain vital contributions to engineering practice. However, the entire body of Quaternary studies has this value, since it provides the regional and local history within which the data of engineering site investigations must be interpreted (cf. Legget, 1979, quoted in Section 2.1). Consequently, in this report we do not distinguish contributions to "engineering geology" from the broader category of Quaternary studies. In the regional context that is appropriate for the work of the Geological Survey, the two are equivalent.

3. THE USER COMMUNITY

3.1 Professions

Geology is a highly professionalized activity. Geologists engaged in regional survey are used to the notion that their maps and reports will be read mainly by other geologists engaged in applied activities, such as mineral development, or by geological and geotechnical engineers. A wide range

Table 3.1. Distribution of questionnaire respondents by major region, profession, and sector

	Major Region																	
Profession	BC/Yukon			Prairie/NWT			Ontario			Quebec			Maritimes			National		
	Prv	Pub	Acd[1]	Prv	Pub	Acd	Prv	Pub	Acd	Prv	Pub	Acd	Prv	Pub	Acd	Prv	Pub	Acd
geologist/ geomorphologist/ geophysicist	5	1	2	1	1	0	6	3	4	2	2	4	3	3	1	17	10	11
geological or geotechnical engineer	2	1	0	4	1	0	2	0	0	5	3	1	0	0	1	13	5	2
forestry/ pedology/ fisheries/ resource planner	2	7	0	1	5	1	0	3	0	0	0	0	0	1	0	3	16	1
archeologist	0	0	1	0	4	2	0	0	0	0	0	0	1	0	0	1	4	3
other[2]	0	0	0	3	0	0	1	0	0	0	0	0	0	0	0	4	0	0
Totals	9	9	3	9	11	3	9	6	4	7	5	5	4	4	2	38	35	17

1 Private, public, academic
2 2 civil engineers, 2 drilling contractors

of other "environmental management" professions, however, is increasingly interested in applying geological knowledge as their responsibilities develop.

Table 3.1 gives the distribution of respondents to our user questionnaire by major region of the country, by profession, and by activity sector (i.e., private enterprise, public sector, or academic). Amongst the respondents, 65% hold one or more degrees in geological subjects or geological engineering, and only 10% have no post-secondary training or courses of any kind in geology. All of the latter group are located in western Canada. Only 5% rated their ability to understand geological reports as less than "adequate."

The dichotomy between geological professions and environmental management professions is reflected in the work situation of information users: 31% of our respondents reported that there is no geologist in their organization and 43% reported 5 or more. Frequency of contact between the respondent and another geologist varied from greater than once a week (64%) to less than once a month (13%).

In our survey we encountered the following range of users of Quaternary and engineering geology information:

- geologists in provincial agencies, mineral exploration companies, and consulting (mainly environmental assessment and planning), including marine geology and teaching;
- geotechnical and geological engineers in public agencies and in consulting;
- foresters in provincial agencies, concerned with forest site classification;
- pedologists (agriculture) in federal and provincial agencies and consulting, concerned with soil survey and land capability assessment;
- fisheries scientists in federal agencies, concerned with riverine substrate and erosion (leading to sediment in streams), and with seabed sediments;
- archaeologists in teaching and consulting (mainly salvage surveys) concerned with stratigraphic and environmental context of sites;
- planners in provincial and regional agencies and in consulting, concerned with resource and land management;
- university professors.

Regional planners (as opposed to resource planners) were, in general, unenthusiastic participants in our survey. We expect that this group may not appreciate, or has found no convenient way to use, geological information. One should, however, be careful of this assessment because of the restricted nature of our survey: it is at variance with the implication of Conclusion 30 of the Coope et al. (1983) report. All other groups indicated a keen appreciation of the realized or potential value of Quaternary and engineering geology information, and there was nearly unanimous recognition of the preeminent role played by the Geological Survey in developing it.

The interest in geological information of the nongeological resource and environmental management professions has largely developed within the past two or three decades as regional land use and natural resource development planning has come to be recognized as a major public

Table 3.2. User opinion of Quaternary mapping coverage, by major region

Region	Regional Mapping ($\geq$ 100 000 scale)			Detailed Mapping ($\leq$ 50 000 scale)		
	Good	Adequate	Inadequate	Good	Adequate	Inadequate
	(number of responses)					
British Columbia/ Yukon	4	11	13	1	2	22
Prairies	9	6	10	3	4	15
Ontario/Quebec	8	13	12	7	14	16
Maritimes/ Newfoundland	5	5	5	2	3	9
Northwest Territories	0	7	3	0	1	8
Totals	26	42	43	13	24	70

Note: The number of responses tabulated does not compare with the number of respondents; some gave no opinions, some gave opinions about more than one region.

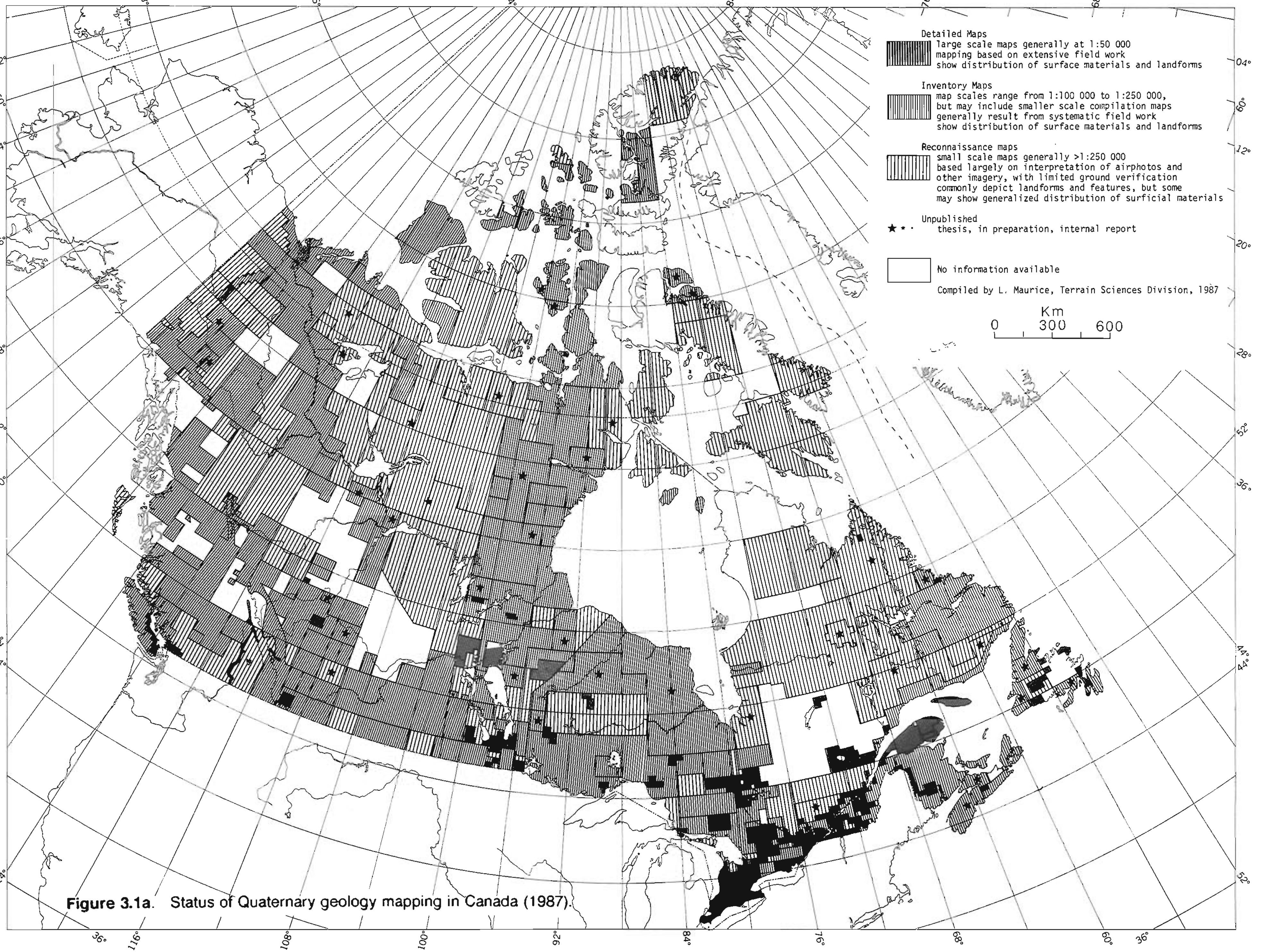


Figure 3.1a. Status of Quaternary geology mapping in Canada (1987).

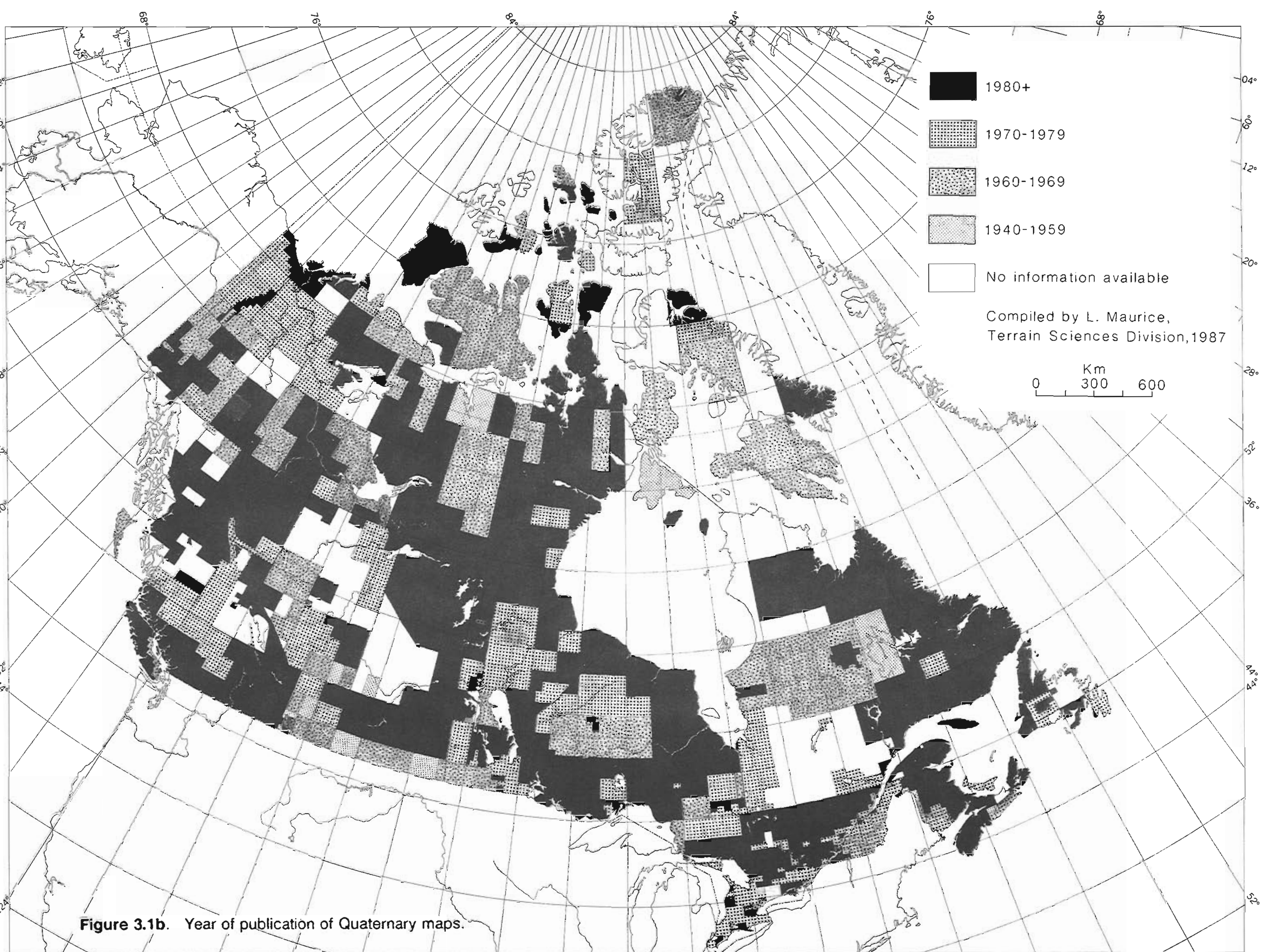


Figure 3.1b. Year of publication of Quaternary maps.

responsibility. The appreciation for geological information within these professions will continue to develop rapidly. However, the best formats for presenting geological information to them are not necessarily the traditional geological map and report. One reason for the interest of land managers (foresters, pedologists, agrologists, planners) in Quaternary geology is that regional land management entails basic resource inventory, carried out mainly by airphoto interpretation or other remote sensed means. In most imagery, landform and surficial materials are what is observed – resource values are then inferred. Resource managers require information in a form that makes these inferences reliable and consistent.

The history of Terrain Science Division of the Geological Survey of Canada is largely coincident with these developments. Indeed, the name of the Division, a departure from tradition in the Survey, appropriately reflects the broadening focus of Quaternary studies and its applications. There has been a persistent influence exerted by nontraditional users, through the special purpose programmes, on the character of products from the Division. We will take up this theme in Section 7.

3.2. Uses and types of information

Our questionnaire respondents use geological information in a wide variety of contexts, as summarized below (from questions 1(a) and 1(b), Appendix 2):

(i) Mineral exploration: aggregate and industrial mineral appraisals, placer and lode gold exploration, drift prospecting, groundwater investigations, development of exploration techniques;

(ii) Engineering investigations related to structures and roads: highways, bridges, tunnels, transmission lines, pipelines, dams and power stations, nuclear waste facilities, harbour design, building site investigations; some of the above in permafrost;

(iii) Other engineering investigations (including hazard investigations): dredging, coastal erosion control, submarine slides, oil spills, seabed geotechnical properties, slope stability (including occurrence of quick clays), landslides, debris flows, groundwater contamination, background radiation studies;

(iv) Environmental management and natural resource development: regional terrain mapping, coastal zone mapping and inventory, forest site classification, soil mapping, soil salinity studies, sedimentary geochemistry, identification of fish spawning areas;

(v) Paleoenvironmental reconstruction: geomorphology, Quaternary stratigraphy, Quaternary history, archeology;

(vi) Planning and regulatory studies: urban suitability, parks, environmental impact evaluation of proposed projects;

(vii) Teaching and research: college and university levels.

This list is remarkably broad. Apart from the somewhat specialized academic field of long-range climate reconstruction, it includes virtually all contemporary applications of Quaternary geological information. This gives us confidence that our survey has tapped a representative range of users of Quaternary and engineering geology information, hence that the replies we have received constitute a sound basis for analyzing user opinions and advice.

The types of data and information used by our respondents (question 1(c), Appendix 2) include the following:

* - surface materials
* - stratigraphic logs
* - depth to bedrock
* - structure of sediments (especially evidence of failure or faulting)
* - age and distribution of tills
* - coastal sediments
* - landforms
- topography
- geomorphological processes
- slope stability indicators
- rock weathering rates
- soil geochemistry
- hydrogeology: groundwater levels
- bedrock geology
- seismicity
- hydrographic information
* - Quaternary history.

Not all of the above information represents conventional geological information. The items marked with an asterisk (*) may be expected to be available from an adequate study of the Quaternary geology. Most types of data collected by the Survey in its Quaternary and engineering geology activities are included in the list. Geomorphological processes and slope stability are both studied, on a regional basis, within Terrain Sciences Division. Soil (parent material) geochemistry has been compiled by Terrain Sciences and Resource Geophysics and Geochemistry divisions for many areas of the country in the course of federal-provincial mineral development special programmes. Of course, bedrock geology and seismicity are reported on by other divisions of the Geological Survey: topography (i.e., topographic mapping) and hydrographic information are the responsibility of other branches of the federal government. Corresponding provincial agencies also contribute information in many of the above categories. Some users also emphasized the value of convenient, direct access to airphotos and Landsat images. This service is provided by special agencies of the federal and provincial governments.

There is one additional theme that a large preponderance of the users emphasized: that the regional Quaternary context is of first importance to know in any study of surficial materials and resources, and that this must be provided by the Geological Survey of Canada. We have been told repeatedly that the basic programme of the Geological Survey, to provide sound regional mapping and an interpretation of the geological history, is the most important product since it is beyond the scope of most users of information to develop themselves. This message was received even from provincial survey geologists, who are tied to their own jurisdictions.

At the same time, many users noted or implied that it is important for them to be able to examine directly the basic field data collected by the Survey – upon which its regional synthesis is based – in the more local context of specific projects. We take up this issue in Section 6.

3.3 Sources and suitability of information

The following discussion is based upon questions 2, 3, and 4(a) of the questionnaire (Appendix 2). Sources of geological information were as follows (as percentages of all respondents):

(i) Own knowledge or personal contacts	86%
(ii) Geologist in own organization	30%
(iii) Geological Survey of Canada	57%
(iv) Provincial agency	63%
(v) University geologist	44%
(vi) Library search	72%

Items (i) and (vi) must be interpreted in the realization that many respondents are geologists. Many respondents have access to a library or to substantial technical files within their own organization. Only one respondent mentioned GEOREF and none mentioned GEOSCAN. Of the remaining choices, GSC and provincial agencies are consulted about equally frequently.

Most respondents were satisfied that they can obtain required information if it exists, and about two-thirds of respondents are satisfied with the format of it. Most dissatisfaction about format is related to three issues:

- map scale too small;
- technical jargon must be "translated" for planners and naturalists;
- Open Files are unwieldy, too expensive, and "poorly presented".

When information is not available, methods of coping include:

- conducting field studies in-house;
- obtaining consultant services;
- photo interpretation or use of Landsat imagery;
- conducting speculative searches in libraries, data banks, and amongst experts (who are identified as authors of reports);
- carrying on without the information.

Budget limitations are often cited as constraints to in-house or consultant studies.

The types of information that are cited as lacking (in one part of the country or another, or in a particular project investigation) include almost everything given in the list of types of information used (Section 3.2). Some notable additional examples include airborne geophysical data, "large scale data", terrain limitation assessments, permafrost and ground ice information, information on contemporary geological processes, hydrogeologic information correlated with surficial geology, stratigraphy, Pleistocene history in particular areas, data on ice flow direction and distance of transport, ^{14}C chronology, geotechnical data, thickness of surficial deposits, and "basic information in northern areas."

The current state of mapping clearly is inadequate in the country. The responses to our question 4(a) are difficult to interpret since individual respondents appear to have used quite disparate standards in their assessments. We report numbers of respondents in each category in Table 3.2. Apart from the appearance that regional mapping is perhaps approaching adequacy in Ontario/Quebec and in the Northwest Territories, there is no region that is considered to have adequate coverage at either generalized scale. The response under regional mapping on the prairies is a clear indication of the limits of interpretability of this table. In comparison, the actual status of Quaternary geology mapping in the country, from all efforts, is shown in Figure 3.1. Detailed mapping is restricted mainly to southern Ontario and Gaspesie, with some in Manitoba and southwestern British Columbia. Only in southern Ontario does it approach adequacy. There definitely remains a major basic mapping effort to be accomplished.

There is a complete spectrum of opinions about whether the Geological Survey should supply missing information. On balance, most respondents recognize that much of the data required in a particular investigation is local or site-specific, and cannot realistically be supplied by the Survey. It is realized that the Geological Survey must maintain a national perspective and that its primary role is to provide the regional framework for local studies. In response to question 3(e), some themes emerged that we shall develop later: that the Geological Survey should lead a co-operative effort to standardize formats for reporting many classes of geological data and that the Survey should act jointly with provincial surveys to compile regional Pleistocene history data from all sources, including company files (for which co-operation was predicted).

The conclusion of this section is, then, the same as that of Section 3.2, that the role of the Geological Survey of Canada is to improve the regional knowledge of Quaternary history and deposits. In that respect, it should take the clear national lead to complete regional mapping and reports of Quaternary history at scales appropriate to the level of settlement and economic activity in each part of the country, and to ensure that the maps become available on a reasonably standard basis. This defines the basic task expected of the Geological Survey, and it is entirely consistent with its mandate.

4. REPORTING ON QUATERNARY AND ENGINEERING GEOLOGY: GSC PRODUCTS AND THEIR USE

4.1 The Publication Record

Table 4.3 presents a summary count of publications by Geological Survey officers in the fields of Quaternary and engineering geology during the period 1974-1985. This period corresponds roughly with that during which the results of the northern environmental assessment programmes, and federal-provincial mineral development agreements – both of which have had a major effect on field and publication programmes – have been appearing. Table 4.4 reorganizes these results on a Canadian regional basis.

The data of these tables were abstracted from the annual GSC publication lists according to subject matter and do not reflect the effort of any particular division. There is, however, a very high degree of congruence between the publications in "Quaternary and engineering geology" as listed in Table 4.3, and the output of the Terrain Sciences Division. Coastal studies of the Atlantic and Pacific Geoscience Centres and geophysical work on the delineation of permafrost (former Resource Geophysics and Geochemistry Division) are also reported in this group. "Resource assessments" in Table 4.3 refers to geophysical and geochemical investigations of surficial materials and lacustrine sediments, and surface and groundwaters, oriented towards mineral exploration. These publications are mainly, but not entirely, the products of the former Resource Geophysics and Geochemistry Division. Since the focus of this review is on products, not on divisional performance, this subject matter orientation is appropriate.

In the review period, very little of the work under Quaternary and engineering geology would be classified narrowly as engineering geology: there are papers on trafficability and sensitivity of soils in permafrost regions and some Open Files summarizing an urban geology information compilation programme of the early 1970s. There is a substantial number of papers on the properties and behaviour of freezing or frozen ground. Still, the entire body of Quaternary studies is important for engineering since it provides the regional context for site investigations (cf. Section 2.3).

A number of underlying factors must be borne in mind in reviewing the data presented in Tables 4.3 and 4.4. First, there is an immense variation in the amount of work represented by an individual GSC report or map. The geographical areas vary, the scale and detail of coverage vary, and the complexity of the products varies. For example, some maps have detailed margin notes; some are part of a paper or major report (which, then, is represented by two or more entries in the table). For this reason, the table is an imperfect indicator of productivity; nor, because many of the products are maps, would other volume measures provide a better index. Indeed, unpublished memoranda and reports, produced for use within the government, represent substantial additional effort by GSC officers that is not easily summarized in any form. We incline to the opinion that simple quantitative measures of the sort given in Tables 4.3 and 4.4 represent a poor measure of the productivity or worth of any technical service. However, they do reveal some important trends in publication during the past decade (representing, mainly, work from about 1971 to about 1984).

Table 4.5 compares the outputs in Quaternary and engineering geology with those of the entire Survey over the period. There are relatively few final reports (Memoirs and Bulletins) in Quaternary and engineering geology. Given the primary focus on regional mapping projects, it is perhaps not surprising that Bulletins (final reports on systematic geology) are underrepresented. The absolute number of Memoirs (definitive reports on regional geology) is small, reflecting a survey-wide trend. The comprehensiveness – hence time required – for the production of Memoirs appears to make them unattractive in the face of today's pressures for rapid communication of results.

Quaternary geology appears to be fairly represented in A-maps (definitive geological maps), and constitutes the bulk of P-maps ("provisional" geological maps) issued by the Survey. Many of the P-maps represent products of northern environmental assessment studies, which constituted for several years the main "special effort" programme in the entire Geological Survey. Their release as P-maps reflects a judgment about map quality based on the necessarily large proportion of airphoto interpretation that has been used in their compilation, with limited opportunity for ground checking. Many of them are, in effect, final products

Table 4.3. Geological Survey of Canada outputs in Quaternary studies, 1974-1985[1]

Series	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Quaternary and Engineering Geology												
Memoirs			1				1	1	2	1	4	
Bulletins		1		2	1		2	2	2	1	1	
A-maps	5	5	2	7	3		7	4	7	3	8	5
P-maps	1	1	1			2	28	30	17	6	1	2
Papers and Miscellaneous Reports	5	5	8	5	4	2	10	8	5[2]	4	8	9
Outside Publications[3,4]	18	18	9	18	10	8	16	13	17	n.d.	n.d.	n.d.
Current Research	21	72	64	48	39	23	18	15	20	17	20	29
Open Files	22	10	23	17	13	14	4	2	10	11	15	15
Maps, Open File	108	21	64	14	36	77	5	8	34[4]	24	11	14
Resource Assessments												
Papers and Miscellaneous Reports	3	1	4			3[5]	3					
Outside Publications[3,4]	8	2	7	8	4	2	8	3	5	n.d.	n.d.	n.d.
Current Research	8	13	10	1	2	6	1	1	2	6	4	1
Open Files	2	13	17	33	23	16	6	30	12	3	8	23
Maps in Open File[6]	7	134	246	321[4]	281	207	33[4]	17	133	15	409	145

1 Includes all reports commissioned or contracted by GSC and published in GSC series, but excludes reports contributed to GSC series by authors not associated with the GSC (principally articles contributed to Current Research by university members)
2 Includes Miscellaneous Report 31 (A chart)
3 Refereed articles in journals and conference papers published in full; conference abstracts are not included
4 Incomplete
5 Chapters in an Economic Geology Report
6 Excludes about 325 computer-generated summary maps at a scale of 1:2 million.

nonetheless. Many additional maps have been released in Open Files.

Contributions of Quaternary and engineering geology results in other publication categories are representative of total proportional effort. There are interesting temporal trends in contributions to Current Research and to the Open Files. The former reflects the establishment of Current Research as a substantive report series just before the reporting period, and initial enthusiasm to use it as a medium for rapid communication of new results. The trend likely is reflected right across the Survey. The latter reflects in considerable measure the spate of environmental assessment reports on the Mackenzie Valley pipeline and communication corridor released in 1974-1976.

Resource assessments have appeared mainly in Current Research and Open Files. The special requirement for currency and the nontraditional nature of the results (e.g. digital data files of geochemical assays) have jointly dictated this course.

Proportional regional effort is summarized in Table 4.6. The reference data in this table are national totals of Quaternary and engineering geology and resource assessment reports (and they are grouped differently than in Tables 4.3-4.5). The

Table 4.4. Regional distribution of outputs in Quaternary studies, 1974-1985

Region	Quaternary and Engineering Geology									Resource Assessments				
	Memoirs	Bulletins	A-maps	P-maps	Papers and Miscellaneous Reports	Outside Publications	Current Research	Open Files	Maps in Open Files	Papers and Miscellaneous Reports	Outside Publications	Current Research	Open Files	Maps in Open Files
Northwest Territories														
Franklin	3	1	5	2	5	17	92	28	92[2]		3	2	8	90
Keewatin	1		1	15	1	4	18	7	55		3	5	8	84
Mackenzie				14	3		27	17	6	1	2	7	11	96
Yukon Territory		2		20	2	8	11	13	23	2		2	16	171
British Columbia	2	3	15	2	11	20	42	17	31		3	2	30	194
Alberta		1(+1)	1	2	5[1]	6	13	4	4				2	
Saskatchewan	(1)	(1)	(2)				4			2	4	4	18	211
Manitoba	1	1	3	19	2	2	5	6	24		1	6	17	216
Ontario														
Northern		1	6			8	8			2	4	1	15	202[3]
Southern			2(+2)	1	5		17	13	36	2		2	9	59[3]
Quebec														
Northern	1	1(+1)	9(+1)	(1)	3	15	11	9	22				1	7
Southern	1	1	2	1(+1)	5		23	12	18			1	1	14
New Brunswick	1		1		2	6	14	4	10		1	2	2	
Nova Scotia					3	9	15	10	23		2	3	25	259
Prince Edward Island						1	2					2	8	
Newfoundland														
Newfoundland		1		10	3		10	4	9		1	3	6	110
Labrador			2	3	1		4	5	67			1	15	204
Eastern Canada			8											
Systematic and General		1	1		21[4]	32	67	8		4[4]	23	17	2	
Total	10	13	56	89	72	128	383	157	420	13	47	58	186	1927

Notes as Table 4.3. A bracketed entry indicates a relevant publication primarily focused on another region.

Table 4.5. Geological Survey of Canada proportional output in Quaternary and engineering geology (QEG), 1974-1985

Product	Number of Items		Proportion
	GSC	QEG	QEG
Memoirs	43	10	23%
Bulletins	131	13	10
A-maps	245	56	23
P-maps	104	89	86
Papers and Miscellaneous Reports	330	72	22
Current Research	1927	383	20
Open Files	964	157	16
All Items	3744	780	21

regional pattern reflects administrative circumstances and provincial efforts in geological survey more than anything else. A comparatively large effort is directed by the Geological Survey towards the northern territories since that is a recognized federal responsibility. Those provinces with historically prominent geological survey units (Alberta, Saskatchewan, Ontario, and Quebec) receive relatively little field attention from the federal survey. Overall, British Columbia appears to be very well served, the Maritimes to be neglected. There are, of course, explanatory circumstances. The Quaternary deposits in the mountains are the most complex in the country and require great effort to interpret. (It also happens that the Survey's geologists in this region have been amongst the most productive individuals anywhere.) At the other end of the country, mapping in the 1950s and 1960s in the regionally compact Maritime provinces has issued in reduced effort more recently.

The distribution of resource assessment outputs directly reflects which provinces have entered into cooperative Mineral Development Agreements with the federal government.

Finally, Table 4.7 examines the distribution of Quaternary and engineering geology outputs in comparison with population distribution in Canada. Population distribution largely mirrors the distribution of economic activity. This comparison can be regarded as mischievous. We have already pointed out that regional effort is in substantial measure set by direct federal responsibility in the territories, by the level of activity in geological survey in the provinces, and by accomplishments in a region before the review period. All these factors are reflected in Table 4.7. Furthermore, mineral resource developments do not reflect the geography of economic development in general. However, to the extent that Quaternary and engineering geology now serves much broader resource planning and development ends, it remains a legitimate policy question whether federal geological survey effort ought perhaps to reflect somewhat more nearly the distribution of economic activity in the country. The table provides the statistical basis for discussion. At present, the necessarily large territorial effort is achieved in effect at the expense of efforts in those provinces where there have been strong provincial surveys.

4.2 Appraising the products

The following discussion derives from information obtained in question 4(b) of our user questionnaire (Appendix 2). Respondents tended not to rank completely the classes of output named in the question, so that a strictly quantitative summary is not possible. There is, however, a perfectly clear pattern of responses, summarized in Table 4.8.

Comments made by individuals reveal the reasons for this outcome. The maps and final report series are esteemed for their authority, wide availability, and significant length of time in print. However, their production is slow and expensive, in large measure because of the thorough review procedures and high production standards that guarantee the authority for which they are valued. We received frequent complaints from users about slow production. We have noted that these production factors have raised questions within the Survey about the long term viability of these series. The reputation of all of the definitive paper series is one of the most valuable assets that the Survey has for transferring its results to the public: ways should be explored to revivify these series in order that their reputation may be used effectively.

Personal contact was ranked most highly of all everywhere west of Quebec, but of only moderate value in Quebec and the Maritimes. Replies from the Maritimes indicate that the large consultants are able to take effective advantage of personal contacts, but that small consultants cannot and that provincial agencies do not. It is perhaps significant, as well, that Quebec and the Maritimes are the two major regions within southern Canada where there is no GSC office with resident Quaternary and engineering geology personnel. The effectiveness of personal contact lies in its interactive character, so that enquiries can be answered in a manner that directly addresses the enquirer's specific interests. From responses to questions 3 and 5 of the questionnaire we learned that officers of the Survey have earned a remarkably high reputation for their responsiveness to individual enquiries, and for the value of the information that they impart.

Outside publications – meaning publications in scientific journals – are also substantially appreciated. Replies indicate that timely

Table 4.6. Regional proportional output in Quaternary studies, 1974-1985

Region	Quaternary and Engineering Geology					Resource Assessments		
	Final Reports[1]	P-maps	Papers and Miscellaneous Publications	Current Research	Open Files	Papers and Miscellaneous Publications	Current Research	Open Files
Territories								
Northwest Territories	14%	35%	12.5%	36%	33%	7.5%	24%	14.5%
Yukon	2.5	22.5	3	3	8	15	3.5	8.5
British Columbia	25	2	15.5	11	11		3.5	16
Prairies								
Alberta	2.5	2	7	3.5	2.5			
Saskatchewan				1		15	7	9.5
Ontario	11.5	1	7	6.5	8.5	31	5	13
Quebec	19	1	11	9	13		2	1
Maritimes	2.5		7	8	9		8.5	15.5
Newfoundland and Labrador	4	14.5	5.5	3.5	6		7	11.5
Eastern Canada	10							
Systematic and General	2.5		29	17.5	5	31	29.5	1
Total Numbers	79	89	72	383	157	13	58	186

1 Memoirs, Bulletins, A-maps

Table 4.7. Regional output in Quaternary and engineering geology (QEG) compared with regional population

Region	Total QEG publications[1]	Proportion of QEG publications	Proportion of Canadian population
Territories			
Northwest Territories	103	28.5%	0.2%
Yukon	37	10.5	0.1
British Columbia	50	14	11
Prairies			
Alberta	13	3.5	8
Saskatchewan	-	-	4
Manitoba	32	9	4.5
Ontario	28	8	36
Quebec	45	12.5	27
Maritimes	21	6	7
Newfoundland and Labrador	29	8	2.5
Total	358		

1 Quaternary and engineering geology categories in Table 4.3, except Current Research and outside publications; maps in Open File not separately counted.

Table 4.8. Summary of users' appraisal of Geological Survey of Canada reporting methods

Medium	Number Reporting[1] Valuable	Number Reporting[1] Marginal	Little Worth	Weighted Sum[2]	Range of Ranks[3]	Summary[4]
Map Series	69	6	0	144	1-4	most valuable
Bulletins, Memoirs, Ec. Geology Series	60	12	2	132	1 - 5	very valuable
Papers, P-maps	57	14	1	128	1 - 3	
Personal discussion	60	6	1	126	1 - 4	
Outside publications	52	19	1	123	1 - 6	
Current Research	34	19	9	87	1-8	somewhat useful (mixed response)
Open File	31	20	14	82	6 - 8	
Conference presentations	18	33	12	69	7-8	much less useful
Open House	11	10	20	32	9	no discernable value

1 Categories do not add to the number of respondents: many respondents checked only some categories
2 2X number of 'valuable' responses + 1X number of 'marginal' responses
3 Most respondents did not provide an exhaustive ranking
4 Committee's judgment

publication, relatively wide availability, and relatively specific subject matter focus are appreciated.

Current Research received decidedly mixed appraisals. It shares some of the attributes of journals (as intended), but appears to be not so readily accessible to many users. One respondent told us that it is one of the best geological journals in print; another bluntly noted that it is much too expensive "for the one or two articles of interest in each issue." Herein perhaps lies the difference: many outside articles contributed by Survey officers appear in relatively specialized journals of regular interest to a particular user, whereas Current Research functions much like a general earth science journal. The cost-effectiveness of this medium should perhaps be appraised further.

Open Files and conference presentations received lukewarm notice, both for reasons of accessibility. Open Files are considered to be physically unwieldy, restricted in availability, and to feature formats and presentation that effectively restricts their use to professional geologists. Many users also regarded Open Files as preliminary and not authoritative. The observation was made that nongeologists (and many private sector geologists) do not attend geological conferences.

Open House was ranked least valuable by everyone. Quite simply, no one at any considerable distance from the location of the event (in the Quaternary and engineering geology sector, at least) deems it cost-effective to attend. Much private sector activity in Quaternary and engineering geology is carried out in small consultancies that cannot afford to follow special events in the manner that the large mineral and petroleum development corporations do.

Some perspective should be given to these less favourably viewed activities. They may serve very well purposes other than communication of results to users. For example, it is difficult to imagine how a range of computerized survey records (including tapes), laboratory records, consultant reports, and bulky "supporting documents" can be made available to the public other than by an "open file" mechanism. The use of this medium should perhaps be more selective, particularly with respect to "unedited" maps and reports that are in fact preliminary versions of the Survey's main products. More expeditious editing to the level of P-maps or Papers may be a better means of output in such cases.

Conferences may be valuable venues for professional contact and information gathering for Survey scientists, even if they do not meet all of their user public there. Similarly, Open House may be an invaluable occasion for substantive contact between field officers in different divisions and with the senior managers of Energy, Mines and Resources, and of other Departments, as well as with a local group of users.

An alternative to conference and Open House presentations suggested by some users is to consider holding regular regional seminars at which geologists from the Survey, universities, provincial agencies, and local consulting companies would provide "updates" on recent results in the region. A cycle of several years duration in which an annual seminar is targeted at a particular sector of the user community may be even more effective. The meetings would also serve to facilitate the development of personal contacts. They should not become expensively elaborate.

Given the wide range of journals available today, it is most difficult, in many respects, to see any uniquely valuable service performed by Current Research. It does not systematically review all projects. Yet we were told: "Nous devrions être tenus informés de tous les projets en cours de réalisation et pouvoir obtenir un état de connaissances (rédigé annuellement) pour chacun des projets." More user-selective methods of disseminating progress reports of current projects (than is represented by Current Research) may easily be envisaged. For example, we suppose that an annually published list of all current projects (as requested by several respondents), annotated to indicate the date of the latest written progress report, could be used to request reports on individual projects. These might be stored in an electronic file (of one or two pages length) and printed or xeroxed on demand. The report need differ little – if at all – from the officer's usual internal progress reports on a project. It should, however, include schedules for production of final reports. The procedure would be user sensitive, ensure access to the status of all projects, could be less disturbing within the Survey than the trimestrial rush to produce Current Research, and may increase the orderliness of project completion.

4.3 Publication procedures at the Geological Survey

The framing of recommendations to improve the publications – the physical form of Survey products – must take realistic account of publication procedures, and must recognize also the motivations for officers to produce reports. What follows is a brief outline of Survey procedures.

Branch publications are identified tentatively, and a rough timetable set for their appearance, at the time when a project is planned by a Research Scientist and the Division Director. (For example, a programme might specify "after one year a report in Current Research; after two years, a paper; after four years, project termination with a Bulletin".)

Manuscripts, as they appear, are checked for presentability in the Division and then sent to one or more critical reviewers, chosen from within or outside the Survey by the Division Director upon advice from the author and other staff. After the review and suitable revision, the manuscript is signed by the Division Director and sent to the Geoscience Information Division for production. (Open Files are approved for release by the Chief Scientist, often without formal review.)

Under the supervision of the Chief Scientific Editor, the report is further appraised by the Branch scientific editors and copy edited, then sent to production editing for layout, word processing, and cartography. Most maps are printed in the Surveys and Mapping Branch, Energy Mines and Resources.

Material from Terrain Sciences Division follows this general route; however, the Division retains its own scientific editor, so that material formally enters the Geoscience Information Division at the production editing stage.

The procedure just described is designed to ensure that reports be clearly written and authoritative, and that production of reports from a project be an orderly part of the project execution. It achieves the first two ends remarkably well but, in light of contemporary users' expectations, at some sacrifice in time and apparent orderliness. There are three major bottlenecks:

(i) report writing;
(ii) review and revision;
(iii) production, particularly of complex cartographical material.

Getting reports written is part of project and personnel management in any scientific organization and is not the brief of this committee. One aspect does impinge upon our concern, however. The career progress of Survey officers is influenced, properly, by the perceived scientific excellence of their results, as well as by the quantity of them. That evaluation is made by scientific peers inside and outside the Survey and adjudicated by the Survey's senior management. To gain favourable evaluation, the officer desires to place his reports where they will be widely seen and appreciated by peers (who are perhaps, but not necessarily, users). That may determine whether main attention is given to maps and Memoirs or to journals and Current Research. It is the policy of the Survey:

(i) that officers should contribute to Survey publication series all results that are appropriately placed there (in particular, all maps); and
(ii) that material should be published in the most appropriate place to reach the user.

This is good policy. It remains difficult to ensure that it works properly in light of the somewhat academic evaluation pressures to which we have alluded. In particular, we wonder whether the production of Memoirs – ideally the final product, with accompanying A-map, of any regional mapping project – has not become to some degree a victim of this situation. (By the arcane rules of academic evaluations, Survey publications might easily be discounted in comparison with journal contributions, since the Survey's review procedures are not controlled by third parties and are not blind. This curious judgment flies directly in the face of the perceived value and authority of the principal publication series. It has no rational basis.)

Review and revision are matters of project management. Time (the most valuable resource) must be budgeted adequately for this within a project. We expect that this often is not the case, because it is not an activity that leads to additional results. Most officers pursue several minor assignments simultaneously with a major project. The most frequent casualty of excessive expectations, in any technical setting, is deliberate review and correction of substantively completed work.

There is little that can be said definitively about production since technology is changing so quickly. We advocate use of the most expeditious and economical means of production consistent with clarity and reasonable appearance of authority. Traditions which do not serve these ends need not be respected. For example, it appears to be traditional to require that A-maps be coloured. An A-map should be a final, hence definitive (for the present day) presentation, which involves thorough work in compilation, a rigorous review, and a high degree of editorial vigilance. It does not require colour, which heretofore has substantially complicated cartographic production and printing. On the other hand, contemporary technique may very well resolve this conundrum: Map 1618A (Helie, 1984) is printed from colour separations obtained photographically from the author's manuscript. Two respondents, presumably sophisticated map users, called for direct printing of geological information on photomosaic base maps.

In concert with other branches of government that have major printing requirements, the Survey should pursue as a matter of priority the best ways to reduce production time for its definitive products.

4.4 Informing the wider public

In periods when government is attempting to restrain or reduce budgets, technical branches of the public service are particularly closely reviewed. The best defence against ill-conceived cutbacks is a public constituency that is well aware of the value of the service. The Geological Survey of Canada maintains good contact with its geologically trained user public – as is evident from our questionnaire. However, there is a much wider public to consider. One geologist-park planner in Ontario told us ". . . more emphasis must be placed on presenting geological information to politicians, administrators, planners, and other laymen. Geological jargon must be simplified, but not at the expense of losing scientific credibility."

Within the Department of Energy, Mines and Resources, the Geological Survey engages in public information programmes through the Department's magazine, Geos, by displays at principal offices, and by publishing semi-technical guidebooks, such as rock and mineral handbooks and geological guidebooks for some of the national parks. These are useful, but they are not sufficiently aggressive to ensure that a large audience takes notice. There appears to be no deliberate effort to sustain a planned programme of general public information. We expect that such a programme would be worthwhile, and we expect that Quaternary geology should be much more prominent in it than heretofore. Most people are naturally curious about the history of the present landscape and, with regard to the details that people notice, this is mainly a history of glaciation. We recommend that a programme be developed to inform the general public about Geological Survey projects and results, with substantial emphasis upon Quaternary geology and its applications. The programme should begin by identifying potential contact points with the public (newspapers? natural history magazines? exhibitions? National Parks? road guides? television spots?) and material should be tailored for these points after they are identified. Some means to gauge the success of the programme should be decided upon before it is commenced.

4.5 Recommendations about publication series

Quaternary and engineering geology publications are part of Survey-wide series. The concerns discussed in Section 4.3 are generic in the Survey. Our recommendations could, then, have repercussions well beyond the Quaternary and engineering geology sector. We make them because we have concluded that they will improve the usefulness of Quaternary and engineering geology products: however, they clearly must be judged in the broader context.

(3.1)* The Survey should give deliberate consideration to reemphasizing its definitive publications (A-maps, Memoirs, Bulletins, Papers) as the repository of its main conventional reports and maps, using contemporary production technology to promote timely publication.

This recommendation is to take advantage of the superior reputation that these series enjoy. Such a reputation plays an important role in ensuring that results are taken up and used. It has been established over many decades, and it would be a major blunder to disregard it. We do not believe that the layout or subject matter of these reports need be narrowly bound by tradition, although the basic thematic distinction represented by the Memoirs – signifying final regional reports – remains useful.

(3.2) The Open File series should be used deliberately for releasing nonconventional material, data sets, certain consultant reports, and other products that will not fit the thematic or physical constraints of the definitive publications.

Provisional reports and maps of essentially conventional nature should be expedited towards normal release as P-maps or Papers, using technologically enhanced editorial procedures. They would thereby gain considerable authority, accessibility and, hence, use. The scheduling and budgeting of projects should recognize this responsibility.

(3.3) Current Research should be abolished in favour of proper use of outside journals and establishment of a user selective project awareness service.

Narrowly focused systematic reports should be sent to appropriate journals. Progress reports of projects should be brief, accessible upon user demand, and frequently updated. This recommendation implies a novel form of communication. We have no final idea of its format. We have made a suggestion in Section 4.2 that would be well adapted to electronic mail services, but could also be used in a conventional distribution system.

(3.4) General conferences and Open House should be abandoned as means of communicating with the user community.

(3.5) The Geological Survey should instead initiate user targeted seminars in regional centres, in collaboration with provincial and other local specialists, to update users on the results of Survey and other pertinent research and inventory activities.

Individual seminars might be fairly specialized. An important function of them will be to facilitate personal contact and familiarization with other Survey products.

* Recommendations are numbered as x.y. x indicates the term of reference that is addressed (see Section 1.1), and y indicates recommendation number.

There are no special costs associated with the foregoing recommendations. There are costs associated with appropriation of new technology to expedite editing and production of definitive reports, but we mean cost-effectiveness to be a criterion for their adoption. Because technology is rapidly changing the character of geological information as well as the means to present it, these should be regarded as short to intermediate term adjustments of the means to communicate results effectively.

(3.6) The Geological Survey should assign members of the Regional Projects staff to have long term commitments to one or another of the settled regions of Canada, and should station them at offices in the regions.

The value of easy personal communication with users – buttressed by day-to-day familiarity with developments in the region – cannot be overemphasized. The model for effectiveness is the Vancouver office, and its orientation should be emulated elsewhere. Regional detachments need not be large (there are two Quaternary geologists in Vancouver). They would most easily be placed in Survey offices, but even this seems unnecessary provided that they do have local access to adequate technical support services. It probably is important that they be placed near large universities or provincial groups to ensure scientific stimulation and contact with other regional experts so that the load of local enquiries does not become overwhelming.

Potentially, the Survey's most valuable output resides in the capability and knowledge of its experienced officers: regional assignment is by far the best way to make this actually available to users.

(3.7) The Geological Survey should establish a programme to inform the general public about its projects and results, in which substantial emphasis should be placed upon Quaternary geology and its applications.

This proposal may have cost implications in that it will – if successfully developed – require communication media technicians or public presentation specialists to help develop and place appropriate material. It should use communication media already well established and widely consulted by the public.

5. CONTEMPORARY PROBLEMS FOR STUDY

5.1 The direction of the mapping programme

It is still the fundamental task of the Geological Survey of Canada to provide a full and scientific description of the geology of Canada, and the basic programme to effect this remains the regional mapping programme. In questions 6 and 7 of our questionnaire, we asked users to discuss emerging problems and needs for geological information. Overwhelmingly, we were told that more progress in regional mapping is required. This is consistent with the finding (Sections 3.2 and 3.3) that users regard the provision of regional geological context as the most important task for the Survey. Whatever the local or specific geological problems that will be faced in the future, this is the indispensible information from which to begin to find solutions.

Most users anticipate a continued predominance of the major problems of today, notably engineering site investigations, aggregate surveys, groundwater investigations, and terrain mapping as the basis for land resource capability assessment, environmental impact evaluation, and hazard assessment. There are some interesting nuances in what users regard as an adequate description of regional context to face these problems. Many users remarked that the synthesis of urban geology (not site-scale information) is grossly inadequate for the engineering needs there, where the Quaternary record is particularly important in comparison with the rest of the rock column. Similarly, some users in Ontario and Quebec noted that mapping in the closely settled regions of southern Ontario and St. Lawrence Valley is inadequate for intensive land management requirements: complete 1:50 000 mapping is called for in these areas by some users. An Ontario user states: "While 1:50 000 mapping in the south and 1:100 000 mapping in the north made substantial advances in the 70s and early 80s, production has fallen off. The program needs more emphasis to fill in the gaps." Calls for more detailed mapping were also received from the prairies. From a respondent in the Maritimes we learned that ... "(In eastern Canada anyway,) till is by far the most extensive and important surficial deposit. It needs to be mapped and subdivided more rigorously, on lithological and textural grounds, not simply relegated to an omnipresent green 'lodgement till'. Geotechnical and geochemical analyses of till should be incorporated into mapping programmes."

The programme of the Geological Survey is presently committed to 1:250 000 scale geological "reconnaissance mapping" of the nation, and to syntheses at even smaller scales. It is a fair question whether this uniform scale will yield uniformly useful results across a country with such large variations in settlement density and economic activity as Canada. Thirty percent of Canada's population is located in the three largest metropolitan centres; 45% in the 10 largest cities, and 56% in the 24 Census Metropolitan Areas (CMA) with greater than 100 000 population each. Southern Ontario and St. Lawrence Valley east to Québec City contain about half of the Canadian population. Figure 5.2 illustrates the density of settlement in

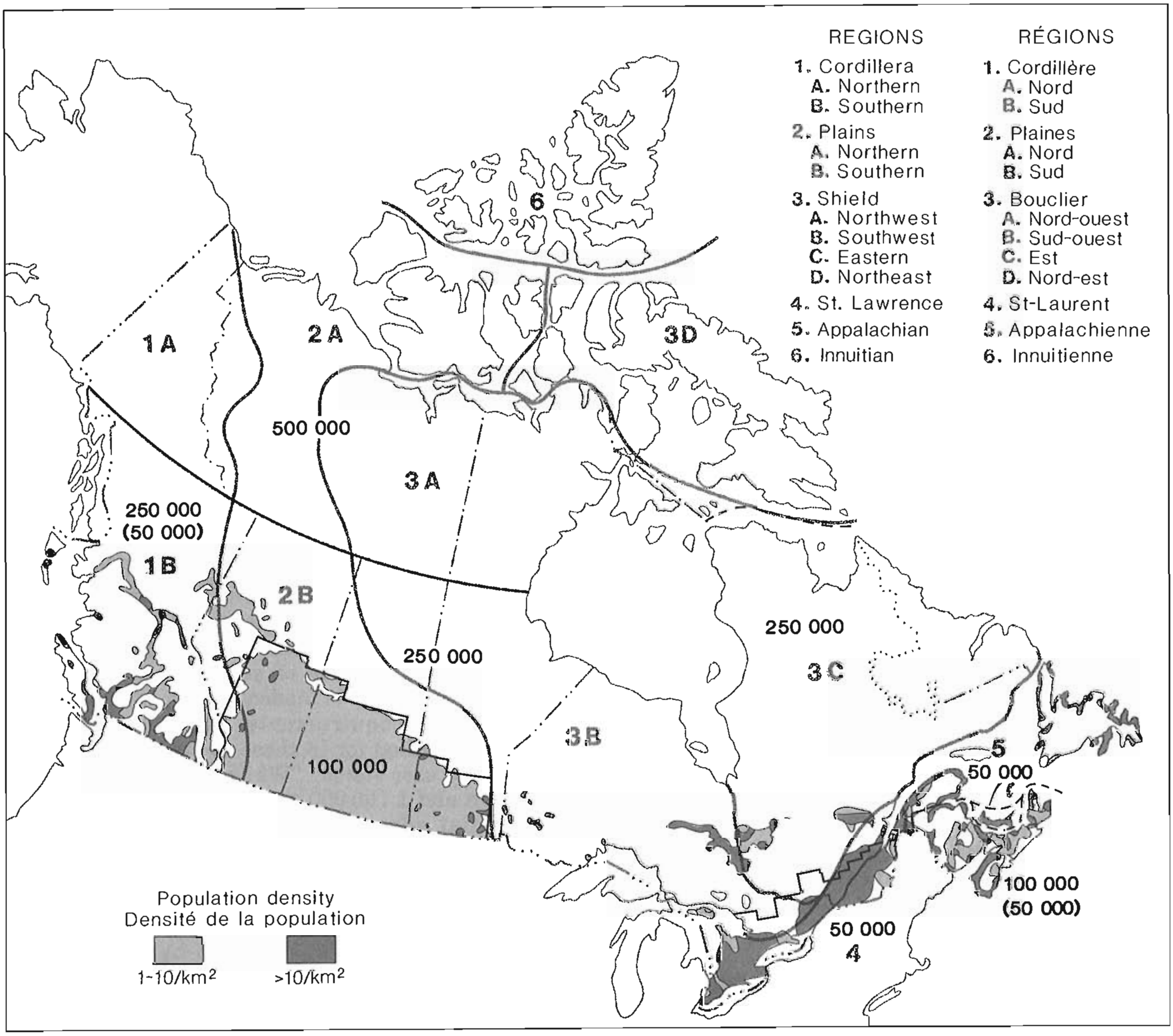


Figure 5.2. Population density, geological regions, and suggested scales for regional Quaternary mapping in Canada.

Canada. Altogether, the population and economic activity are strongly concentrated. The requirements that this creates for information about Quaternary geology are also substantially variable, and this is reflected in user remarks.

This Committee cannot finally determine optimum "regional" mapping scales for the country, but we recommend the following as a basis for discussion, following user opinions and our own judgements:

- 1:25 000: 9 largest CMAs (population greater than 500 000) and their fringes;
- 1:50 000: southern Ontario, St. Lawrence Valley, Prince Edward Island, closely settled areas in New Brunswick and Nova Scotia, certain British Columbia valleys;
- 1:100 000: balance of New Brunswick and Nova Scotia, settled Prairies;
- 1:250 000: balance of the Provinces, except Labrador;
- 1:500 000: Territories and Labrador.

(The areas are outlined in Figure 5.2.)

Adoption of a variety of mapping scales would follow a long established tradition in bedrock mapping in the Survey whereby significant mineral districts have received larger scale coverage.

Final selection of scales must await the establishment of some information standards for mapping (see below Section 6.6). Nor are we certain of the impact that adoption of revised, regionally variable mapping scales will have on the total mapping effort. Many officers of the Survey certainly prepare field compilations now in substantially greater detail than is required for 1:250 000 scale reconnaissance mapping in order to study details of Pleistocene glacial history, knowledge of which substantially improves the consistency of the mapping.

Variable scale mapping would redirect greater attention to the settled, southern regions of the country, which is another persistent user suggestion. In this report, detailed mapping around the major population centres or remapping to improve standards (cf. Armstrong, 1980a, b, 1984; Armstrong and Hicock, 1980a, b, in the Fraser Lowland of British Columbia) is called for by users.

5.2 Inshore marine and coastal mapping

Substantial and special development pressures affect the coastal zone. Industrial, residential, and recreational land use pressures are focused upon the coast in many places; oil spills and effluent dumping may foul the shoreline and inshore waters; special engineering problems arise in the severe environments there. In the long term, we may have to face special engineering consequences of rising sea levels. All of these problems come to an especially intense focus in biologically rich and diverse estuarine areas. Yet less is known about the coastal environment than about any other part of Canada.

The reason for this relative ignorance is a matter of technique. Terrestrial mapping methods cannot be extended offshore. Marine methods – practised from ships – cannot be extended into shallow waters beyond the limit of safe navigation. In general, waters inside headlands and shoreward of 30 metres depth are poorly known.

The geological environment of inshore marine areas is, furthermore, often much more variable than that offshore. Mapping standards and station frequency that may yield adequate information offshore may be inadequate inshore. Small boats and light equipment are operable in inshore waters, and are adapted to the relatively intensive observation programmes that may be required. However, their operation is expensive, with many days lost to weather, and may be hazardous.

Interest in making special maps of coastal and shorezone features is scarcely more than a decade old. Whilst progress has been made in developing useful mapping systems (cf. Owens et al., 1981), there is not yet sufficient experience for standard methods and definitive maps to have appeared. On the other hand, methods have been oriented toward semi-parametric description and data banking right from the start. We will return to this subject in Section 6.

Information on the inshore marine environment is vital to obtain, particularly for geotechnical purposes. The vast majority of "marine" engineering activity consists of harbour, navigation, and shore protection structures. Furthermore, proper understanding of regional geology requires a collation of onshore with offshore results. We concur with the opinion of one user who wrote: "I have a general reservation about separating the collection of land and marine geological information. I consider that the present coastline is, from a geological point of view, a very temporary feature and has no place as a major boundary on our maps. The groups concerned with collecting information on land and under the sea should be encouraged to work as closely as possible together to promote a fuller understanding of the processes involved and a better presentation of the data acquired...." There is, in this remark, the further implication that some regrouping of investigators is desirable to attain co-ordinated study.

The issues encapsulated here will have to be dealt with by increased small craft operations inshore, by increased use of shallow water geophysical methods, and by increasingly sophisticated use of remote sensing (the waveband 0.5 to 0.6 µm – yellow/green visible light – will penetrate up to 50 m of clear water: atmospheric absorption in this band discourages spaceborne use, but low altitude use perhaps remains possible). These efforts may have to be motivated largely by the Geological Survey. Canada's oceanographic institutions appear to have little commitment to or expertise in coastal zone work, and the geophysical techniques are relatively specialized.

This is an area in which relatively increased personnel and effort may have to be assigned during the next decade; we wonder whether the much larger oceanographic programme may be the place to find the resources.

5.3 Geology and the soil resource

Parent material (surficial geologic material) is a major factor that determines the character of pedologic soils. Contemporary soil survey begins from a process of "stratification", the subdivision of the survey area on the basis of criteria that will delineate primary groups of soils to be mapped (Mapping Systems Working group, 1981). Almost everywhere in Canada, stratification is achieved on the basis of physiography and parent materials (surficial geology) or "terrain units" (ibid, table 4; p.20).

Soil surveys, to be useful, must be relatively detailed (cf. Mapping Systems Working Group, 1981;

table 2, p.11), scales of 1:100 000 or larger being normal. The cost of such surveys has led to greatly increased use of remote imagery, mainly air photographs, in recent years. At the same time, pressure for an increased pace of survey – just as for surficial geology mapping – has grown with increasingly close land management. In the most efficient approach to mapping the soil resource, this places substantially increased emphasis upon basic geological survey. On airphotos, landform, surface material, and/or vegetation units are delimited: they are associated with specific soils by field inspection and the surveyor's prior experience. Hence, maps of surficial geology and terrain units – the primary products of the Quaternary mapping programme – represent basic information for modern soil surveys. The soil survey, in turn, becomes the basis for biophysical land capability assessment in the Canada Land Inventory and other land resource evaluation systems.

In addition to soil delineation, assessment of erosion, or soil erosion potential, under various land uses represents an increasingly important land management task (Canada Parliament, 1984). In natural and forest land use settings, this is a matter of geological or engineering interpretation of the performance of surface materials. This lends a distinctively geological aspect to the matter of soil resource management.

In some provinces, the convergence of interpretive skills required for terrain and soil mapping has led to close operational co-ordination of programmes to produce maps of both types, followed by biophysical land capability interpretive maps (for example, in the land resource mapping procedure of the British Columbia Ministry of Environment). It is possible that greater operational co-ordination should be considered between geological and pedological mapping efforts in the country in general. This may be difficult to manage, given the traditionally different orientations of geological (mineral exploration, engineering) and pedological (agriculture, forestry) surveys and the different training of the practitioners. In western Canada, however, a positive response was received to our question about co-operative work with the Geological Survey of Canada from pedologists engaged in agricultural soil survey. The Saskatchewan Soil Survey has contracted Quaternary geologists of the Saskatchewan Research Council to provide the geological framework for soil mapping. More widespread achievement of such co-ordination would effect an increasingly important application of geological information on a more systematic basis than heretofore, possibly at substantial saving in cost for the comprehensive survey of geology and soils.

5.4 The chemistry of the surface environment

Acidification of the surface environment, apparently a result of hydrocarbon fuel burning, has emphasized in recent years the significance and sensitivity of the geochemical environment of the earth's surface (Canada Parliament, 1981). There are, in fact, many other aspects of surface geochemistry that are important in human affairs:

- parent materials influence soil fertility, particularly patterns of micronutrient occurrence (Chesworth, 1982);
- surface materials and wastes disposed of on the land have a major effect on water quality;
- surface material may influence public health, especially through its influence on water quality, ingested elements, and chronic health problems (cf. Kramer, 1982);
- the chemistry of surface materials is a significant prospecting tool (Shilts, 1976; 1984);
- changes in the chemical properties of surface materials may bring about changes in mechanical properties that are of geotechnical significance.

Too little is known about the chemistry of surface materials to serve the management of these effects well.

The Geological Survey programme to study till geochemistry has made a commendable beginning toward incorporating the chemical characterization of surface materials into routine Quaternary mapping. Soil chemistry is complex, so that a number of questions must be addressed before a regional programme can be executed successfully:

- What are the geographical scales of variability of the target elements?
- What are the stratigraphic and textural affinities of the target elements?
- How are the geochemical data best integrated with other geological information for interpretive purposes?

The Survey programme has been oriented primarily toward mineral exploration methods. The extensive resource geochemistry surveys carried out under the Mineral Development Agreement programmes have provided substantial experience in regional data assembly. In this context, progress has been made on all of the questions above (see Shilts, 1984). When the techniques are turned to other purposes and to other materials, these questions may have different resolutions. Again, the Survey has begun to make progress in applications of surface geochemistry in environmental management (Card et al., 1981; Shilts, 1981).

It is probable that public concern for ecological and health related aspects of environmental geochemistry will force far more attention to be paid to the subject. This concern eventually will issue in demands for co-ordinated management of atmospheric, hydrologic, and surface chemistry. Since the hydrological cycle is the major mobilizing agency for elements in the surface environment, this is a reasonable position. If there is to be a useful response, however, several agencies of government – including the Geological Survey – must begin now to consider the requirements for comparable regional data. For there to be a worthwhile data base for management purposes by the turn of the century, it is necessary that co-ordinated definition of measurements and data structures be achieved by the early 1990s, so that instrumentation, surveys, and monitoring (essential for the atmospheric and hydrologic components) can proceed in the following decade. There are substantial pieces of this implied programme already in existence, but no co-ordinated scheme.

This may represent the most significant emerging problem for the Quaternary and engineering geology sector of the Geological Survey in the next 15 years. It is subtle, complex, and eventually will require a high degree of interagency co-operation. The latter requirement may influence data handling and information development methods in entirely nontraditional ways. To begin, the integration of investigations of surface chemistry into the regional mapping programme is an important goal.

5.5 The geological record of environmental change

Climate change is a second major aspect of environmental stability that has become prominent as a result of human industrial activity. The balance of expert opinion suggests that, within the next century, human activity may effect a rise in global mean temperature of the order of one or a few degrees (Celsius) (see Liss and Crane, 1983, for a thoughtful review of the issues). The consequences for Canada – a cold, northern country – may be substantial (Atmospheric Environment Service, 1985, 1986), hence the country should pursue an active research programme into the regional consequences of climate change. This focus would be quite different than the presently dominant theme of determining global controls of climate.

The study of climate change entails Geological Survey effort because a retrospective picture of past climate is an important part of the work. Instrument records (of 100 to 200 years length, at most) are inadequate for this task, and the prior record lies in the stratigraphy of continuously accumulated sediments (see Church, 1980, for a further perspective). There are two distinct aspects of the interpretation of sediments in studies of past environments:

(i) estimation of climate parameters;
(ii) estimation of the land surface and vegetation conditions.

Most attention has been given to the former; insofar as this issue impinges on society and public policy, the latter is more important.

The policy and management problems presented by the prospect of climate change will be analyzed in terms of decades over a range of a century or so. Retrospective research on climate variability that can contribute usefully to considerations at this temporal scale requires records of annual resolution. Sediments preserve such records only fortuitously where annual rhythmites occur – although the signature may be chemical rather than physical. On the time scale of centuries, woody vegetation and glacier ice are more generally useful indicators of annual events (which is not to say that sediments should be ignored). The environmental response to different climates in the past, however, is preserved only in the geological fossil record of floral and faunal remains, of former soils, and indicators of erosion and sedimentation. The regional consequences of climate change must be studied, retrospectively, by geological work.

The bulk of geological effort everywhere has been oriented toward understanding the tempo of Pleistocene glaciations and the changes accompanying the glacial/nonglacial transition of 14 000 to 10 000 years B.P. This contributes to the grand enterprise to understand the ultimate controls of climate. It will not directly contribute to appreciation of the environment that we may face in Canada within the next century. The current estimates of projected changes are comparable with changes that have occurred within the Holocene Epoch. The widely forecast 2-4 Celsius degrees warming would perhaps yield hypsithermal conditions (as at ca. 7000 years B.P.) in Canada (although significant phase lags in terrestrial vegetation response may prevent the analogue being realized).

It appears that the Geological Survey should anticipate the requirements for information about regional environmental response to climate change by encouraging a substantial increase in the study of Holocene environments in Canada. The Paleoecology Subdivision within Terrain Sciences Division comprises the core group of scientists around whom this effort would be developed.

5.6 Environment as hazard: Holocene geological processes

Increasingly dense settlement around Canada's major metropolitan centres has pushed building activity onto sites that are exposed to environmental hazards such as landslides, floods, or wave forces (on coasts). Similarly, some resort and cottage areas are sited – for supposed amenity value – in hazardous areas. Major engineering works in steep terrain, including main communication routes, may be similarly exposed. Canadians demand a high degree of protection from natural hazards and expect public officials to provide it through a mixture of land use zoning, safety patrol (on communication routes), and requirements for or provision of adequate structural defences. Many of these hazards are the direct result of contemporary geological processes.

In addition to active hazard, many sites present difficult building conditions because of topography or soil characteristics. Ice-rich permafrost, muskeg, and certain soils that are subject to piping are examples.

Site scale geotechnical investigations are the means to identify and assess hazardous conditions in any particular project. That task is the responsibility of the project developer, or of provincial or municipal licencing or regulatory agencies. There remains a critical role for the Geological Survey of Canada, beyond that of providing the regional geological context for site investigations:

(i) The characteristic regional occurrence of geological hazards, in light of bedrock and surficial geology, recent earth history, and contemporary seismicity, should be studied and described. This is an effective contribution to both engineering knowledge and education in the country (e.g., Clague, 1982).

(ii) Documentation of the occurrence and history of sensitive soils should be a prominent part of surficial geology investigations.

(iii) For planning purposes, the regional incidence of some types of events is desirable to know, but they are too rare at individual sites for there to be an adequate historical record. The regional mapping and dating of events (such as major landslides) or stratigraphic studies of recurrence (debris flow) is then the best basis for hazard evaluation.

These matters introduce us to the study of geomorphological processes. There is no single well developed centre for such studies in the Canadian government, and it appears unlikely that one will develop, if only because this would cause major administrative difficulties in the water sector. Even studies of the more obviously geological aspects, such as soil and slope stability, have been carried on in several federal agencies (National Research Council, Division of Building Research; Environment Canada, National Hydrological Research Institute, Snow and Ice Section; Geological Survey) as well as in various provincial agencies. Emphasis on mappable, regional aspects of slope hazards, and thus correlation with the geology and Quaternary history (cf. Mollard, 1977; Cruden, 1985), appears to be a suitable focus for Survey activity. The recently established programme to study regional occurrences of major landslides (e.g. Evans, 1984) and the contribution of major reviews of the geological context of certain hazards (e.g., Eisbacher, 1979; Eisbacher and Clague, 1984, on debris flows) represent appropriate work.

The mapping of ground ice and permafrost sensitive soils is a difficult task. It is also important, since 50 per cent of Canada is underlain by permafrost. To some degree, landform interpretation can achieve the result; however, geophysical methods appear promising, and it possibly is in further development of geophysical technique for regional characterization that the Survey should concentrate its efforts.

5.7 Hydrogeology

Groundwater supplies domestic water for about 25% of Canada's population. On the prairies, it also serves as a significant source of water for agriculture. Furthermore, groundwater studies are a significant means for assessing environmental change. It has come to be expected, in Canada, that the environment should be monitored to obtain records of natural conditions, thence to determine the environmental effects of resource development. The best method of monitoring the geological environment of surficial materials is to investigate the head and quality of groundwater. For this purpose, monitor wells must be installed in major aquifers.

For many years prior to 1966, the Geological Survey was responsible for groundwater investigations in Canada. Since then, it has been the responsibility of Environment Canada, Water Resources Branch. There has never been a systematic programme of groundwater data collection, and geological studies of groundwater occurrence have not been a prominent part of federal science in recent years. In part, this probably arises from the provincial control of water resources. Nonetheless, the Enquiry on Federal Water Policy (Pearse et al., 1985) noted with concern the relative lack of groundwater studies.

Several of our questionnaire respondents remarked that studies of groundwater occurrence should be reemphasized and consider that the Geological Survey is the appropriate agency for this activity. There is also considerable sentiment within the Survey that this is an appropriate activity to incorporate within Quaternary geological mapping programmes, since the stratigraphy of surficial deposits is closely examined at that time. The intimate relation between groundwater occurrence and many geological engineering problems gives an immediate practical point to the issue.

This introduces a difficult matter of dividing responsibility between water and earth science sectors in the federal science service. We are inclined to the view that the geological context and engineering implications of groundwater occurrence make regional reconnaissance and identification a suitably geological topic (cf. Mollard, 1970), but that groundwater management remains a federal-provincial water sector concern. Geological concerns extend also to groundwater quality determination in regional geochemical investigations, and to the use of geophysical methods to determine groundwater occurrence. Whether this division of activity is administratively feasible we cannot judge: if something like it were to occur, it would require that personnel resources be added to the Geological Survey by transfer from the federal water sector.

5.8 Methods for data acquisition

We received a number of suggestions from users for possible areas of Geological Survey research under this rubric, but no single suggestion was widely repeated. They included the following:

- remote sensing of surface materials;
- mineral exploration techniques;
- techniques of engineering geophysical measurements;
- interpretation of geological information;
- dating methods.

The Geological Survey relies heavily on remote sensing methods (which include conventional airphoto interpretation) and has participated in development of airborne geophysical remote sensing methods. For many years now, researchers have attempted to automate airphoto or satellite image interpretation by techniques for classification of spectral signatures of reflected signals. The approach remains insufficiently reliable at present for routine adoption. Because of the special difficulties of access (Section 5.2), inshore marine areas may be a significant area for development work in remote sensing methods.

The till geochemistry programme of the Geological Survey represents a contribution to mineral exploration technique (cf. Shilts, 1984). We have discussed the significance of this work in its broader context (Section 5.4) and certainly expect to see further developments.

Engineering geophysical measurements have also been a subject for substantial research in the Geological Survey of Canada, especially in application to permafrost and ground ice mapping. We expect that this effort will continue. Inshore marine areas may, again, prove a fruitful area for development of practical geophysical methods.

Several users called for work on the interpretation of geological information. These represent nongeological users – foresters, planners, and other resource managers – who may not be well trained in geological science. They are seeking a systematic basis for interpretation of geological maps in terms of their own information needs. This appears to be a useful area to which to give attention, for it simultaneously informs the Geological Survey about the uses of geological information. Some interpretation techniques can be reduced, at one level, to semi-objective decisions (cf. Ryder and MacLean, 1980); others retain the need for substantial interpretive judgement. Continued attention to this topic by the entire regional mapping staff – rather than any special project – appears to be warranted.

The Geological Survey's radiocarbon dating laboratory is the major Canadian centre for absolute dating of Quaternary materials. Many users consider it appropriate for the Survey to provide a dating service. In recent years, a range of other suitable dating methods has appeared. Users consider that the Geological Survey is the major Canadian scientific authority to appraise these methods and to place ones that will have wide application on a readily available basis.

Special skills are required for development work in all of the above areas. There is no guarantee that the Survey (or any other body) can make breakthroughs at any particular time. The development of methods appears to be a particularly good topic for the Survey to enlist the collaboration of the wider earth science community in Canada. We will return to this matter in Section 8.

5.9 Summary recommendations on contemporary problems

This section provides a brief statement of the major problems in Quaternary and engineering geology that we expect may engage the attention of the Geological Survey during the next 10 years. We add some remarks on resources that may be available to tackle them.

(1.1) The Geological Survey should continue to regard the regional geological mapping programme – and attendant interpretation of Quaternary history – as its major and most important activity. However, mapping scales should reflect the level of economic activity in the regions of Canada. Final selection of appropriate scales, as large as 1:25 000 in the Census Metropolitan Areas, should be made following studies of information standards in maps.

This recommendation need have no net effect on resources dedicated to the regional programme, but would entail a redistribution of effort. There is substantial sentiment in the user community to increase the pace of the regional mapping programme should the total resources available to the Survey for Quaternary geology be increased.

(1.2) Increased attention should be given to coastal and inshore marine mapping with the objective of producing integrated maps of onshore and marine surficial geology and coastal features. Geophysical, remote sensing, and small boat techniques should be developed to improve field technique.

This recommendation probably would entail increased personnel and effort in the Geological Survey, initially best deployed in the area of development and evaluation of methods, but with a clear view to establishing criteria for mapping and then proceeding to that task.

(1.3) Enquiries should be made into the possibility for increased co-ordination between Quaternary geology and soil mapping activities at the regional scale. Initially, this should take the form of consultations between the Geological Survey and the Soil Survey of Canada.

There are no immediate resource implications of this recommendation. If coordination were affected, it probably would influence regional assignment of current personnel. If successful, it may consist largely of upgrading standards for co-ordinated mapping in several agencies (mainly provincial) rather than leading to distinct new programmes. A similar recommendation was made (informally) by Coope et al. (1983: p. 23).

(1.4) Investigations of the geochemistry of surficial materials should be integrated into the regional mapping programme. By reviewing current experience, an analysis should be made of what information and what procedures for data collection, analysis, and reporting are apt to be of most general use in the next 15 years, bearing in mind applications both in mineral exploration and in environmental management.

In view of the current expertise in the Survey, this recommendation has no immediate resource implications; however, it may affect the effort involved in regional mapping and, eventually, the laboratory resources and mix of geological skills present in the Survey.

(1.5) The Geological Survey should encourage a substantial increase in the study of Holocene environments in Canada.

This is a significant emerging issue since it will contribute to analysis of the environmental consequences of expected climate change and resource development activities. The basis for this work lies in the regional mapping programme, as does the basis for interpretation of Pleistocene history. However, Quaternary scientists in Canada have customarily dealt with Holocene events as clearly subordinate to Pleistocene history, much as an earlier generation of bedrock geologists dealt with Quaternary events. This recommendation does imply a substantial broadening in the focus of regional work and a more central role, perhaps, for the Palaeoecology Subdivision. Reorientation of individual's efforts, rather than a net addition of staff, will serve this recommendation, at least initially (see also Section 8).

(1.6) The Geological Survey should encourage the study of regional, mappable elements of environmental hazards related to bedrock and surficial geology, and should give emphasis to sensitive soils and permafrost occurrence in regional mapping.

These are, again, aspects of investigation that are best executed within the regional mapping programme. They are most likely to affect the pace of mapping and the skills of the geologists, rather than the absolute level of resources required. A small cadre of specialist experts will be required to support the work and to develop methods. The current establishment appears to allow that (see also Section 8).

(1.7) The Geological Survey should consider reemphasizing regional appraisal of groundwater conditions in its regional mapping programme, particularly in the Prairie Provinces.

This recommendation has implications for the organization of federal technical studies of groundwater resources: serious pursuit of it would entail transfer of personnel resources to the Survey. This course appears rational to us because of the essentially geological nature of the task; however a decision about it cannot be made from within the Branch.

The above recommendations collectively imply more interpretive and special purpose effort in regional mapping and, to report the results, more attention to the publication of comprehensive regional reports (Memoirs). This may appear to slow the pace of work. There is no easy way to balance judgments about how best to use time and resources in regional projects. It depends upon the most pressing needs for information in each region of the country. We do note that much of the information is more easily marshalled and interpreted on the basis of the larger scale mapping recommended for settled areas, where the results are of greatest significance (cf. Armstrong, 1984, for an example). The need to make these judgments is another reason why regional mapping staff should be present in and closely associated with their regions of activity: in particular, onshore, coastal and inshore marine mapping should be coordinated by project groups working from the same base.

It may be argued that the range of interpretive tasks discussed here is too great for an individual geologist. Bearing in mind the primacy of regional context in all of the Survey's work, we have little sympathy with this view. The prospect does fairly imply, however, that the Survey must continue to encourage specialist interests within the establishment, and to use specialists to conduct continuing in-service training for its staff. We will touch this matter again in Section 8.

The first recommendation, on the conduct of the regional mapping programme, has substantially the greatest priority. However, several of the other recommendations have operational consequences chiefly for regional mapping, and all of them impinge upon regional mapping. The priority to be accorded to the other individual recommendations may shift within the decade as public policy issues rise and decline. However, recommendations 1.4 and 1.5 – concerned with long range environmental stability – will require consistent, purposeful attention if the country is to be well prepared to manage its environment.

User opinion does lead to one clear recommendation on priorities for work within the regional programme:

(2.1) The Geological Survey should give relatively increased attention to mapping within the settled regions of the country, including compilation of updated maps near the major centres of population.

This directly reflects the areas where Quaternary geological information will be of greatest use and most economic value. This activity will in part be achieved with provincial collaboration.

6. ACCESS TO GEOLOGICAL DATA

6.1 Using and archiving geological data: time for a change

We received a good deal of advice from users on this topic, nearly all of it to emphasize that the Geological Survey should use contemporary data processing technology to allow results to be released more quickly than heretofore, in more standard format, in machine-readable form, and including both field observations and geological interpretations. This matter seems like Pandora's box!

Twenty-six per cent of our respondents asserted that information developed by the Geological Survey should be stored in a computer archive; 32 per cent stated that data banks should be created for Survey data or for all national geological data. These two tallies do not overlap, so that 58 per cent of all our respondents mentioned these closely parallel themes. Yet we did not specifically ask a question about them. Our question 6(b) (Appendix 2) – enquiring whether users foresee the need for changes in the 'means of presenting geologic information' – represented our lead. We also received statements about automation of data storage in replies to questions 3 and 7. The comments came overwhelmingly from geologists and engineers, who form 69 per cent of our respondents but who supplied more than 80 per cent of the remarks on the topic. Comments arose from all parts of the country and from all employment sectors. Only 13 per cent of our respondents explicitly mentioned the need to obtain access to basic field data, but it is clear from the remarks of most of the 58 per cent that they intend as much. Amongst all issues raised by our respondents, only the importance of the regional mapping programme merited more comment. A rationalization of this interest in data processing technology is required.

All geological investigations require first a study of existing information, including published and open file reports, and – increasingly – access to original field observations and laboratory analyses. The geological syntheses available in the published and open file reports provide a framework for further investigation. To update a study or to conduct more detailed investigations, however, certain original field observations and laboratory analyses should be available for collation with information collected for the specific investigation. Hence, one respondent emphasized the need for "... automated access to site specific data, independent of map scale. Site data catalogued according to coordinates (of the military grid reference system) allow for frequent updating and revisions of automated plots and maps. If all resource data collection procedures used this reference system, integration of data bases would be greatly facilitated" (parentheses added). In addition, in many engineering and land capability studies today, it is desirable to interpret and present field information in a manner different from that achieved by a conventional geological map. This fact makes the issue discussed in this chapter particularly relevant in the fields of Quaternary and engineering geology, though it is, in fact, a perfectly general problem.

Published information is available in libraries and open file reports are accessible in agency offices or from private distributors. Field observations and laboratory analyses, if available, should be held in data banks.

Most primary information in the Geological Survey of Canada remains in field and laboratory notebooks which are essentially inaccessible outside the Survey. Aside from the extensive files of geophysical and geochemical data, the basic system of recording and preserving field observations has not changed since Sir William Logan's day. Until relatively recently, the field books of Survey officers ultimately were deposited in a central technical file where they could be consulted. (Many of the earlier books are now in the Public Archives of Canada.) Beginning in about the mid-1960s, however, the rush of special purpose projects and the rapid expansion of the Branch establishment to execute them led to the breakdown of this system. Today, most of the notebooks remain with the field officers. We suspect that many of them would not be usefully interpretable by a third party, even if they were available. (This is not quite the critism of officers' conduct that it appears to be; the widespread adoption of airborne field reconnaissance is a major reason for the deterioration of notebook manners. The machines move quickly, and operational costs apparently are too great to permit essays on an outcrop; much too much is seen in a day for even an arctic evening's writing.)

This is an unsatisfactory situation. Field information is collected at substantial expense and should be permanently accessible to save the cost of recollection. Indeed, much evidence may not be re-collectable, since outcrops are destroyed and excavations filled. Nor should one assume that the interpretation of field evidence that is made immediately after its collection is definitive. Finally, the present Access to Government Information Act seems to require that primary technical records of the federal government be available for inspection.

Field books are no longer the appropriate place to store much of the information. Contemporary methods for handling data make machine transfer, editing, storage and analysis possible. Most geophysical and geochemical records are efficiently handled in this way, and a large amount of outcrop and surficial data could be similarly handled. One respondent identified an important application of the resulting archive: "For data integration,most geological information would have to be in a digital format. Currently most remote sensing data are in digital format. Data integration is now a *must* for exploration strategy." (user's emphasis) Another, more laconically: "Anyone working in a map medium needs to be looking at electronic forms of data and computer processing." Geological information is being handled in this way in some provincial surveys. It is time for a definitive change at the Geological Survey.

6.2 Data stream: acquisition and banking

There is, then, a widespread opinion amongst users that the Geological Survey should commit basic field observations to a standard machine-coded format, and release them along with the geological maps. It is supposed that input cards would be made out in the field, with later collation of laboratory data. It is thought that this will expedite completion of maps and reports, as well as preserving data in an accessible form: "As inevitably more data become available it will be necessary to obtain access to data more readily. Therefore the real advance will be improving access to existing information, not collection of different types of data."

We received many suggestions for specific items of information to be handled in this way (many derived from our question 3). Items of field observation included lithology or lithostratigraphy of deposits (several mentions), section logs, depth to bedrock (several), fabric of deposits, and ice flow direction. Laboratory data included geochemistry of soil and water (seven mentions), texture of deposits (three), heavy minerals (two), soil salinity, and per cent calcium carbonate. Complex information requested included geotechnical properties of soils, aquifer characteristics, geophysical borehole logs, and marine subbottom profiles. One might imagine that much of this information could be of substantial value only if known in considerable spatial detail; however, one thoughtful respondent remarked that it remains of indicative value even when collected on a reconnaissance basis. Further, the total accessible information would be cumulative in an automated storage system.

There is a wide range of opinion amongst field officers (and amongst geologists in general) about the desirability of all this. Some suppose that reduction of field activity to "form filling" will destroy the geologist's ability to integrate field observations of different types, to synthesize field evidence, and to follow emerging regional interpretations in the field. In a technician's approach to geological mapping, there is some danger of this, but for a professional geologist it is a spurious argument. It is unreasonable to suppose that all field information must be reduced to formal categories and that the geologist's notes and sketches will no longer exist or be important. It is unreasonable to suppose that standard field data forms need constrain observations. Figure 6.3 illustrates two such forms, one designed in the Geological Survey with no single mapping system in mind; the other designed in the British Columbia Ministry of Environment with their terrain mapping system (see Ryder, 1986) in mind. Neither exhausts the range of desirable observations; neither precludes taking notes.

Field data forms may or may not expedite the subsequent analysis and release of geological information – that probably depends upon many subsequent stages in the work – and the users should not regard standard taking of notes as a panacea for information transfer problems. However, standard

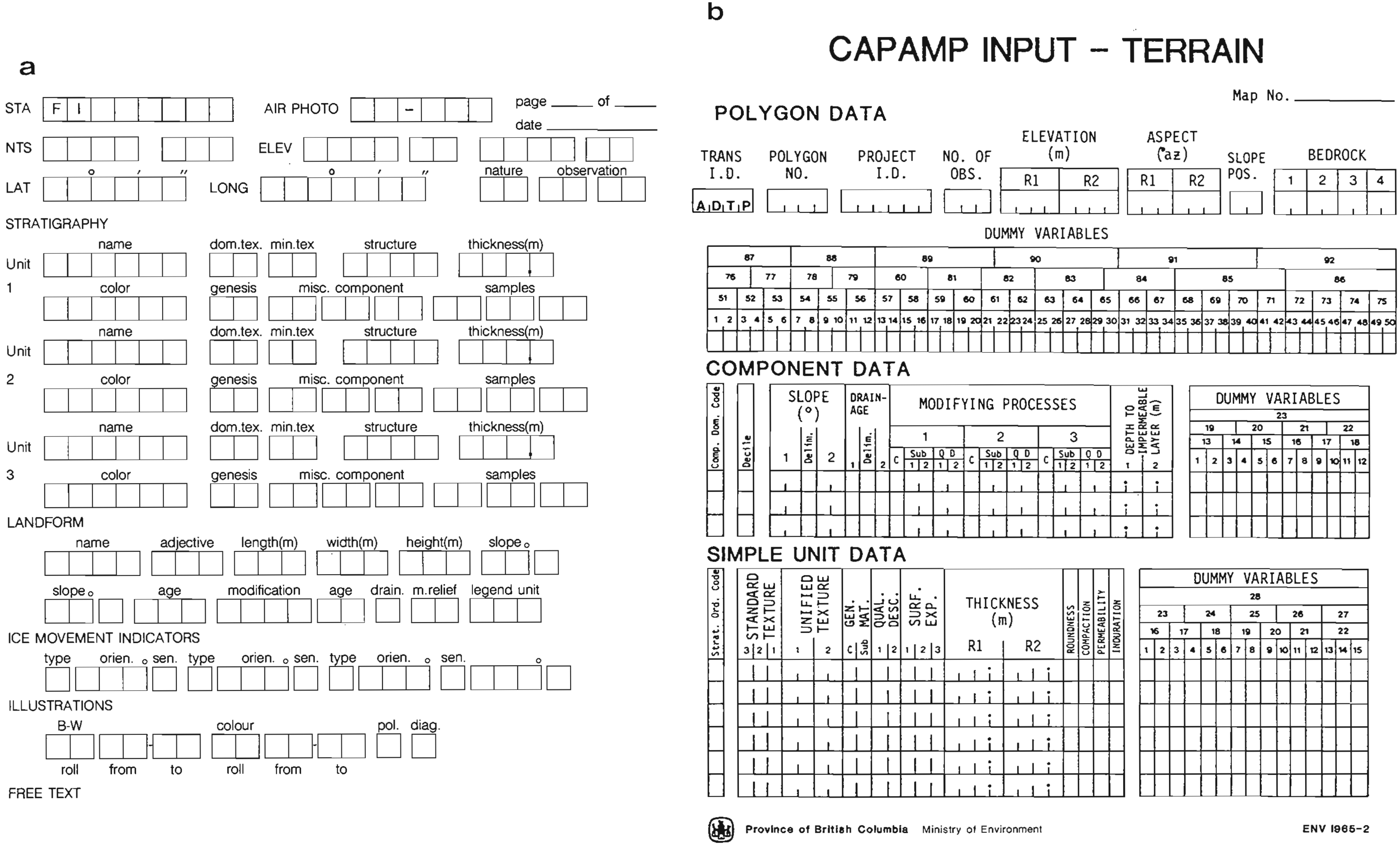


Figure 6.3. Examples of terrain data acquisition forms: (a) Geological Survey of Canada; (b) British Columbia Ministry of Environment Terrain Analysis data entry form.

notes will substantially simplify the archiving for public access of certain basic observations and may improve the consistency with which they are recorded. These are desirable ends. They will become more imperative as certain geochemical assays or geotechnically oriented measurements become integrated with regional mapping on larger scales. Efficient methods for machine-aided data recording and banking should be pursued with a view to a degree of standardization in basic site observations, and ready accessibility to them by users.

6.3 Data stream: retrieval

Users wish to have Geological Survey data available on-line via computer terminals. One user notes: "With present technology improvements, the geologic information should be computerized such that access can be made from the Geological Survey of Canada centre to a user via a telephone line patch anywhere in Canada. So much time and money is wasted chasing information hidden in offices and on mainframe computers." We understand the sentiment. It is, however, curiously at variance with the appearance that on-line bibliographic services are not so widely used as they could be. For many users, costs may intervene, and these may not have been considered by users in formulating their opinion.

The Atmospheric Environment Service has recently instituted a system of substantial charges for recovery of costs of computer edited climate data. Furthermore, the main public report of Canadian climate data is now published only on microforms. This restricts the dissemination of climate data to those with access to certain machinery, or with the ability to pay costs. Some users of data, especially students, casual and occasional users, are left at a disadvantage. We think that such a situation should be avoided for data of surficial geology. Data ought to be available via intermediate machines such as microcomputers, and there should be a "hard copy" alternative. This might restrict the use of a computer data bank for some time. We are not certain that, in the short run, it would be cost effective. There can be no doubt, however, that this will become the main means of information transfer for nearly everyone in the intermediate term.

Given the necessity for a period of experimentation with any new information service, we endorse the notion that the Geological Survey should begin now to develop an appropriate general system of data management with a view towards direct user retrieval for Quaternary and engineering geology information. The 'shopping list' of items of information given in Section 6.2 is very broad. Some of the items already are released in special purpose Open Files. We suggest that for the development period attention be restricted to data that are amenable to direct recording by machine compatible codes on the outcrop or in the laboratory. For example, a record made for principal field observation and sampling sites might consist of the following (as available): co-ordinates of the observation, surface landform code, ice flow direction, surface material (C horizon) texture and lithology (qualitative; quantitative if available), surface material chemistry, stratigraphy (thicknesses and textures), recent process code, codes for samples taken. This covers most data that it would be reasonable to expect to use without direct collaboration with the field officer. It hardly differs from the data that would be recorded on the extant GSC coding sheet illustrated in Figure 6.3a.

To date, Terrain Sciences Division has established limited experience by developing a data management and analysis programme for data derived from geochemical and textural laboratory results (Burns, 1985). Already, this sets some minimum field description standard requirements for samples.

6.4 A geological data structure: integrating data streams

Geographic data structures (GDS) are formal arrangements for storing information with geographical coordinates. Geological data are of this sort; however, geological data possess several characteristics that are difficult to reconcile in contemporary computer data banks.

(i) Certain data are point-parametric; that is, the observation is summarized by a single number or code at a discrete point in geographical space (e.g., a geochemical assay; topographic gradient).
(ii) Data may be chorological; that is, a (supposedly) homogeneous unit is identified which has finite spatial extent (landforms or terrain units; outcrop pattern of a formation).
(iii) Data may be stratigraphic; that is, a string of information representing variation with depth below the surface is recorded at a point in space.
(iv) Data may be linearly distributed; that is, there is continuous variation in some geographical direction(s).
(v) Data may be fully distributed geographically.

The characteristics of the data may owe more to the method of observation than to an intrinsic property of the phenomenon. For example, fully distributed fields, such as magnetic field strength, are often observed by airborne line scans. The field is estimated by interpolation between lines.

Data of types (iv) and (v) can be made consistent with type (i) by taking discrete estimates of the field at fixed points. Type (iii) data similarly can be made compatible with type (i) by attaching a multi-field descriptor to the geographical location of the stratigraphic exposure. All of these data can be incorporated into normal x-y matrix based GDS, although there is a tradeoff to be made between data density (hence file size) and information preserved when fields are made discrete. This becomes a matter of data standards (Section 6.6).

Type (ii) information represents the classical product of geological mapping exercises – to delineate areas of the earth's surface of more or less homogeneous geological character. Computer storage of this information is more difficult than storage of point data and is scarcely compatible with it. For this reason, an efficient, completely automated "geological data structure" is not yet in view. This should lend caution to the planning of computer data banks for comprehensive storage of geological information. It should not be an excuse for ignoring them.

6.5 Regional data banks

Another view held in the user community is that the Geological Survey should take the lead to develop regional data banks – or data management systems – containing all available information from all sources. It is suggested that a central data bank be housed in the Geological Survey of Canada, with a regional bank in each province. They would be operated as archives with computer transmission and paper reproduction facilities. Analogue records (e.g., geophysical borehole logs) and maps could then be stored and distributed as well as digital data.

Again, users do not consider costs (it is supposed that the banks would be jointly funded by federal and provincial governments), hence the cost-effectiveness of such a venture is hard to predict. And again, charges to users would influence accessibility to the service and the real effectiveness of it.

On the other hand, the service surely would make the available geological data more widely useful. It could substitute for substantial additional and expensive field activity provided the contributed data meet certain standards for resolution and precision. The idea may be practical in certain regions or in special circumstances. For example, one user noted that: "The large offshore area with its many engineering constraints to development has and will in the future result in large data collection and interpretations by GSC, university and industry. This will be a disjointed data base and repetition of expensive data collection at the taxpayers' expense, no matter who collects, will occur unless a policy of co-ordination is formulated." The feasibility of regional data banks should be studied further. The likely costs of operation will be influenced by the requirements that are imposed upon contributors for data formats and standards, and by the developments that may occur in data banking within the Geological Survey. We will return to this issue at the end of Section 7.

6.6 Standards and formats for geological data

Data that are to be manipulated, stored and transferred by machinery must conform with some specified formats. Furthermore, if they are to be widely disseminated, they should meet some criteria for quality (meaning, principally, resolution and precision). A number of users suggested that the Geological Survey of Canada should lead attempts to establish some national standards for mapping surficial deposits. No one was specific about what this means. Beyond the requirements of automatic data processing systems, there are several substantive reasons why some standards appear to be desirable:

(i) They would guide the appropriate effort – hence cost – to map a given area at a given scale, hence contribute to rationalizing project planning;
(ii) They would help to co-ordinate mapping by different individuals, allowing contract work and private work to be incorporated into a national data base of relatively superior quality;
(iii) They would guide the practice of appropriate generalization for production of regional synthesis maps at small scale;
(iv) Their existence would simplify the problems that nongeological users experience in learning to interpret geological maps.

The last point was the subject of several user comments. For example, "There is a definite need for a standardized means of presenting terrain information on maps. The professional geologist can cope with the variations, but they make life unnecessarily complicated for non-geologists."

Some degree of standardization in formats has occurred for terrain mapping inasmuch as the system of terrain representation developed by Fulton (Fulton et al., 1975) has become the basis for mapping legends developed by others (e.g., Rutter, 1977; British Columbia system of terrain classification, Ryder, 1986). It must be cautioned, however, that there is a limit to how far standardization can be taken, since the variation in terrain across the country requires that description of units be varied, just as in traditional geological maps. In British Columbia, individual map legends vary within the framework of the Terrain Classification System.

Geologists in Canada have paid relatively little formal attention to questions of mapping standards. Within the Geological Survey of Canada, Terrain Sciences Division maintains a Map Legends Committee which scrutinizes manuscript maps to ensure that there is consistency in the presentation of the Survey's surficial geology maps. The committee does not apply rigidly uniform rules, nor does it proceed from a strictly standardized classification.

Canadian pedologists have considered the matter of map standards at length (cf. Valentine, 1981; Mapping Systems Working Group, 1981). Their results are conventionally expressed in terms of "survey intensity", which describes the number of ground site checks per map unit (cf. Mapping Systems Working Group, 1981, tables 2 and 3; their table 2 is reproduced here as Table 6.9). There are two factors underlying the judgment about desirable survey intensity: (i) the purpose for which the map is being made, hence the precision of its unit delineations, and (ii) area covered and scale of presentation.

The examination of field effort in terms of site checks does not exhaust the problem of mapping standards, since the variability of the landscape itself will influence the level of effort necessary to achieve a given precision in mapping. If we suppose that the precision achieved in a mapping exercise should approach map resolution (for the smallest units present in the map area), then the mapping scales discussed in Section 5.1 imply something about mapping standards.

To obtain a notional idea of the correspondence, let us suppose that 2 mm is the smallest unit dimension that can be recorded reasonably on a map. Then at 1:25 000, the smallest field unit dimension would be 50 metres, at 1:50 000, 100 metres, and at 1:500 000, 1 km. Beyond 1:100 000 scale, most genetic map units probably would be of compound character in most parts of the country. For a 50x50 cm map sheet, the upper limit number of units would be 60 000. This figure is unlikely to be approached, but it does serve to remind us that the costs of data manipulation in practice impinge upon achievable map resolution.

The only way to learn about the comparative standards for mapping at various scales appears to be to conduct trial mapping at several scales in several regions and to directly compare the information that is recorded. This exercise has not been pursued in Canada (but see Valentine, 1981, for a soils example), but we believe that it should be, so that a basis can be established for the "precision of mapping." (We would be sceptical of an attempt to resolve this issue on the basis of collation of results from elsewhere in the world because the nature of the terrain may influence the outcomes. Indeed, it will be found necessary to tailor results regionally within Canada; standards – even criteria – for mapping in the Cordillera will be different than those for the prairies.)

A related issue is interpreter skill. Valentine (1978) conducted a comparison of terrain mapping from 1: 20 000 air photography and from enlarged LANDSAT imagery with experienced and inexperienced interpreters. Image quality and terrain character were found to affect interpreter performance significantly, but interpreter variance was satisfactorily low for a given image. The results indicate that terrain character will have an important influence on mapping effort for a given level of precision (related to map scale) to be achieved. Forested terrain of moderate to low relief is difficult to interpret. More trials of this sort are desirable to form a basis for judging appropriate mapping effort and ground checking.

The format of geological information represents a more difficult topic since appropriate representation may depend both on the nature of the landscape and the purpose of the study. One-factor parametric maps present little difficulty; at the other extreme, full geological syntheses are strongly constrained by the landscape. At the intermediate level of terrain units (see Section 7.1), which have been of interest to many users of geological information (e.g., Rutter, 1977; Nasmith and Gerath, 1979; Gartner, 1981, 1984), it is possible that a nationally useful set of formats could emerge. An expert workshop may be best the way to motivate an enquiry.

This Committee can make no final recommendations about formats and standards for Canadian data of surficial geology. The former will depend in substantial degree upon decisions about the form that automatic data manipulation might take. The latter requires information that is not to hand. We believe that the issue is significant for a variety of substantive reasons and endorse the proposal that the Geological Survey of Canada should co-ordinate a broadly based effort to work towards some recommended national standards for mapping, and for data amenable to standard definition.

6.7 Summary on access to geological data

Users strongly indicate that they wish to see the development of data banks of field observations, and provision for computer transfer of files. They also emphasize the need for more rapid release of field data and appear to see data bank facilities as part of the machinery to achieve this. In summary, there is a widespread conviction that, in the interests of consistency, currency, and accessibility, the handling of many geological data should become more like that of parametric geophysical records. The proposed developments could serve well the necessity for the Geological Survey to regain control of its primary data archive.

Table 6.9. Survey intensity level guidelines[1]

	Definitive Characteristics				Associated Characteristics	
Level	Procedure Intensity	Method of Field Checking	Range of (and usual) Publication Scale	Appropriate Levels of Soil Taxonomy (usually phases of.....)	Approximate Rates of Progress Per Surveyor, for 20 Day Month*	Typical Survey Objectives
1	At least one soil inspection** in every delineation. Boundaries checked in the field along entire length in open country, or over 30% in woodland (1-5)***	Traverses primarily on foot less than 0.5 km apart. Profile descriptions and samples for all soils.	1:14 000 or larger (1:5000)	Series	50-1000 ha	Information for many purposes down to the level of small farms, small stream catchments, conservation areas and urban sub-divisions.
2	At least one soil inspection in over 90% of delinea-tions. Boundaries checked in the field along most of their length in open country, or less than 10% in woodland (2-30)	Traverses on foot and by vehicle about 2 km apart. Profile descriptions and samples for all major named soils.	1:5000 to 1:40 000 (1:20 000)	Series or family	500-6000 ha	Information for many purposes down to the level of local planning for groups of farms, stream catchments, large urban sub-divisions or small national parks.
3	At least one soil inspection in most (60-80%) delinea tions. Boundaries checked in the field at intervals but mainly extra-polated from aerial photographs (20-200)	Some traverses on foot, many by vehicle up to 4 km apart. Profile descriptions for all major named soils; samples from the majority of soils.	1:30 000 to 1:130 000 (1:50 000)	Series, family, or subgroup	20-200 km^2	Information for limited number of purposes to level of farming areas, country planning, major stream catchments, and large national parks.
4	At least one soil inspection in 30-60% of delinea-tions. Nearly all boundaries extra-polated from aerial photographs (100-1000)	Traverses mainly by surface vehicle up to 8 km apart. Helicopter used in some areas. Profile descriptions for all major names soils; samples from the majority of soils.	1:50 000 to 1:300 000 (1:100 000)	Family or subgroup	75-500 km^2	Information for relatively few purposes to level of large agricultural areas, regional and provincial plans, major river catchments.
5	At least one soil inspection in less than 30% of delineations. All boundaries extra-polated from aerial photographs (1000-20 000)	Traverses entirely by vehicle up to 20 km apart. Heli-copter or fixed wing aircraft essential in some areas. Profile descriptions for any major named soils, samples from the minority of soils.	1:100 000 or smaller (1:250 000)	Subgroups, great groups, or orders	250-800 km^2	Information for few general purposes for broad regional or provincial plans.

* Rates of progress includes legend development, checking, correlation, and soil description, as well as the mapping itself.
** The term "inspection" is defined in Section 3.5
*** Approximate number of hectares represented by one ground inspection
[1]Mapping systems working group (1981, Table 2).

Figure 7.4a. Surficial geology (Jackson, 1983).

All this should not obscure the fact that geological data are complex and cannot entirely be reduced to computer codes. Developments in data management should be evolutionary and should give primacy to the need to preserve the full information content of observations. However, data manipulation and communication technology, and user adoption of technology are both evolving so rapidly that the Geological Survey must move now to be able to take advantage of them.

In addition, the Survey should co-ordinate an effort to move towards establishing some potential standards for data acquisition and presentation. Beyond the formal requirements of machine technology, there are sound substantive reasons to launch such an exercise.

We give our next Section to a further consideration of the basis for effective use of communication technology and we reserve our recommendations until the end of that section.

7. GEOLOGICAL INFORMATION AND GEOLOGICAL KNOWLEDGE

7.1 Approaches to mapping surficial geology in the Geological Survey

The presentation of "surficial geology" on Geological Survey of Canada maps has varied according to the assigned task that gave rise to the map, and according to the precedents followed. Leaving aside adjustments made to permit effective representation of particular landscapes, two major "styles" of map can be defined. Examples are given in Figure 7.4.

SURFICIAL DEPOSITS

NONGLACIAL ENVIRONMENTS

13 Organic deposits: bog, swamp and ephermeral lake deposits composed of peat and organic and inorganic silt and clay, 1 to 10 m or more thick.

12 Colluvial deposits: nonsorted debris, ranging from clay to boulders in texture, soliflucted, washed or tumbled into place from up slope areas; thickness ranges from less than 1 m on upper slopes to 10 m or more near slope toes; 12a, rock glaciers: slowly moving spatulate or lobate bodies of ice cored or ice cemented, angular and coarse rock rubble restricted to high alpine valleys; 12b, talus deposits: aprons or cones of coarse rubble accumulated through episodic, free falling and cascading of rock fragments from adjacent steep slopes and cliffs.

11 Fluvial deposits: gravel, sand and minor deposits of silt and clay, 1-30 m thick, deposited on floodplains or alluvial fans; 11a, modern alluvium, seasonally flooded; 11b, terrace deposits above the present floodplain or active parts of alluvial fans.

GLACIAL AND PROGLACIAL ENVIRONMENTS

Neoglacial Deposits

10 Neoglacial drift: sandy bouldery till lateral and end moraines adjacent to cirque glaciers and related minor deposits of sand and gravel.

Glacial Episode 4

9 Eisenhower Junction Drift: calcareous, stony, sand to clay loam-textured till and minor deposits of sand and gravel, restricted to areas adjacent to the Continental Divide (distinguished from the Bow Valley and Canmore tills by geomorphic relationships); 9a, hummocky moraine: hummocky till and kame deposits; 9b, discontinuous ground moraine: patches of till and minor sand and gravel interspersed with outcropping bedrock; 9c, outwash deposits: terraced or planar deposits of sand and gravel.

8 Midnapore Silts: sands and silts deposited in a lake ponded by the Laurentide Ice Sheet. It is entirely restricted to the Bow River Valley in the vicinity of the Midnapore district of southeast Calgary below 1035 m elevation.

7 Canmore Drift: stony till, glaciofluvial and glaciolacustrine deposits directly underlying valley bottoms and margins over most of the Rocky Mountain Front Range. It can only be distinguished from nearby deposits of Eisenhower Junction and Bow Valley drifts through geomorphic or stratigraphic relationships; 7a, hummocky moraine: hummocky till and kame deposits; 7b, discontinuous ground moraine: scattered areas of till and minor sand and gravel scattered in predominantly bedrock areas; 7c, outwash deposits: terraced, planar, or locally pitted deposits of sand and gravel; 7d, associated minor lacustrine deposits: fine sand, silt and clay; 7e, undivided.

Glacial Episode 3

6 Sheep River Silts and Clays: laminated to thick bedded clayey silts, silty clays and fine sands deposited in proglacial lakes in the Fish Creek, Sheep River and Highwood River drainage basins above 1035 m elevation; 6a, discontinuous deposits.

5 Erratics Train Drift: slightly stony, clayey loam and silty loam-textured till of mixed Rocky Mountain and Laurentide provenance, 1-10 m thick, includes minor kame deposits of sand and gravel. It can be distinguished from Bow Valley Drift by the presence of up to 1 per cent granitic and metamorphic clasts North of the Highwood River it grades continuously westward into Bow Valley Drift; 5a, hummocky ground moraine: hummocky till and poorly sorted sand and gravel; 5b, discontinuous ground moraine: patches of thin till in areas of bedrock or colluvium-mantled bedrock; 5c, kame deposits: ridged deposits of sand and gravel.

4 Bow Valley Drift: Slightly stony or stony sandy loam to clay loam till and associated glaciofluvial deposits, 1-5 m thick, entirely of Rocky Mountain provenance includes deposits of the correlative Ernst Till and related deposits in the Livingstone River basin, grades continuously eastwards into the Erratics Train Drift. Bow Valley Drift totally lacks granitic or metamorphic pebbles in its till or outwash; 4a, hummocky ground moraine; hummocky deposits of till and kame deposits; 4b, discontinuous ground moraine; thin, discontinuous patches of till scattered over exposures of bedrock or colluvium-mantled bedrock; 4c, outwash deposits; 4d, undifferentiated deposits of till and glaciofluvial sediments.

Glacial Episode 2

3 Chain Lakes Clays and Silts: laminated clays and silts and minor gravels 1-30 m thick; confined to elevations above 1300 m in the Willow Creek drainage basin; 3a, thin discontinuous silts and clays in an area of Maycroft or Maunsell drift or bedrock.

2 Maycroft Drift: stony, clayey loam, silty loam and loamy till of Rocky Mountain provenance and related glaciofluvial deposits, 1-10 m thick. Till lacks granitic or metamorphic clasts; 2a, hummocky moraine; hummocky till and kame deposits; 2b, discontinuous ground moraine: patches of till in areas of bedrock or colluvium-mantled bedrock; 2c, outwash: terraced or planar deposits of sand and gravel.

1 Maunsell Drift: slightly stony, clay loam till of Laurentide provenance and minor glaciofluvial deposits; granitic and metamorphic pebbles may comprise 20 to 50 per cent of till clasts; 1a. discontinuous moraine; patches of thin till in an area of colluvium mantled bedrock; 1b, hummocky moraine; hummocky till and kame deposits; 1c, kame deposits.

PRE-QUATERNARY

Precambrian to Tertiary

R Bedrock, undivided.

Oriented feature, direction unknown

Streamlined bedrock feature: direction unknown; direction known

Lateral moraine

Slope break

Glacial drainage course

Ice carved bedrock basin

Landslide: arrows show direction of movement

Glacier

Patterned ground

Areas known to be beyond the limits of glaciation

Boundary: defined; approximate; gradational; inferred

Symbol designation (used with morainal, stream and directional features): n - neoglacial; e - associated with the Eisenhower Junction Drift; c - associated with Canmore Drift; b - associated with Bow Valley and Erratics Train Drift; m - associated with Maycroft and Maunsell Drift

CORRELATION CHART

Glacial Episode	Provenance		
	Rocky Mountains	Mixed	Laurentide
Neoglacial	Neoglacial		
Episode 4	Eisenhower Junction Drift, Canmore Drift		Midnapore Silts
Episode 3	Bow Valley Drift	Erratics Train Drift	None recognized in the map area
Episode 2	Maycroft Drift		Maunsell Drift

A fragmentary record exists for Glacial Episode 1. This primarily consists of erratics located in the Porcupine Hills above the limits of the deposits of Glacial Episode 2.

Geology by L.E.Jackson Jr. 1974-1976

Figure 7.4a (cont'd.)

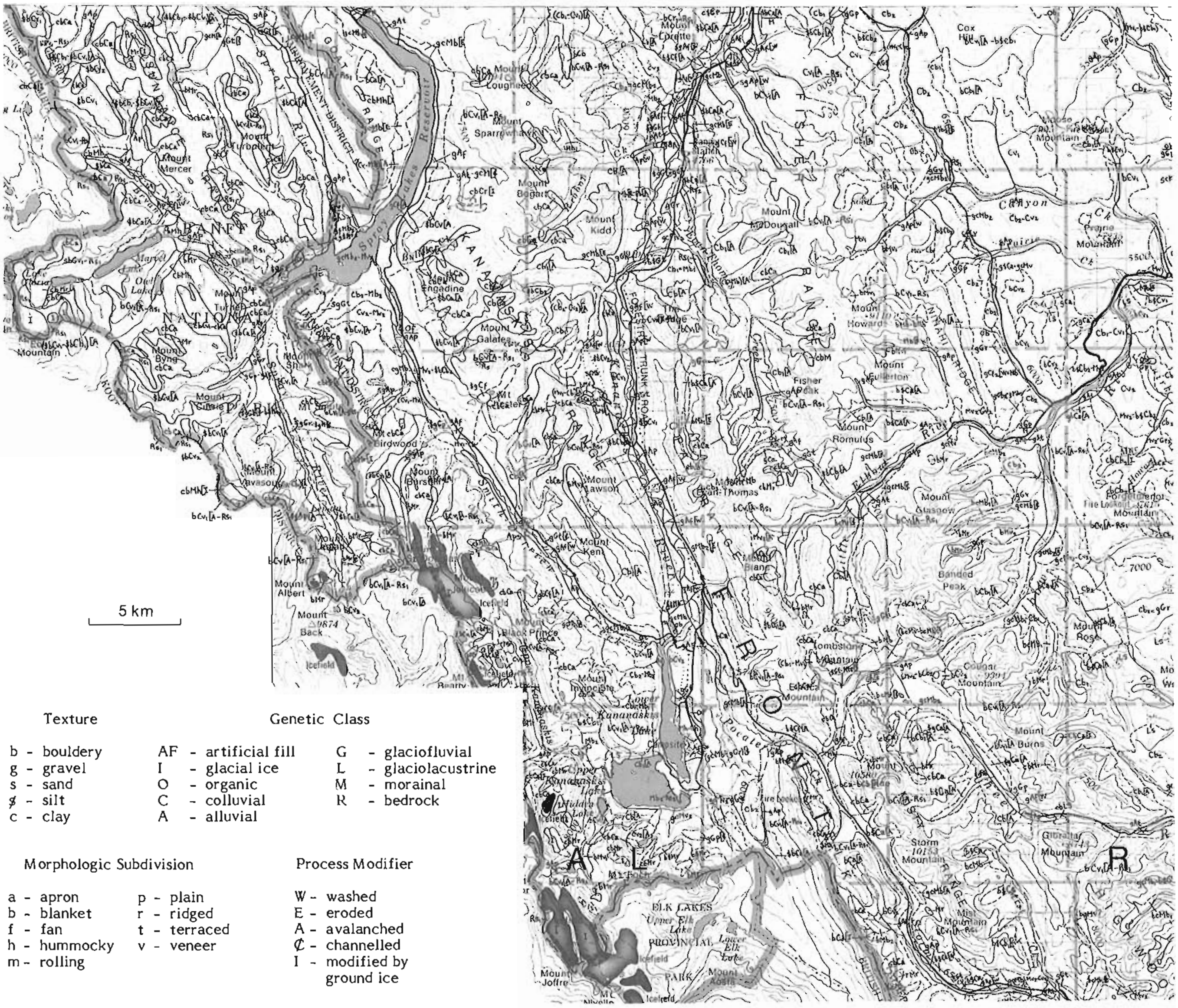
The first mapping "style" adopted for surficial deposits is the same as that used to produce a bedrock geology map. Lithostratigraphic units are identified and then surface outcrop pattern is mapped. Stratigraphic columns may be used to demonstrate subcrop relations. A correlation chart gives more or less precise chrono-stratigraphic equivalencies (Figure 7.4a). The style was borrowed directly from bedrock mapping when the regional mapping programme for surficial materials was established in the Pleistocene Geology Section of the Geological Survey after World War 2. The map is a classic "geological map", incorporating information of stratigraphic equivalence and geological history. For the professional geologist, it is the logical synthesis of a regional study. However, for nongeologists seeking specific descriptive information about land units, it is difficult to interpret because the synthesis leaves much of the descriptive field information only implicit. This is

	Deposit Name	Material	Thickness (m)	Topography	Slope (degrees)	Comments[1,2]
AF	artificial fill	diamicton	0-5	parallel to underlying topography; fills in low areas; forms artificial hills	<5	highly variable – ranges from engineered fill to buried inorganic and organic refuse
I	glacial ice	may be partly covered by bouldery rubble		cirque glaciers or complexes of cirque glaciers		may be subject to sudden calving, collapse, or jökulhlaups
LS	landslide	broken masses of bedrock	<1, >10	undulating or hummocky	0-25	may be creeping or subject to reactivation or inundation by new landslides
Cb	colluvial blanket	diamicton; poorly sorted stony sands and silty clays	>1	parallels underlying surface	0-5	USCS – ML–CL; low erosion and slope stability hazard; supports commercial and noncommercial forest, pasture
Cv	colluvial veneer	as above	<1	as above	0-5	as above
Cb_2	colluvial blanket on s_2 bedrock slopes	diamicton to very stony, poorly sorted stony sands and silts, local lenses of poorly sorted gravels	>1	as above	5-25	as above; erosion hazard increases with slope
cbCa	talus	bouldery rock rubble	0-10	aprons or cones along the base of a s_1 bedrock slope	25-38	subject to rockfalls from adjacent cliffs; constituent material near the angle of repose
Cf	colluvial fan	diamicton, bouldery rock rubble, poorly sorted gravel	5-25	cone or fan	4-25	USCS – GW, GM; subject to invasion by flood and debris flows and snow or rock avalanches; land use commercial or noncommercial forest
cbCa [I	rock glacier	bouldery rock rubble and interstitial ice or ice core	>1	lobate with longitudinal and transverse ridges on surface	>5	may be in slow downhill motion and in the process of slow collapse due to meltout of ice core
Ap	floodplain	sand and gravel and minor silt; clay and organic deposits	>1	plain	<1	subject to periodic flooding and lateral migration by streams
At	alluvial terrace deposit	as above	>1	terrace and scarp	<1,>10	highly permeable; usually good sources for sand and gravel
Af	alluvial fan	gravel, sand, diamicton	0->20	fan or cone	1-12	may be incised and inactive except for channel; active fans subject to flooding, lateral migration by streams, debris flow
Gr	kames and eskers	sand and gravel	1->10	ridges or isolated hills	0-15	USCS – G, S; highly permeable; source areas for sand and gravel
Gp	outwash plain	as above	1->10	flat or terrace and scarp	<1	as above
Lm	rolling glaciolacustrine plain	fine sand, silt, and clay	>1	flat to undulating	1-5	USCS – MH to CH soils in Prairies and easternmost Foothills; ML to CL soils in the Foothills and Front Ranges; LL 32-66%; PI 12-45%; UCS 15-45 psi; PR 10-34 blow/ft; WD 120-125 pcf; SPD 91-100 pcf; OPM 22%; low permeability
Mb	morainal blanket	till	>1	parallels underlying surface	0-5	USCS – ML and CL soils; LL 30-42%; PI 15-25%; UCS 31-43 psi; PR 31-35 blows/ft;
Mv	morainal veneer	till	<1	as above	0-5	WD 128-134 pcf; OPM 12-18%; permeability low
Mv_1	morainal blanket	till	<1	as above	15-35	as above
Mh	hummocky moraine	till, minor sand, and gravel	>2	complexes of rounded hills	0-15	complex stratigraphy
Mr	ridged moraine	bouldery till	0-8	ridged lateral or end moraine	0-25	very stony and low in plasticity; high elevation and rugged topography restrict land use; may contain buried ice near glaciers
R	bedrock	sandstone, shale, limestone, dolostone, quartzite, minor coal and conglomerate				

[1] USCS – Unified Soil Classification System; LL – liquid limit; PI – plasticity index; UCS – unconfined compressive strength; PR – penetration resistance; WD – wet density; SPD – Standard Proctor density; OPM – optimum Proctor soil moisture

[2] Test for easternmost Foothills and Prairies parts of the study area except where specifically indicated

Figure 7.4b. Terrain inventory (Jackson, 1986) for part of the Kananaskis Lakes (NTS 82J) map area and examples of units in the legend.



Texture		Genetic Class			
b - bouldery		AF - artificial fill		G - glaciofluvial	
g - gravel		I - glacial ice		L - glaciolacustrine	
s - sand		O - organic		M - morainal	
∮ - silt		C - colluvial		R - bedrock	
c - clay		A - alluvial			

Morphologic Subdivision		Process Modifier
a - apron	p - plain	W - washed
b - blanket	r - ridged	E - eroded
f - fan	t - terraced	A - avalanched
h - hummocky	v - veneer	₵ - channelled
m - rolling		I - modified by ground ice

Explanation of Letter Notation

A combination of letters is used to designate each map unit or component of compound map units, e.g. Ap. The upper case letter indicates the broad genetic class. The lower case letter(s) that generally follows indicates morphology. The texture of most map units is implicit in the genetic type (see 'material'); textural modifiers are utilized where closely spaced sampling and abundance of exposures permit a greater precision in description. Postdepositional modification or erosion of a unit is indicated by an upper case which follows the lower case morphological symbol and is separated from it by a square bracket, e.g. Cv [A. Compound units are designated by more than one group of letters; these areas consist of more than one component that could not be separated at the scale of mapping. Where two or more elements are of equal abundance, they are written together e.g. MvCv. Where the components are separated by a hyphen, the first element is dominant and makes up 60% or more of the unit area; the second element makes up 20-40%; and the third makes up from 5-20% of the unit area, e.g. Mv-Gh or Mv-Gh-Cv. An equal sign is used where the first element constitutes 60% of the unit area and the second 5-20%, e.g. Mb=Mv. One term placed above another, e.g. $\frac{Lv}{Mm}$, indicates a stratigraphic succession within the unit. Three general slope categories are identified.

Slope

An s_1 slope terminates at the crest with a bedrock face with a steepness of 30° or more; these slopes are subject to erosion and burial by rapid mass wasting processes, such as snow and rock avalanches and debris flows, and acceleration of fluvial erosion and creep. An s_2 slope ranges from 5°-30° or more and is marked by a rounded crest covered by a residual mantle of weathered material and little or no exposed bedrock; erosive and depositional processes are restricted to fluvial erosion and creep. The last slope type has an inclination of less than 5° and is not depicted by a symbol.

Geological boundary (defined, approximate, gradational, inferred) ....

Drumlin or drumlinized bedrock ridge (direction of ice flow known, unknown) ....

Meltwater channel ....

Direction of landslide movement ....

Geology by L.E. Jackson, Jr., 1974-1976

Figure 7.4b (cont'd.)

particularly the case for maps of Quaternary deposits which, having experienced little or no postdepositional modification, remain remarkably variable even within stratigraphic equivalents. The legend in Figure 7.4a illustrates this (though, of course, a map at larger scale would divide units further and reduce this problem).

In order to present more descriptive information of terrain conditions for direct application in land management, a different "style" of map has evolved. Descriptive terrain units are mapped, usually on the basis of physiography and material texture. These criteria lend themselves well to airphoto interpretation, which is useful for relatively rapid coverage of large, isolated project areas. Geological Survey experience with this approach began with an extensive project in Labrador (Fulton et al., 1975) undertaken in response to a request for terrain information for forest resource management. It was necessary to obtain maps of land units that could be treated as a replicate pattern of generic units for management purposes. The approach was rapidly expanded as a series of special projects was undertaken by the Terrain Sciences Division after about 1970: these largely had to do with resource development or transportation corridors – prominently in Mackenzie Valley (cf. Hughes et al. 1973; Rutter et al. 1973) – and so, again, required descriptive terrain information for interpretation of land capability. The descriptive nature of the maps made rapid production possible: the maps of the Mackenzie transportation corridor notably were released within months of the field work and immediately benefited engineering feasibility and environmental impact studies. For the same reasons, provincial agencies have adopted similar approaches to mapping surface materials within the past two decades. The most ambitious such project has been the Ontario engineering geology terrain studies (Gartner et al., 1981; Gartner, 1984).

Other environmental management disciplines have, in this period, also considered mapping land characteristics. It is supposed that several factors influence land resource values, so that multiple-factor classifications are constructed within which geological terrain attributes may be more or less prominent (cf. Lacate, 1969; Jurdant et al., 1977, for Canadian examples). Figure 7.4b shows an example of a multiparameter terrain inventory classification currently used by the Geological Survey. It remains essentially geological in character since the units are defined according to genetic process (Fulton et al., 1974). Nonetheless, there is no systematically stratigraphical or chronological organizing principle, so that the geographical nature of the mapping exercise is much more dominant.

There appears to have been no concerted attempt, within the Survey, to reconcile these two approaches to mapping surficial materials. Indeed, the Committee discovered that, to some degree, groups persist with philosophically opposed views about what constitutes the appropriate style of map for the Survey to produce. This is, in part, the legacy of the history of Quaternary geological mapping in the Survey (Section 2.2). However, it also reflects uncertainty about the nature of the main user group. Professional geologists and geological engineers accept and utilize the classic geological maps, even though the synthesis that they present remains somewhat academic for immediate applications in land resource management. Nongeologists cannot use these highly interpretive maps well; they require the "terrain inventory" maps or even simpler derivative maps. The information that such maps contain fits readily into a multifactor resource information base.

Beyond that, the philosophical opposition is a false dichotomy. This must be demonstrated in order to be able to construct a useful basis for information management in the contemporary Survey.

7.2 Quaternary stratigraphy

The place of stratigraphy in this view of geological information is worth emphasis. A study of Quaternary deposits in Canada is a study of glacial and postglacial deposits and a study of the bedrock surface on which they rest. The bedrock surface and structural marker beds within the bedrock provide the primary reference datum. For engineering purposes as well, the upper part of the bedrock must be included in investigations of Quaternary deposits. We require, then, a study of the surficial deposits and a stratigraphic investigation of the deposits down to a base of exploration in the bedrock. Such an investigation includes inferences about geological history and the geological processes which were operative during and since deposition.

Because exposures in Quaternary deposits are rare in many parts of Canada or, if present, do not reach a reasonable base, thorough studies require test drilling. Quaternary stratigraphic information can be recovered from boreholes by using geophysical methods. Techniques and equipment used by rotary test drilling and electric logging contractors were developed originally for the oil industry. In the early 1960s, the Saskatchewan Research Council developed a sidehole sampler capable of retrieving samples from the walls of testholes. Geophysical techniques have improved to such a degree that they have become the main basis for interpretation from boreholes. In the late 1970s, electrical logging was complemented by gamma-ray and caliper logging (Fig. 7.5) in some site investigations.

In the prairies and in closely settled areas of eastern Canada, regional studies desirably should include a grid of cross sections, surficial geology maps including isopachs of surficial drift, bedrock

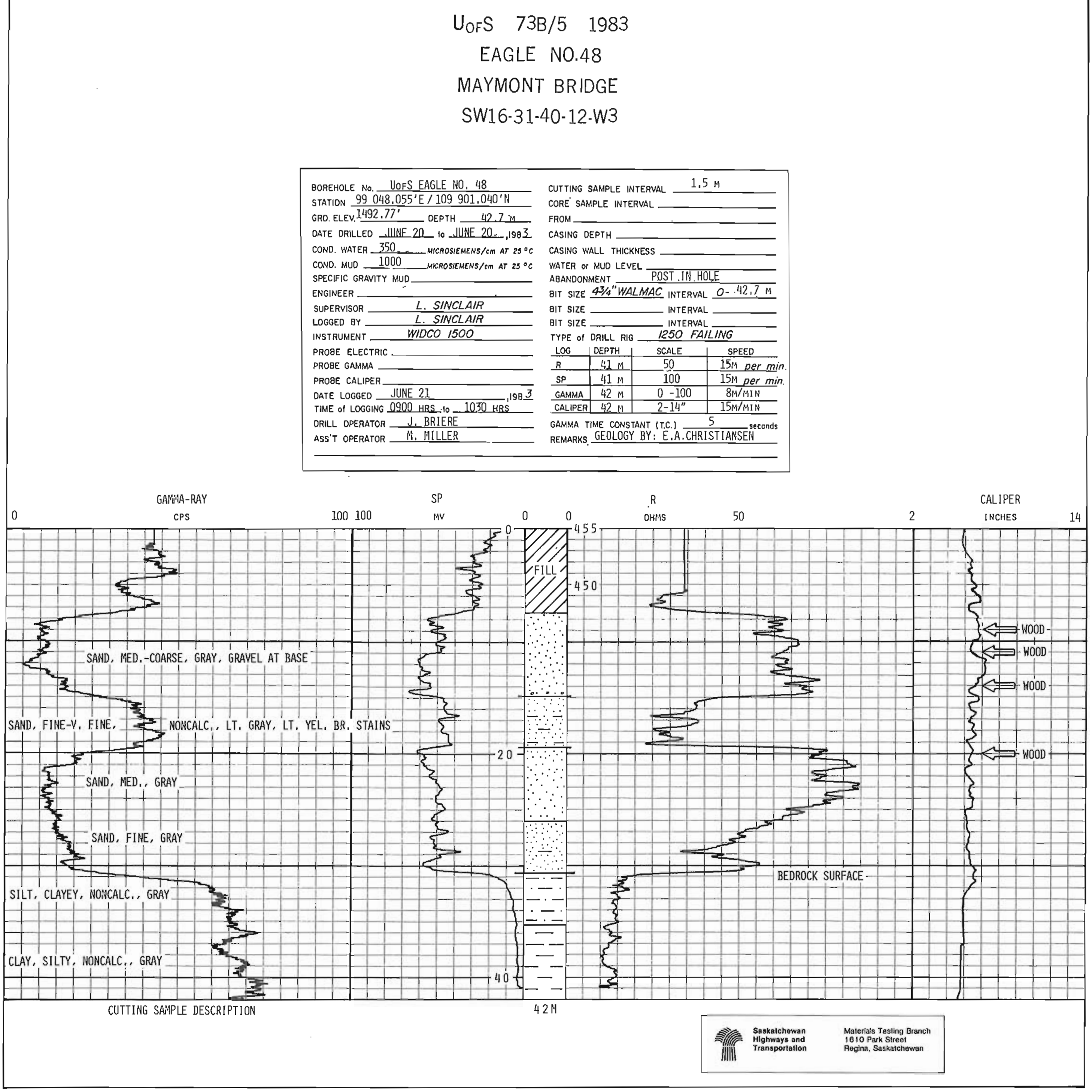


Figure 7.5. Geophysical stratigraphic log of surficial deposits.

geology and topographic maps, isopach maps of aquifers, and a history of the last deglaciation. Such a geological investigation will provide a regional framework for earth science purposes and for geotechnical investigations of a more site-specific nature. Much of this information is based on stratigraphy.

The results of stratigraphical investigations – from boreholes or outcrop – are implicit in the lithostratigraphic synthesis of the geological map. Individual records, however, remain important to users. We received several suggestions, such as the following, for "... a more extensive use of geophysical logging of all groundwater wells (as required in Saskatchewan) and purpose-drilled holes. With this kind of information the correlation and understanding of subsurface information would be enhanced."

Whatever the feasibility of establishing anything like a systematic borehole survey for surficial materials, it is apparent that direct information in the third dimension of surficial deposits is of substantial concern and value to users. It is in fact vital for engineering and water resource investigations, and for studies of regional history.

7.3 A geological information structure

In Section 6, we introduced a range of issues related to the acquisition, handling and dissemination of geological data. Ultimately, the consistent resolution of operational questions depends upon a clear concept of the nature of geological information, and the role of a particular organization in developing it. In this section we present a "geological information structure" (Fig. 7.6) as a concept for discussion about some of the questions we have outlined.

A geological map – especially a map of Quaternary strata – represents a highly synthetic document. Field observations of several types – such as landform, material texture, material provenance, stratigraphic succession – are combined and reexpressed in a conceptual set of stratigraphic/chronological units which are then mapped. Correlation of deposits (correct placement in the stratigraphic/chronological sequence) across the map area may require substantial geological judgment. The map, then, incorporates information that abstracts it a long way from the field observations.

Figure 7.6 presents a sequence of information levels – which may be realized as map products – that depict characteristics of the earth's surface arranged in order of increasing abstraction. Maps of topography, material texture, etc., represent systematic field observations. These already possess some degree of formalism or abstraction from the landscape inasmuch as the observations pertain to selected, isolated properties of the landscape, and the measurements are made by arbitrarily (but consistently) defined methods to some limit of real spatial resolution.

At the next information level, observations are combined in consistent ways to produce descriptive landscape classes. A taxonomic organizing principle is imposed upon the observations. There is a substantial degree of abstraction present at this level, since observed associations derived from broad experience and knowledge about genetic processes are used to construct the classification, hence to provide "shorthand" descriptions of the individual landscape units. Higher levels of abstraction are represented in traditional lithostratigraphic or chronostratigraphic maps – or the hybrid "geological map" – and in soil maps. Here, specific inferences about genesis and about correlation in the landscape under study are the organizing principles.

Maps expressing land capability or probable engineering performance are also interpretive maps, since they incorporate other correlations or associations which express measures of land performance. Some of the information incorporated into these maps may be nongeological in character.

St-Onge (1981) emphasized that the essential component of any map is the legend; the legend should be constructed so that description and interpretation can be separated: "... it should be possible for a person studying the map to arrive at a different conclusion from that of the author. If the

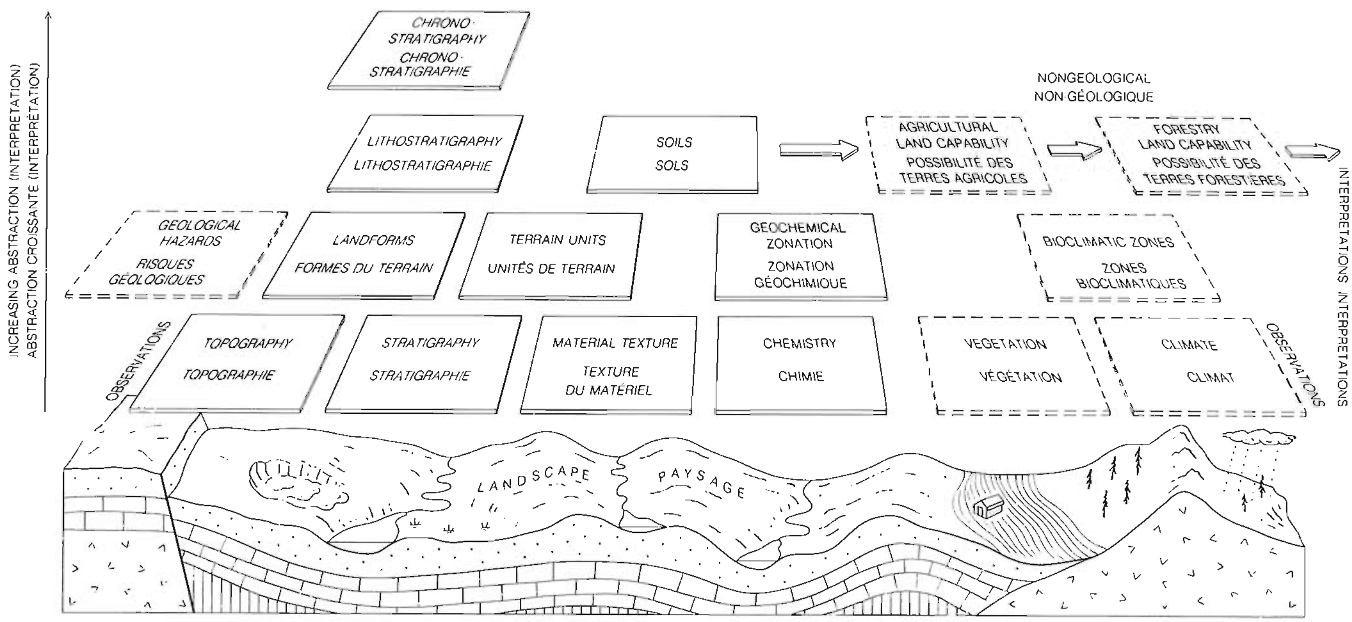


Figure 7.6. A geological information structure.

data cannot be reinterpreted the map becomes a simple illustration of the author's views" (St-Onge, 1981, p. 313).

Some of the map types in Figure 7.6 differ from each other simply in content of the legend (for example, material texture, and terrain units). Other interpretive maps represent conflations of two or more basic maps. The descriptive map units are combined in different ways to represent various aspects of the landscape, whilst the map legends carry additional inferential material that is pertinent. The basic descriptive information may thereby become largely implicit.

Geologists often proceed directly to construct the geological map, using descriptive information that remains in field books and on photographs, or in manuscript compilations. The degree in which a reader of the map may alter the geological conclusions is constrained strongly by the degree to which the descriptive information has become implicit. In a regional geological programme today, there is substantial merit in producing maps with primarily descriptive content as well as the ones with substantial interpretive content. Many users of geological data wish to appropriate the descriptive material for uses other than geological synthesis.

The descriptive maps, in our typology, serve to fulfil the mandate of the Geological Survey to describe the geology of Canada; the geological maps fulfil the mandate to explain the geology scientifically, and to establish the context for further work.

This hierarchical view of mapping banishes the "dichotomy" alluded to in the last section. There are also practical consequences. The highly abstracted maps are in substantial measure an expression of the author's views: as information improves, inferences about sequence, correlation and history may change. However, the primarily descriptive maps should retain currency even after methods of observation change, provided that the basis for the information portrayed on the map is known and understood.

The descriptive maps portray information that is amenable to machine coding, automatic manipulation and data banking, hence electronic transmission. This is increasingly true, even, of stratigraphic information. At the second level (landforms, terrain units, geochemical zonation) a greater degree of interpretive skill is introduced. Even here, however, computer assisted data acquisition is possible; for example, if land units are identified on airphotos mounted in an orthoplotter and directly transcribed to a map or digitized. Geological maps requiring collation of several streams of information are likely to remain largely manual compilations. Production of planning maps may be more or less automated, depending upon whether the interpretive criteria can or cannot be reduced to objective re-expression of descriptive characteristics (see, for example, Ryder and Maclean, 1980, for an approach to geological hazard mapping that is amenable to automatic reinterpretation of a terrain unit map.)

The geological information structure, then, reveals a hierarchy of descriptive and interpretive levels for various purposes, and they all should be available in products from a regional mapping programme that serves a range of users with diverse purposes. In particular, the final geological map is far from being the only product of interest. The information structure also helps to indicate where effort in automation is apt to be most useful.

7.4 The role of the Geological Survey in developing geological information

The geological information structure can be compared with the mandate of the Geological Survey: to describe and explain the geology of Canada for the "common good". "Description" implies presentation of the basic descriptive maps shown in the information structure (Fig. 7.6); "explanation", the presentation of the geological maps. The development of methods for effective presentation is also implied.

The development of geological knowledge about a region is unlikely to follow a simple path upward through the information structure. Production of good maps at any level requires that the outline of regional geological history be well known. Consequently, early on in the development of knowledge about a region rather great attention is given to geological interpretation – the top of the information structure – and rather few final maps may appear. That seems to be the situation, at present, for coastal and marine studies, for example. There is a great deal of activity to work out offshore Quaternary history, which has replaced the fragmentary terrestrial record as the expected standard record, and there are experimental attempts to define classifications for descriptive maps. There are few final maps. In many parts of the country, however, the terrestrial record is sufficiently well known to permit high quality mapping of elements of greatest applied interest.

There are some ramifications of this for the mix of skills necessary to the task. In the early stages of developing geological knowledge about a region, the work is mostly of a research nature. However, the production of descriptive maps is largely a technical task. The Quaternary geology sector in the Geological Survey has, on the whole, been preoccupied with delineating regional history to provide the context for mapping. Accordingly, the establishment contains a very high proportion of research to technical personnel.

A fair number of users complained about the length of time necessary for maps to be produced in the Geological Survey. We have investigated this issue (Sections 4 and 6) in terms of handling information. We raise here the additional possibility that continuing preoccupation with explanation – with historical geological science – in most projects may serve to obscure the importance of reporting descriptive information quickly. A more technical approach to terrestrial Quaternary mapping may serve many users well by speeding the completion of descriptive level mapping.

This is not to suggest that Quaternary science is unimportant; it is crucial to the enterprise. The Geological Survey has established a high reputation as the leader in Canada in the interpretation of Quaternary history, and the only world-scale centre of excellence in the country (Bird, 1987). This reputation should be guarded by continued work, for it is an important source of authority in Geological Survey of Canada products and a valuable basis for the reputation of Canadian private sector work. Furthermore, geological maps and reports – expressing the understanding of regional and local history – remain fundamental for interpreting the implication of descriptive information at particular sites. For an engineer engaged in site-scale work, for example, a clear statement of geological events and processes in the region remains the most valuable guide for interpreting the information obtained in the site investigation.

Still, there is now a range of regional land and resource management requirements for descriptive terrain information, as well as the traditional needs for the regional geology. We wish to emphasize that, accordingly, the mandate of the Survey requires today a judicious balance of science and inventory, and that the proportion bears careful management.

There are a range of "derivative" land capability or performance maps required for engineering and planning. Many users are primarily interested in these. To be practically useful, they commonly are produced at relatively large scales. Their production could absorb much effort. There is no consensus amongst users on who should bear responsibility for that. On one hand we were told "if the GSC is doing the mapping, then they have the required on-site knowledge to develop the interpretive maps and terrain property guidelines." On the other, "the GSC should continue to concentrate its efforts on regional reconnaissance mapping and 1:50 000 detailed Quaternary geology mapping, with palaeo-environmental reconstruction. It should be left to the Provincial Survey (generally speaking) to use and interpret the geological information in terms of resource management or environmental studies" (user's parentheses). The Committee inclines to the latter view. It is our opinion that the "derivative" maps are appropriate products for generation by local geologists (provincial or private sector) as needed, building on the regional mapping of basic terrain attributes completed by the Geological Survey. Survey officers must be familiar with these maps both so they can proffer helpful advice to the "interpretive mappers", and so they can present information in an appropriate form for use. The routine production of such maps appears, however, to be a provincial prerogative.

7.5 Recommendations on geological data and information

In Sections 6 and 7 we have reviewed a major group of problems surrounding the issue of future evolution of products in Quaternary and engineering geology. Automation for archiving and transmission of results, increasing use of semi- automated, geophysical methods of data acquisition, data banking, standards for data acquisition and presentation, and, underlying all this, the nature of the geological products themselves, are tied together in a complex way. Precipitous action on one or another of these issues could upset a survey programme that presently works quite well, without achieving the gains that a coordinated evolution of data handling might bring. The issues raised here require considerable further study.

Accordingly, our major recommendation is that

(1.8) The Geological Survey of Canada should establish a working group to study opportunities and impacts of new systems for data acquisition and manipulation on the conduct of the programme in Quaternary and engineering geology, and to make recommendations to the Branch to implement effective measures.

This group should consider all of the matters raised in our Sections 6 and 7, and any other issues that seem pertinent. It should have the authority to conduct research (as into mapping standards) and trials of methods and to commission studies. Its work probably will continue for several years, but it should work to a planned schedule.

The group should be established within the Survey. It should include, however, representatives from provincial geological agencies: it usefully could include members from other technical departments of government with similar problems (e.g., Environment Canada Lands Directorate, where there is nearly twenty years experience with the Canada Geographic Information System, and Agriculture Canada's Land Resource Research Centre, where the Canada Soil Information System is operating). It should include members from outside government with special skills, who should be paid for their services. The central group should consist of no more than eight or ten individuals. The chairman should be a senior member of the Geological Survey who should maintain this activity as his or her primary task.

We believe that we have identified here the major issue that faces the Geological Survey in the next decade. The challenge is put by Dr. Roger Tomlinson, a major architect of the Canada Geographic Information System: "For the future, it is obvious that we must integrate the process of creating a digital record with the initial processes of observation and measurement of the resources. We cannot continue to be satisfied with the manual creation of hardcopy maps which must then be digitized before they can be read and analysed effectively. To improve the system we must rethink the overall process of data gathering; this will involve significant changes in methodology of data gathering agencies that have served us faithfully and well."

An Advisory Committee sitting for a short time cannot resolve the issue constructively. Since it will touch all aspects of the programme, it deserves deliberate study. The study group requires continuity to be able to supervise the introduction of changes into the Survey in an evolutionary way and to evaluate their effectiveness. There must be close collaboration with the field staff, who indeed will be responsible for researching and developing the operational procedures that finally are adopted.

We note, in passing, that the inshore marine mapping programme (recommendation 1.2) may provide a useful test area for many aspects of changing data management. Mapping techniques are still being developed for this environment so there is little methodological tradition to overcome; there is a necessary bias toward remote sensing and geophysical methods that yield machine manageable data; and the field scientists have demonstrated readiness and ingenuity to use modern methods.

We make a further recommendation that can be implemented in the short term to support this activity:

(1.9) The Geological Survey of Canada should convene a national workshop meeting to discuss standards for surficial geology mapping and for map legends, formats, and presentation of surficial geological data.

It should be evident that we do not expect some rigidly fixed system to emerge. At this stage, however, there does appear to be merit in comparing several approaches with a view to coordination so far as is practical.

We make a final recommendation on manpower to carry out the programme in the coming years:

(4.1) The Terrain Sciences Division should alter the balance of its personnel to increase the technical complement relative to research officers.

We see this as the long term requirement for research officers to be able to direct programmes with increased technical components, and for increasingly automated data management to be achieved. We do not intend that the present staff be arbitrarily rearranged.

8. COLLABORATION IN QUATERNARY AND ENGINEERING GEOLOGY WORK

8.1 Context

We have found, from our survey of users, that a more rapid pace of mapping by the Geological Survey is desired. We also have noted some emerging problems in the field that will require more personnel or different skills than are presently found at the Survey (including, particularly, increased attention to coastal zone work, to Holocene geological processes, and to innovative means of recording and transmitting geological information). It is unlikely that the Survey establishment will be expanded appreciably to serve these ends, and so the question arises of collaboration with the earth science community outside the Survey to help realize them.

There also is the circumstance that the Geological Survey is the leading institutional centre in Canada for research in Quaternary geology (Bird, 1987). The wider community looks to the Geological Survey for leadership in many aspects of Quaternary studies.

There has been in recent years an emphasis by the Canadian government upon contracting for technical services. There is in Canada a substantial community of Quaternary and engineering geologists, and of coastal geomorphologists, who can present work of good quality. The establishment of guidelines for mapping standards would facilitate specification of the quality of work required. Although most contracts are let in the context of special projects, mapping should always be completed to a sufficient standard that the results can be presented also as a contribution to the regional mapping programme, or incorporated directly into Geological Survey of Canada work to that end. In recent years a disconcerting proportion of contract work has apparently ended with Open File presentation.

There seems to be little reason why, with agreement on standards, provincial mapping should not be formally incorporated into the national mapping programme. In provinces where Quaternary mapping is not being carried out by either the Survey or by a provincial agency, the Survey might seek funds – perhaps co-operatively with the province – to permit work to proceed. One of the most important outcomes of such arrangements would be the maintenance of a group of consultant geologists in the province with good regional experience. This is a desirable end in every region of the country.

8.2 User views on collaborative work with the Geological Survey of Canada

Most users expressed the desire to see increased direct collaboration. Some university and provincial geologists enjoy ready, continuing collaboration now. There was a suggestion that GSC personnel might benefit from working in provincial survey offices for a while.

Private sector respondents noted that it would be more practical for the GSC officer to move than vice versa – the loss of a key individual from a firm for some time can be a serious competitive disadvantage. However, engineering firms noted that continuous collaboration with public servants may be difficult in many jobs. What really seems to be needed is collaborative input or advice from Survey officers at key points in the development of a project when regional experience is needed to confirm or provide a context for project information. This could work well if GSC officers were stationed in the regions. A particularly fruitful area for collaboration is seen in development of equipment and technique. Seismic survey equipment, coring and drilling equipment and remote sensing methodologies are mentioned as areas of possible collaboration.

Interchange between the Atlantic Geoscience Centre and the marine geological consulting companies, both of personnel and ideas, is noted favourably. The Director has deliberately promoted personnel movement, to good effect.

In the provision of technical services to support Canadian Quaternary science, most respondents (except in Quebec) seemed to regard it as the responsibility of the universities and the private sector to provide analytical services, except dating. Most users regard the GSC radiocarbon laboratory as a public service (despite the declared policy that most of its capacity will be used directly to support Survey work), and apparently look to the Survey to develop other dating techniques. Quebec respondents look to the Survey for a wide range of analytical services.

8.3 Innovative arrangements?

Actual facilitation of collaboration faces a number of institutional problems. Beyond contracts or term employment – nearly always related to special projects – it seems to be very difficult to effect a formal connection between an outside worker and the Survey. A major problem appears to be Civil Service regulations related to benefits and liability. (This is a major problem in other institutions as well.)

There are some advantages to honorific appointments for clearly committed workers (mainly university personnel) in areas of direct interest to the GSC programme, and of "when actually employed" status for other direct collaborators. For the appointee, there is the advantage of direct access to Survey facilities and services; for the Survey there is the opportunity to direct a programme of work toward its needs, and to establish some degree of obligation for work to be completed and presented.

In a time when the Survey cannot hire all the expertise it requires, and when many good Canadian earth scientists no longer find continuing employment, it may be appropriate for the government to review its regulations and to ask whether – in scientific fields – the public good is best served by the narrow range of cooperative or employment arrangements currently available.

Questionnaire respondents identified several fields in which the Geological Survey might benefit substantially from direct access to additional expertise. They included Quaternary stratigraphy, geohydrology, glacial processes, periglacial processes, fluvial and coastal processes, geochemistry with Quaternary applications, neotectonics, geotechnical engineering, and remote sensing applications to engineering and terrain studies. Some of these are surprising, but the appearance of geomorphological topics and applied topics is not – these clearly are areas where the Geological Survey requires additional support.

8.4 Adopting the universities

University geologists, geomorphologists, and engineers are an obvious possible source of fruitful collaboration. Quaternary studies in Canadian universities are not well developed, despite the presence of outstanding individuals (Bird, 1987). There seems to be a good opportunity for the Geological Survey to gain a substantial body of collaborators by using its influence to encourage development in this area. The Survey already has a distinguished record of supporting student thesis research.

At the same time, one should not expect too much. Canadian universities are primarily teaching institutions – not research centres – and their members have substantial responsibilities before research.

Some possibilities for collaboration with the universities are immediately clear:

(i) using university faculty members to provide substantial in-service training to GSC officers;

(ii) carefully reviewing theses for possible publication in the GSC definitive publications series when of appropriate topic and standard;

(iii) giving deliberate encouragement to faculty with well defined projects to consider spending sabbatical leave at the Survey;

(iv) encouraging GSC officers to spend periods of one or two years in a university when collaboration with faculty members will substantially facilitate the officer's project.

There are qualifying statements attached to each of the above suggestions: they are not meant to promote casual exchange. The most substantial extraordinary expense possibly would be attached to a programme to publish theses. Publication of appropriate theses (ones that serve the ends of the GSC programme) is about the cheapest way possible to complete and report work, since the field costs and stipends may not be borne by the Survey. It is rather surprising that the Survey has, in the past, ignored such bargains.

8.5 Recommendations on broadening collaborative efforts

Several proposals appear sufficiently feasible at present to warrant specific recommendations:

(4.2) Contracts for mapping, by the public or private sectors, should always be written to require a standard of performance sufficient for incorporation of results into the basic mapping programme. Provincial mapping should be incorporated into the formal national mapping programme when agreed standards are reached.

In many cases, this will entail no more than ensuring public access to and cross-cataloguing of extant provincial maps. To the extent that these arrangements might entail costs that displace other mapping efforts, they remain an economical way to obtain results because the costs are shared. The co-ordination between soil mapping groups in various provinces and the Land Resource Research Centre of Agriculture Canada provides examples of such arrangements in a related survey and mapping operation.

(4.3) The Geological Survey should explore the possibility to institute innovative arrangements for formally retaining scientific staff on an honorific or part-time basis.

This might be particularly important in several emerging problem areas in which the current staff is small.

(4.4) The Geological Survey should seek more extensive collaboration with the universities in several areas which could serve the mandate of the Survey very well.

Herein lies the largest resource of available talent in Canadian earth science. Its mobilization will require fine managerial judgment, though, since the obligation of these people to their universities must not be compromised, and university researchers should not be used to displace work that can be done most effectively in the private sector.

Underlying ideas in these proposals are that the Geological Survey of Canada should interpret its mandate to include coordination of the programme for describing the geology of Canada, and should regard its publication programme as the record of achievements rather than just as the record of GSC results.

9. SUMMARY OF RECOMMENDATIONS

Following is a list of the major recommendations from the Canadian Geoscience Council Advisory Committee to the Geological Survey of Canada on outputs in Quaternary and engineering geology. It repeats the numbered recommendations made in the conclusions of Sections 4, 5, 7, and 8 of the report. Commentary or justification of the recommendations is found there. The first number of each recommendation indicates the term of reference to which it is directed; the second is a sequence number.

(1.1) The Geological Survey should continue to regard the regional geological mapping programme – and attendant interpretation of Quaternary history – as its major and most important activity. However, mapping scales should reflect the level of economic activity in the regions of Canada. Final selection of appropriate scales, as large as 1:25 000 in Census Metropolitan Areas, should be made following studies of information standards in maps.

(1.2) Increased attention should be given to coastal and inshore marine mapping with the objective of producing integrated maps of onshore and marine surficial geology and coastal features. Geophysical, remote sensing, and small boat techniques should be developed to improve field technique.

(1.3) Enquiries should be made into the possibility for increased co-ordination between Quaternary geology and soil mapping activities at the regional scale. Initially, this could take the form of consultations between the Geological Survey and the Soil Survey of Canada.

(1.4) Investigations of the geochemistry of surficial materials should be integrated into the regional mapping programme. By reviewing current experience, an analysis should be made of what information and what procedures for data collection, analysis, and reporting are apt to be of most general use in the next 15 years, bearing in mind applications both in mineral exploration and in environmental management.

(1.5) The Geological Survey should encourage a substantial increase in the study of Holocene environments in Canada.

(1.6) The Geological Survey should encourage the study of regional, mappable elements of environmental hazards related to bedrock and surficial geology, and should give emphasis to sensitive soils and permafrost occurrence in regional mapping.

(1.7) The Geological Survey should consider reemphasizing regional appraisal of groundwater conditions in its regional mapping programme, particularly in the Prairie Provinces.

Amongst these recommendations on programme to meet national information needs, the first (1.1) is substantially the most important. The major implications of the others devolve onto the regional mapping programme as well. There is substantial opinion that additional resources – if they come to the Survey – should be devoted to the mapping programme. Recommendation (1.2) will require assignment of additional resources if it is to be pursued with determination; we wonder whether the very much larger oceanographic programme is not the place to find them. Action on recommendation (1.7) would entail reassignment of personnel from the federal water resources sector, hence is not just a matter for the Geological Survey.

Within the constraints just enumerated, these proposals can be acted upon with present resources. They are recommendations to influence the pace and focus of the mapping programme.

In the long term, the major problem facing the Quaternary and engineering geology sector is the adaptation of its mapping programme to contemporary data management methods and information needs. This is vital if Survey results are to be used effectively. It is much too large an issue for an Advisory Committee to settle. Accordingly,

(1.8) The Geological Survey of Canada should establish a working group to study opportunities and impacts of new systems for data acquisition and manipulation in the conduct of the programme in Quaternary and engineering geology, and to make recommendations to the Branch to implement effective measures.

To initiate this activity,

(1.9) The Geological Survey of Canada should convene a national workshop meeting to discuss standards for surficial mapping, and for map legends, formats and presentation of surficial geological data.

All users emphasize the priority of the regional mapping programme. They recognize that more specialized or specific information should be gained by their own resources, or by informal contact with Survey personnel. It is, therefore, difficult to discriminate priorities beyond that for the overall regional mapping programme. Within that, we recommend

(2.1) The Geological Survey should give relatively increased attention to mapping in the settled regions of the country, including compilation of updated maps near the major centres of population.

This activity will, in part, be achieved with provincial collaboration.

The following recommendations are made about the present programme of publication and public contact. Of their nature, they would affect the entire Survey, rather than just the Quaternary and engineering geology activities.

(3.1) The Survey should give deliberate consideration to reemphasizing its definitive publications (A-maps, Memoirs, Bulletins, Papers) as the repository of its main conventional reports and maps, using contemporary production technology to promote timely publication.

(3.2) The Open File series should be used deliberately for releasing nonconventional material, data sets, certain consultant reports, and other products that will not fit the thematic or physical constraints of the definitive publications.

(3.3) Current Research should be abolished in favour of proper use of outside journals and establishment of a user selective project awareness service.

(3.4) General conferences and Open House should be abandoned as means of communicating with the user community.

(3.5) The Geological Survey should instead initiate user targeted seminars in regional centres, in collaboration with provincial and other local specialists, to update users on the results of Survey and other pertinent research and inventory activities.

(3.6) The Geological Survey should assign members of the Regional Projects staff to have a long term commitment to one or another of the settled regions of Canada and should station them at offices in the regions.

(3.7) The Geological Survey should establish a programme to inform the general public about its projects and results, in which substantial emphasis should be placed upon Quaternary geology and its applications.

The main new cost associated with the above recommendation may occur in recommendation 3.7. It should not, initially, be large.

On the mobilization of expertise to carry out the programme, we make the following recommendations:

(4.1) Terrain Sciences Division should alter the balance of its personnel to increase the technical complement relative to research officers.

(4.2) Contracts for mapping, by the private or public sector, should always be written to require a standard of performance sufficient for incorporation of results into the basic mapping programme. Provincial mapping should be incorporated into the formal national mapping programme when agreed standards are reached.

(4.3) The Geological Survey should explore the possibility to institute innovative arrangements for formally retaining scientific staff on an honorific or part-time basis.

(4.4) The Geological Survey should seek more extensive collaboration with the universities in several areas which could serve the mandate of the Survey very well.

The kernel of the problem of making more effective use of the substantial pool of expertise in Canada lies in the restricted range of arrangements currently available for formal collaborative effort.

In conclusion, we should note that users have widely complimented the Geological Survey on the character and authority of its maps and reports of Quaternary geology. Even for engineering geology, these represent (following Legget, 1979) the most important results that the Survey can contribute. The strongest message that the Committee received was for more of the same, more quickly. There are also requests for convenient access to field data and for "descriptive" maps to serve a range of regional environmental management issues. These are good messages since they confirm the practical value of the Survey's work. To respond to them within foreseeable resources, we have suggested that the Survey begin to adapt more aspects of its data gathering and dissemination methods to standard or semi-automated procedures. This must, however, be done in a deliberate and evolutionary manner since the current orientation toward production of maps and reports of Quaternary geology must remain a prominent part of the developing programme. We have the impression that the user community would wish us to congratulate the Survey on its achievements in the field.

ACKNOWLEDGMENTS

We wish to thank the 90 interested members of the Canadian earth science and environmental management communities who responded thoughtfully to our questionnaire. The consensus of their views constitutes much of this report.

The librarians at the Geological Survey of Canada, Vancouver office, Ms. Mary Akehurst and Ms. Wynn Horwat, provided assistance in the review of the publications, especially in sorting out (and unrolling) the Open Files.

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APPENDIX 1
INSTITUTIONAL QUESTIONNAIRE

CANADIAN GEOSCIENCE COUNCIL
ADVISORY COMMITTEE TO THE GEOLOGICAL SURVEY OF CANADA ON OUTPUT IN QUATERNARY AND ENGINEERING GEOLOGY

Questionnaire: to identify users of Quaternary and engineering geological information

1. Your organization? ______________________________

2. Your position? ______________________________

3. Do you receive and respond to requests for Quaternary and/or surficial geologic data from outside your own organization?

____

4. List in order of importance the groups to whom you supply Quaternary or related geologic data (e.g. other government organizations, consultants, mineral exploration companies, students, well drillers, etc.etc.). For major recipients, be as specific as you can.

____

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5. What percentage of the requests are you able to satisfy?

____

____

6. What classes of requests cannot be satisfied?

____

____

____

____

7. What percentage of the data you supply comes from

   1. Your own organization ______________________

      ____

      ____

   2. Another Canadian organization? Please name.

      ____

      ____

   3. Some other source? Please name. ______________

      ____

      ____

8. Please name some individuals or organizations (from amongst those named in Q.4) who may be able to provide us with a thoughtful review of information sources for Quaternary and surficial data pertinent to their work. (It is of greater importance for us to identify a broad range of users - or should-be users - than to exhaust any one groups of users in your region.

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APPENDIX 2

QUESTIONNAIRE SENT TO USERS OF QUATERNARY AND ENGINEERING GEOLOGY INFORMATION

Dear

The Canadian Geoscience Council has been asked by the Geological Survey of Canada to undertake a review of its outputs in Quaternary and Engineering Geology, and to make recommendations for improvements. We are asking you, as one of the users of geological information, to complete the enclosed questionnaire as part of this exercise. In fact, it is the most important part.

We have decided to address a relatively small number of Canadian earth scientists and earth science organizations in this endeavour. We have chosen deliberately to solicit your views, which we know will be valuable. Our strategy requires a 100% return of our enquiries. We have abandoned the large survey technique, and accordingly our questionnaire can be more informal and informative - we seek your considered opinions, rather than check marks. The questionnaire includes space for comments. Please feel free to expand onto a separate sheet if the space we have provided is not adequate. The questionnaire has been prepared and reviewed by the committee members. If we have omitted or neglected any topic which you feel is important please expand in your comments at the end of the questionnaire.

We enclose two copies of the questionnaire as you may wish to use one as a worksheet in formulating your replies. In many cases, we will follow up this questionnaire with a personal contact. If you wish particularly to discuss the exercise, or some of the questions with us, or to elaborate your views at greater length, please place a note on the top of the questionnaire. Although we may quote from your replies in our report, no statement will be attributed to any individual except by specific arrangement. The questionnaires ultimately will be filed at the Geological Survey, but they will be made entirely anonymous first by removing the last page. If you have information or opinions that may be 'sensitive', please ask us to contact you.

The time you spend to consider our questions will represent a valuable service to the Canadian earth science community and, we hope, to you. Our report will be published under the auspices of the Council. Please help us to realize our 100% strategy successfully.

Thank you very much for your consideration.

Yours sincerely,

for Jean-Yves Chagnon, Quebec
Earl Christiansen, Saskatoon
Michael Church, Vancouver
Brian McCann, Hamilton
Hugh Nasmith, Victoria
Clark Topp, Ottawa

CANADIAN GEOSCIENCE COUNCIL
ADVISORY COMMITTEE TO THE GEOLOGICAL SURVEY OF CANADA ON OUTPUT IN QUATERNARY AND ENGINEERING GEOLOGY

Questionnaire for users of GSC output in Quaternary and Engineering Geology

1. The purpose of these questions is to determine the use which is made of geologic data by the respondent or by the respondent's organization.

(a) Classify the project area(s) within which you would use geologic data:

(i) mineral exploration ____

(ii) engineering investigations related to structures and roads ____

(iii) environmental management and natural resource development (including engineering investigations not related to structures) ____

(iv) palaeoenvironmental reconstruction ____

(v) other - please specify

____

____

(b) Describe one or more of your projects in which geologic information or concepts were used.

____

____

____

____

____

(c) Describe the geologic information required and how you acquired it.

____

____

____

____

____

2. The purpose of these questions is to determine the methods used to acquire geologic information.

   (a) In your organization who would be responsible for identifying a need for geologic information?

   ____

   (b) Does your organization maintain a library of geologic publications?

   ____

   (c) When a need for geologic information is identified, where do you find the data you require

   (i) from your own knowledge or personal contacts? ______

   (ii) contact a geologist in your own organization? ______

   (iii) contact Geological Survey of Canada? ______

   (iv) contact a provincial agency? - please name ______

   (v) contact university geologists? ______

   (vi) library search? ______

   Please elaborate.

   ____

   ____

   ____

3. The purpose of these questions is to determine if the required information is complete and in a suitable form.

(a) In general are you able to get the geologic information you require?

(b) What kinds of geologic information that you would like to have is generally unavailable?

(c) Is the information you obtain in a form suitable to your needs? If not, please elaborate.

(d) If the geologic information is not available, what do you do? Please elaborate.

(e) Do you think it should be the responsibility of the Geological Survey of Canada to provide the information currently unavailable to you? Please justify your reply.

4. The purpose of these questions is to assess in more detail the services and products provided by the Geological Survey of Canada.

(a) Please evaluate the status of Quaternary/terrain mapping in <u>your</u> region(s) of work (consider the output of provincial surveys, if appropriate, as well as that of the GSC in this assessment).

	Regional (100 000+)			Detailed (50 000−)		
	Good	Adequate	Inadequate	Good	Adequate	Inadequate
BC/Yukon						
Prairies						
Ontario/Quebec						
Maritimes/Newfoundland						
Northwest Territories						

Please elaborate. Your opinions on rate of map production and rate of map revision will be helpful.

(b) By considering convenience, timeliness and authority, assess the value, in your work, of the following GSC reporting methods.

	Valuable	Marginal	Little worth	Overall Rank(1-9)	Discussion (continue on reverse)
(i) Map series					
(ii) Bulletins, memoirs, Ec. Geol. series					
(iii) Papers, preliminary maps					
(iv) Current Research					
(v) Open files					
(vi) Articles in refereed journals					
(vii) Conference presentations					
(viii) Open House					
(ix) Personal discussion					

5. In many fields in which Quaternary or engineering geology is used significant benefits arise from closer co-operation between the geologist and the specialist in a different field. For example a Quaternary geologist working within a survey of agricultural and forestry soils can provide a better understanding to the soil scientists of the origin of parent materials while their studies will improve the geologists' understanding of weathering processes and climatic and drainage effects. Similarly, a Quaternary geologist can provide information during engineering feasibility studies and during construction which will form a geological framework for the geotechnical engineer. This, in turn, provides the geologist with an opportunity to obtain information available only during engineering excavations. At the same time the geologist would become more aware of the geologic features which are important in engineering design and construction. Other examples could be quoted from the fields of archaeology, land use planning, mineral exploration, etc. These questions are designed to explore the possibility to expand avenues of professional contact with the GSC and to increase the availability to the GSC of expert advice and manpower.

(a) Would you like to develop closer contacts with GSC scientists working in areas of interest to you? Please elaborate.

____

____

(b) If so, would you welcome GSC scientists to work with you or your organization on collaborative projects (you supply work space; EMR continues salary and normal expenses of officer)? What would be the value of this?

____

____

(c) Would you welcome the opportunity for you or your staff to work at the facilities of the GSC on collaborative projects?

____

____

(d) Are there any research subfields within your area of interest in which the GSC appears to need access to additional expertise? Please elaborate.

____

____

(e) Should the GSC arrange access to high-technology analytical services, such as radioisotopic assays, special absolute dating procedures, on a cost-recovery basis? Give an example that would interest you.

____

____

6. The purpose of these questions is to assist in determining future needs for geologic information. Use a 10-15 year time horizon.

   (a) Do you anticipate projects in your field of interest which will require more or different types of geologic information in the future?

   ____

   ____

   ____

   ____

   ____

   (b) Do you foresee the need for different means of presenting geologic information to the user in the future?

   ____

   ____

   ____

   ____

   ____

7. General Comments

   Do you have any comments on the way the collection, presentation, and distribution of information on Quaternary and Engineering Geology could be improved? Are there topics or areas that are not being addressed adequately at present
   (i) within the GSC? (ii) in general?

8. The following questions are intended to indicate the level of geologic knowledge of the respondent and the organization for which he or she works.

   (a) Indicate the background you have in geology

      (i) a university degree in geology or in geological/geotechnical engineering ______

      (ii) one or more university courses in geology ______

      (iii) high school courses, TV programs, popular lectures ______

      (iv) learned 'on-the-job' ______

   (b) How many geologists, geomorphologists or geological/geotechnical engineers are employed by the organization for which you work?

   ____

   (c) How often do you have contact with geologists, geomorphologists or geological/geotechnical engineers in the course of your work?

      (i) more frequently than once a week ______

      (ii) more frequently than once a month ______

      (iii) infrequently ______

   (d) How would you rate your ability to understand geology reports?

   ____

______________________ Name of respondent

______________________ Organization

Energy, Mines and
Resources Canada

Énergie, Mines et
Ressources Canada