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REGIONAL GEOSCIENCE INFORMATION: OTTAWA - HULL

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1980

Here is a "response" to the question regarding the geology (faults, in particular) of the Ottawa area.

Ottawa lies on the edge of the Precambrian Shield. The Gatineau hills are the remnants of ancient Precambrian mountains that are over a billion years old. Rock types include metamorphics and intrusives. About 450 - 500 million years ago, the Ottawa valley was covered by a shallow warm sea. The limestone cliffs that are visible beside Carlington Hill were created during this time. Dolomites, shales and sandstones also were deposited.

There are several major faults through the Ottawa area. The main ones are: Gloucester Fault: from Scott Road to Carling Avenue, west of Dow's Lake, extending SE; Hazeldean Fault: north of the Jock River, extending west to Hazeldean, Carp and beyond the Mississippi River.

To view the geology (including faults) of the Ottawa go to the following web site: Geological Survey of Canada: Terrain Sciences Division: Urban Geology of the National Capital Area :---- http://sts.gsc.nrcan.gc.ca/urban/introduction.asp and click on "Bedrock Geology" from the listing on the left side; this should bring up Bedrock Geology: Regional Synthesis Map; click on "Maps - GeoServ" to activate the map viewer; this will bring up an "interactive" map showing the geology of the Ottawa area; on the left side in the legend, at the top, there are two "buttons, one "maps" the other "layers", click on the "layers" and click on the "fault" layer (click in the box); this will then highlight the faults in red; you can use the various buttons, e.g. zoom in, to view specific areas.

If you require more detailed information than this, you should contact the city and possibly the National Capital Commission. The city should have a more detailed location for the faults within the city. Try the Regional Municipality of Ottawa-Carleton - Planning Department.

Info on Canada's Capital Region: National Capital Commission - E-mail: info@ncc-ccn.ca; Phone: (613) 239 5000 / 1 800 465 1867; Fax: (613) 239 5063

Other sources
Baird, D. M., 1968. Guide to the Geology and Scenery of the National Capital Area. Misc. Report 15, Geological Survey of Canada, 188 pp.
Generalized Bedrock Geology, Ottawa - Hull, Ontario & Quebec; GSC Map 1508A, scale 1 : 125,000 (1979);
Surficial Geology, Ottawa, Ontario & Quebec; GCS Map 1506A, scale 1 : 50,000 (1982)

Useful web-sites:
Urban geology of the National Capital :--- http://sts.gsc.nrcan.gc.ca/page1/urban/urb.htm
Geological History of the National Capital Area :--- http://sts.gsc.nrcan.gc.ca/urban/his_silurian.asp
Ottawa "Paleozoics" (Hooper Virtual Paleontological Museum) at http://superior.carleton.ca/~tpatters/Museum/hvpmdoor.html
Parks Canada: "Paleozoic" geological map of the Ottawa area with stratigraphic column:--
http://park.org/Canada/Museum/ottawa/INDEX.HTM
Geology of the Rideau Region:-- http://www.rideau-info.com/canal/history/geology.html

Geological Association of Canada: Special Paper 42: Urban Geology of Canadian Cities :--- http://sparky2.esd.mun.ca/~gac/PUBLICAT/sp42toc.htm

National Capital Commission :--- http://www.capcan.ca/corporate/index_e.asp

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REGIONAL GEOSCIENCE INFORMATION: OTTAWA-HULL

Abstract

Initiated in 1970, the project to supply geoscience information for the Ottawa-Hull area provides both background data on geological conditions and reference material for regional planning. Precambrian igneous and metamorphic rocks outcrop to the north and on the upthrown side of major faults, as well as form the basement of the area. Flat to nearly flat-lying limestone, sandstone, dolomite, and shale of Paleozoic age overlie the Precambrian rocks in most of the study area. Glacial deposits of till and sand and gravel have been modified extensively by wave action or have been buried under thick marine clays during inundation of the area by the Champlain Sea. During and following emergence of the land from the sea, the present river channels were cut and older channels were abandoned resulting in the formation of numerous scarps.

Data on bedrock geology and geotechnical characteristics of the bedrock were compiled on two maps included in this report. The presence of major faults, jointing, and the easily erodable nature and the sulphureous water content of some shales all influence regional planning. The map of surficial materials and terrain features reveals the area to be complex with the predominant depositional unit, from the urban planning point of view, being Champlain Sea clays. Borehole and seismic data form a data bank from which bedrock topography and drift thickness trend maps have been produced by computer. Bedrock topography maps reveal a deep buried channel beneath the present course of Ottawa River downstream from Chaudière Falls and a bedrock valley underlying the present course of Rideau River. Drift is up to 240 feet (75 m) thick along the course of the Ottawa River buried channel; thicknesses over 100 feet (30 m) are not uncommon east of Ottawa and along the north side of Ottawa River in the Quyon map area.

The data presented are primarily for the purpose of demonstrating the utility of geoscience information. Urban areas are urged to gather, analyze, and use more geoscience information in regional planning.

Résumé

Le projet amorcé en 1970, a pour but de produire des documents géoscientifiques pouvant servir de base à l'aménagement du territoire de la région d'Ottawa-Hull. Le présent rapport comprend des cartes de la géologie de la roche-en-place, et des dépôts meubles. Celles-ci révèlent la présence d'un socle précambrien formé de roches ignées et métamorphiques précambriennes affleurant au nord de la région et dans les lèvres soulevées des failles majeures et formant la base de la région recouverte de calcaire, grès et dolomie du Paléozoique située plus au sud. Les dépôts glaciaires formés de till, sable et gravier ont été en grande partie modifiés par l'action des vagues ou ensevelis sous une épaisse couche d'argile marine lors de l'invasion de la Mer de Champlain. Durant la période qui a suivi le retrait de la mer, les rivières ont creusé leur lit actuel et plusieurs anciens chenaux ont été abandonnés formant ainsi de nombreux escarpements.

Les cartes géologiques et géotechniques de la roche-en-place jouent un rôle important en aménagement régional en indiquant les endroits où se trouvent les failles, les diaclases, les roches tendres, la nature des eaux souterraines et plusieurs autres facteurs pertinents. La carte de la géologie des dépôts meubles fait ressortir la complexité du terrain et met l'accent sur les dépôts argileux de la Mer de Champlain, étant donné leur importance dans l'établissement des plans directeurs. On a monté, à l'aide d'ordinateur, une banque de données géotechniques provenant soit de forages ou relevés séismiques. Cette information a servi à produire des cartes de l'épaisseur des dépôts meubles et de la topographie de la roche-en-place. On peut appercevoir sur la carte de la topographie de la roche-en-place, la présence d'une ancienne vallée enfouie sous le présent chenal de l'Outaouais en aval des Chutes de la Chaudière ainsi qu'une vallée creusée dans le roc, sous-jacente au cours actuel de la rivière Rideau. Les dépôts meubles atteignent jusqu'à 240 pieds (75 m) d'épaisseur à certains endroits de l'ancienne vallée de l'Outaouais; à l'est d'Ottawa ainsi que le long de l'Outaouais dans la région de Quyon ceux-ci dépassent souvent les 100 pieds (30 m).

Les faits présentés dans le rapport servent surtout à démontrer l'utilité de l'information géoscientifique en aménagement régional et cherchent à motiver les différents gouvernements à utiliser ce type d'information dans l'élaboration des plans directeurs.

INTRODUCTION

Rationale for the Study

Had this introduction been written four or five years ago, several paragraphs would have been spent justifying the role of geology in urban planning. Today, with McHarg's (1969) "Design with Nature" and Legget's (1973) "Cities and Geology" enjoying wide circulation, there is a growing acceptance of the philosophy that an understanding of the geology of urban areas is an excellent starting point in the process of good planning. In many urban areas, however, there is little evidence that even the most basic geological information is being integrated into the planning process (Mathewson and Font, 1974). There are at least three reasons for this: (1) the required information does not exist; (2) access to it is difficult; or (3) the information is in a form that is not compatible with the user's needs.

It is in response to these information needs that a new area of study has developed out of the more traditional fields of geology and engineering. Dubbed 'urban geology', it "is essentially the application of the principles of geology in concert with the other component disciplines of geotechnique to the problems of the physical aspects of the urban environment" (Scott, 1974). Urban geology, therefore, encompasses a range of activity from a single site investigation to a synthesis of the geological setting of an entire city and its surrounding area.

This study deals with the cities of Ottawa and Hull and their surrounding areas and is an attempt to bring together various facets of geoscience information in order to provide a regional synthesis. One objective of the study is to provide a framework of geoscience information in a format that will be useful for large-scale planning and policy making. This overview also should allow more detailed studies to be viewed within a broader context.

A second objective of this study is to provide a sample of the type of geoscience information that should be available in every large and growing urban area. The study has been based primarily on existing information with additional data collected to fill major gaps or to demonstrate the type, extent, and consistency of information required for a thorough study of the urban environment. The data used were the best available at the time of compilation, and the very exercise of compiling the data has provided valuable information on deficiencies.

During the early stages of the study it was found that the bedrock geology of the area had been mapped substantially over the past 60 years. Although some revision in local bedrock mapping, both with respect to stratigraphy and structure, probably is warranted, such was beyond the scope of this study. It is assumed that while such a revision might result in some minor boundary changes and perhaps affect correlation with adjacent areas, the effect, from the point of view of a regional framework for planning, would not be significant.

Whereas the bedrock geology data were available for most of the study region, information concerning surficial deposits existed for only 25 per cent of the area. It was necessary to initiate a program to fill this information requirement.

This report consists of two parts: maps and text. The maps can be divided into two categories: those produced by traditional mapping methods and those produced by a plotting machine attached to a computer. The two drafted maps, prepared by compiling the work of a number of researchers, depict bedrock geology (Fig. 1) and Surficial Materials and Terrain Features (Map 1425A). The map depicting geotechnical characteristics of rock formations (Fig. 2) is a derivative of the bedrock geology map and groups the bedrock map units into new units that have common geotechnical characteristics.

Computer drawn maps are fundamentally different in that the basic information, primarily drillhole data, is processed and the maps are drawn by a plotter attached to a computer. These maps provide information on the depth to bedrock (Figs. 3 and 4), bedrock contours (Figs. 5 and 6), and borehole and seismic data locations (Fig. 7).

Whereas the maps can be considered independent of the text, the user must be aware that employing these maps without a full understanding of their uses and limitations can lead to serious error. The maps in this package, with the exception of the borehole and seismic data location map (Fig. 7), provide continuous information, that is, they depict areas of uniform characteristics or, in the case of contours, of uniform elevation or thickness. Yet the basic information that makes up a map is the single observation, whether it be an outcrop, a roadcut, or a borehole. The mapper, in generalizing the information from site specific to areal, must make certain assumptions and therefore extrapolates. The map user often is interested in translating the map in the other direction, that is, from continuous information to site-specific information. The degree of reliability of this site-specific information can only be judged if the user understands the assumptions and extrapolations made by the mapper. One of the purposes of this text is to provide the person using the map with a framework within which to make such judgments.

The text also provides a historical framework within which to interpret the maps. The framework allows the user to not only obtain information on the material at the surface but to extrapolate into the subsurface. A description of the computer programs used to handle the data and to draw the contour maps is given. An understanding of this aspect of the map production is fundamental to a correct interpretation of the maps.

Historical background

The desirability of launching an environmental geology pilot project was first discussed in the early 1970's at a gathering of engineers and developers of the National Capital Region who decried the lack of geoscientific information needed for regional planning and the difficulty of obtaining such information from earlier civil engineering work carried out by private firms or government agencies.

In response to this expressed need, the Geological Survey of Canada in 1970 initiated a project entitled "Environmental Geology Prototype Study — Ottawa-Hull Region" (Scott, 1971), the purpose of which was to assist engineers, developers, and administrators by providing a methodology for compiling, evaluating, and organizing geological information. The project consisted of three parts: mapping of unconsolidated deposits, mapping of rock formations according to their geotechnical characteristics, and developing a computer-based information system. The system was to include a geotechnical data base, and its output was to be in the form of machine drawn maps. The rationale for adopting a computer-based system was to enable new data to be readily incorporated into the system and new data maps to be produced without having to recompile the data base manually. In the early 1960's, a drift thickness map was prepared manually for a small portion of the city (Bostock, 1960). With the rapid increase in both city growth and the available data, manual compiling and contouring of the data, particularly if it was to be updated periodically, was too expensive and time consuming.

As early as the summer of 1970 experimental computer-drawn maps showing the bedrock topography in the Blackburn area (east of Ottawa) were produced. Such maps, which were produced using the SYMAP system, illustrated the advantages and disadvantages of machine produced maps as compared to conventional, hand drawn maps (Bélanger and Morin, 1972). As this preliminary study was encouraging, the decision was made to proceed further and to create a bank of geological data for the Ottawa-Hull region.

During the winters of 1971-72 and 1972-73, using a modified version of the system tested for the Blackburn area, nearly 120 000 geotechnical files were compiled. These were based on engineers' borings and were gathered in 28 metropolitan centres in Canada (Bélanger, 1974). Although the method of data compilation proved to be adequate when used for well controlled areas, experience soon showed that it was not adequate when applied to such a large mass of data, particularly when assembled by individuals without data processing training. A third phase of the project, therefore, was launched in 1974 to increase the capacity of the information system through the use of more sophisticated data processing techniques. Efforts were aimed primarily at developing a data gathering system that could be used easily by people who lacked training in the use of computers. Another objective was to devise a highly effective data management system and an automated mapping system geared to the problems of urban environmental geology. Thus the Urban Geology Automated Information System (UGAIS) was developed (Bélanger, 1975a) and has been used to produce the five computer drawn maps (Figs. 3 to 7) included in this report and to provide other data maps and microfiche (Bélanger and Harrison, 1976).

GENERAL SETTING

Study Region

The Ottawa-Hull area was chosen as a prototype study area for a number of reasons, not the least of which is its proximity to the Geological Survey of Canada. The area contains a variety of rock and soil types, thus a wide range of conditions could be examined. The area also is known to have problems of interest to an urban geologist: landslides, settling foundations, sulphureous water, swelling bedrock, etc. Data, particularly borehole data, are relatively abundant and well distributed in the area, and many districts where data were not available have excellent road accessibility thus allowing seismic surveys to be conducted to supplement borehole information. Finally, the National Capital Region has a number of levels of government, all of which are potential users of geoscience information. Although it is recognized that geoscientific data can be used with benefit by many sectors, experience has shown that the largest users are the planning departments of government.

The boundaries of the study area were chosen to conform approximately to NTS (National Topographic System) boundaries, to include most of the Municipal Region of Ottawa-Carleton, and to produce a map of convenient size. Early in the development of the computer programs, which are an integral part of this work, it was decided to adopt the UTM (Universal Transverse Mercator) grid system to locate data points. This system has the advantage of being orthogonal and, therefore, simplifies the machine plotting of data. The disadvantage of this grid system is that it does not conform exactly in orientation to the NTS map sheet boundaries that are drawn on the basis of latitude and longitude. Also, in order that the study area have round numbered UTM co-ordinates, the designated boundaries only approximate NTS map sheet borders. The relationship between these two systems is shown in Figure 8 which locates the study area and the extent of the Regional Municipality of

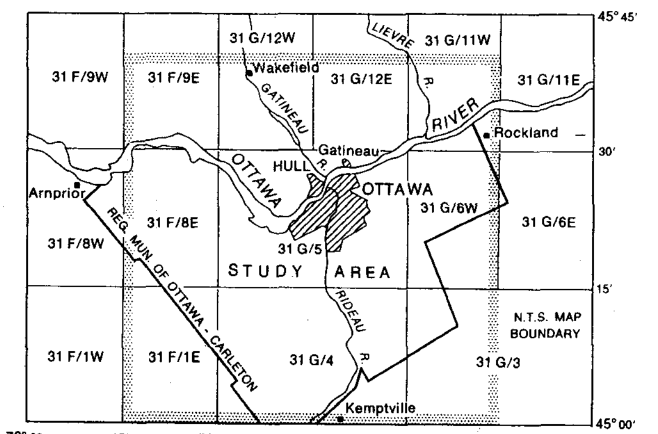

Figure 8. Location map showing the relationship of the NTS map sheets. Regional Municipality of Ottawa-Carleton (solid line), and study area (strippled boundary).

Ottawa-Carleton. It is unfortunate that at the time the study was initiated the Outaouais Regional Community had not been established and so only the southern half of it is included. The study area, covering 5600 km^2 ($\approx$2160 square miles), is bounded on the north by UTM 5 055 000, on the south by 4 985 000, on the east by 480 000 and on the west by 400 000.

Physical Environment

Prior to a detailed discussion of bedrock geology, surficial geology, drift thickness, geomorphology, etc., an overview of the area is presented. The purpose of this overview is to establish a framework upon which more detailed discussions can be based and to illustrate some of the concepts basic to a geologist's approach to planning problems. The block diagram shown in Figure 9 (modified from Brandon, 1961) is an ideal starting point for a discussion of the geology because it provides both a simplified map view and an interpretation of how map units are related to one another in the subsurface. The three basic geological units in the Ottawa-Hull area identified by Brandon on the basis of the era in which they were formed are the Precambrian, Paleozoic, and Cenozoic. Each of the three units has associated with it not only different types of material, but also the time during which the materials were formed or deposited and a history of how they came to be in their present condition. A historical approach, therefore, is used in discussing these deposits.

The Precambrian

The oldest rocks in the study area began their history some time prior to 1000 million years ago when sedimentary and igneous rocks were thrust up to form a mountain chain. The processes of erosion, deposition, deep burial, and mountain building may have occurred several times for there is some evidence that the most ancient of these old rocks have undergone several cycles (Wynne-Edwards et al., 1966). Some time between 1200 and 800 million years ago (Stockwell, 1968, p. 49) remnants of earlier cycles, as well as a new mass of sedimentary and volcanic rocks, were thrust up to form a new mountain system. Within the core of this mountain system, heat and pressure changed limestone to marble, sandstone to quartzite, and left a distinctive imprint upon the masses of granite. With time, erosion stripped the overlying material away exposing the mountain core of highly contorted, altered rocks. Little is known about this time of erosion but it was brought to a close some time around 500 million years ago when the now nearly flat exposed core of the former mountain chain slowly was inundated by a sea that advanced from the east (Wilson, 1946).

The Paleozoic

As the land slowly was inundated, the waves of the advancing shoreline reworked the surface materials and formed a sand and gravel deposit, the first of the Paleozoic sediments. During the next 70 to 80 million years the sea withdrew and readvanced three times over the area (Wilson, 1946). The sediments laid down in this everchanging environment became lithified and are represented by the layers of sandstone, conglomerate, limestone, and shale that today cover much of the area south of the Gatineau Hills. These flat-lying layers of rock are seen today broken by faults which have moved blocks up or down relative to one another. This faulting occurred some time after the deposition of the youngest consolidated rock unit in the area. Whether all the faults were developed at the same time or whether several episodes of faulting took place is not known. The Paleozoic limestone, sandstone, and shale were down-faulted with respect to the Precambrian rocks of the

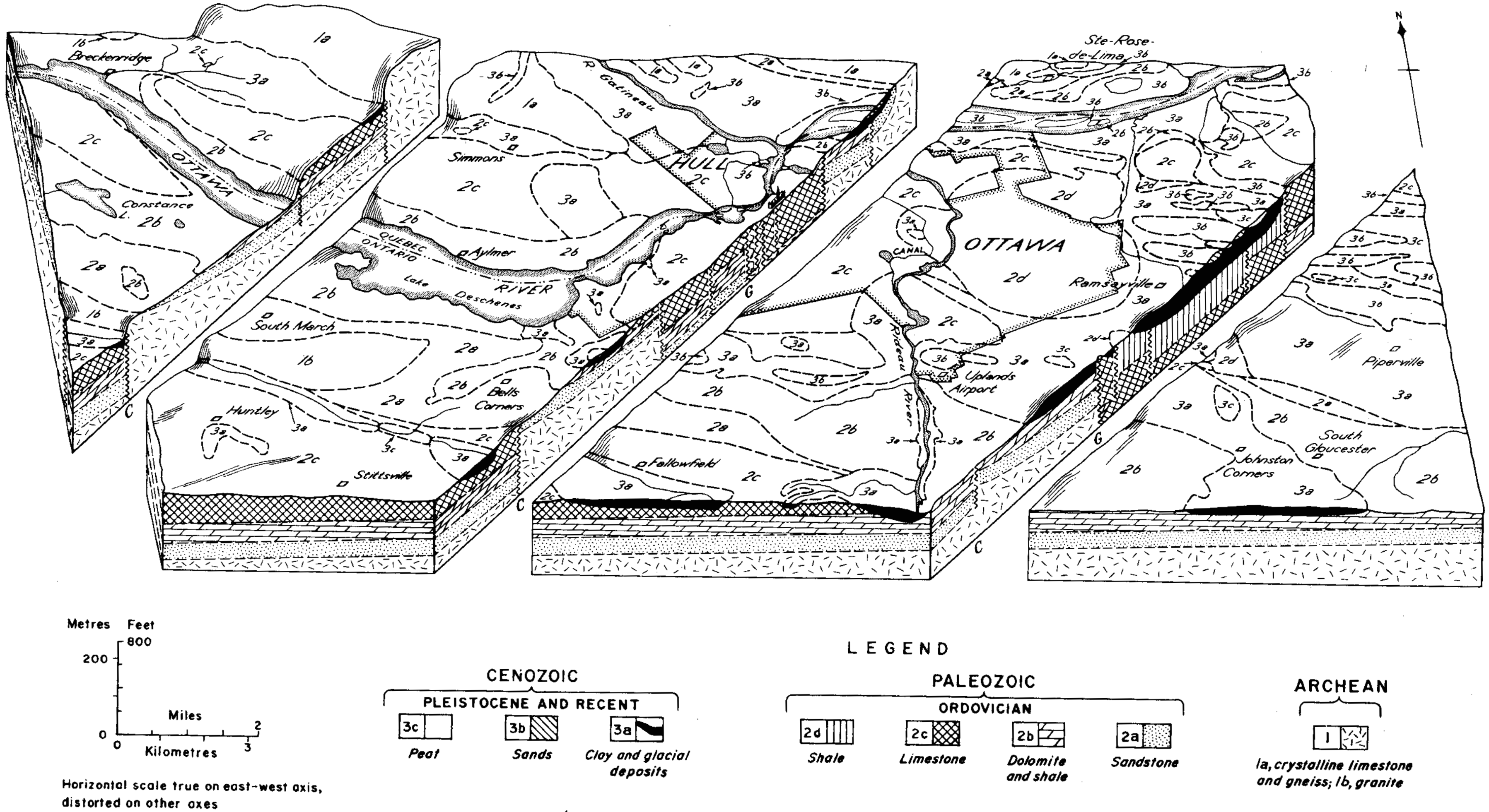

Figure 9. Block diagram showing generalized rock succession in the Ottawa-Hull area (from Brandon, 1961).

Gatineau Hills. Northwest of Hull the hills are separated from the lowlands by a single fault, the Eardley Fault, whereas to the northeast of Hull a series of faults have resulted in a less abrupt change in topography. Perhaps the upthrust Precambrian rocks to the north originally were covered by Paleozoic rocks, but these may since have been eroded away. Little is known of the history of the area for the next 430 million years.

The Cenozoic

The gap in our knowledge of what occurred in this region extends to perhaps less than 25 000 years ago. At that time the entire area was buried under several thousand feet of ice. This was at least the fourth time the area had been buried under a continental ice sheet (Prest, 1968, p. 677), but no sediments from these earlier events have been found in the area. As the last ice mass advanced, some sands and silts were deposited and later were covered by the material that was transported directly by the ice (till). As the ice retreated it left sand and gravel ridges as well as a blanket of till. The great weight of this ice mass depressed the crust of the earth a minimum of 600 feet (180 m) below present sea level, and when the ice melted the crust only slowly rebounded to its former position. For a time following deglaciation, therefore, the area was submerged by marine water, and thick accumulations of marine clay were deposited in a large arm of the sea that extended up St. Lawrence and Ottawa river valleys. As the land emerged the rivers re-established themselves and cut new channels. The complex unconsolidated sediments lying on the bedrock are the result of these events and some recent sedimentation by modern rivers and streams.

Figure 9 shows three major divisions according to geological time: the Precambrian, Paleozoic, and Cenozoic, each represented by different materials in complex relationships to one another. The surface of the block shown in Figure 9 represents a combination of both the bedrock map and unconsolidated deposits map. Only the thick unconsolidated material appears on the diagram; thin sediment cover is not shown but is represented by the rock that underlies it. Precambrian rocks underlie the entire region, and in most places are less than 1500 feet (470 m) below the surface. Faults have raised this group of rocks to form ridges in the Carp area as well as to the north in Quebec. The sedimentary rocks above the Precambrian rocks are essentially flat lying except where deformed by faults. Near faults the upthrown block exposes older rocks along the fault trace. Beds commonly are deformed in the vicinity of the faults. The

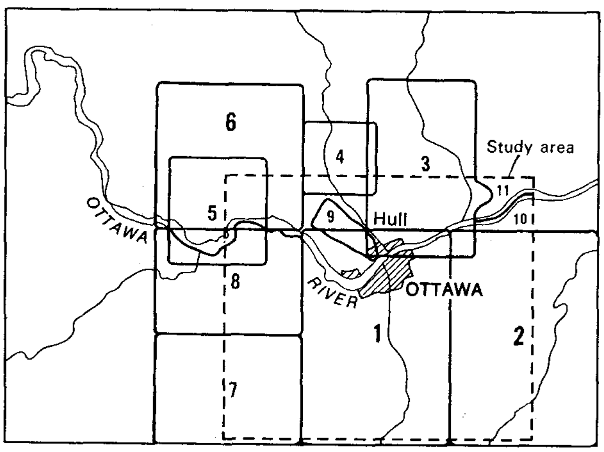

Figure 10. Sources of information for the Ottawa-Hull portion of the bedrock compilation map (MacDonald, 1967).

sedimentary rocks form a fixed sequence of units, and if a given unit is exposed at the surface it is usually possible to find all the units in stratigraphic sequence below it.

BEDROCK AND GEOTECHNICAL MAPS

In this section the bedrock geology map (Fig. 1) and the geotechnical characteristics of rock formations map (Fig. 2) are discussed. Both maps have boundary lines between map units based upon geological information but differ in the units mapped and the characteristics of these units. Figure 2 derives its boundaries from Figure 1 but incorporates a number of other factors into the legend.

Bedrock Geology

The bedrock geology of the study area is shown in Figure 1, which is taken from a geological compilation by MacDonald (1967) based on sources given in Figure 10. References 8 and 9 of Figure 10 were published after the compilation although MacDonald had access to the data. Information for the area south of Wakefield (Béland, 1954) was obtained from unpublished manuscripts by Béland on file with Ministère des richesses naturelles, Gouvernement du Québec (Quebec Department of Natural Resources). A number of changes have been made to MacDonald's (1967) original compilation, the most important of which is the elimination of the sub-epoch names originally published by Wilson (1946). Revisions to the stratigraphic terminology of eastern North America have made these terms obsolete.

No attempt will be made here to provide detailed stratigraphic descriptions of the map units shown in Figure 1; those concerned with such detail are referred to the source material. Figure 1 first will be discussed with reference to the map units and symbols in the legend, followed by general comments on the map and the relationships of formations, faults etc.

Commencing at the bottom of the legend and working up: map-unit boundaries are perhaps the most important and most misunderstood symbols on the map. An aerial view of this area would show only a small portion to have any rock at the surface. Most of the rock would be mantled by soil, vegetation, and unconsolidated deposits. What the bedrock mapper has available is a series of "outcrops", places where the rock is exposed at the surface or in excavations and boreholes. If the rock is well exposed over a wide area, it is possible to follow the contact between two units, and this is shown by a defined boundary. More commonly, however, the outcrops are small and scattered; in such cases a broken line is used. Should observations be spaced more widely or should a contact disappear under thick overburden to emerge some miles away, an assumed boundary line is drawn. This latter type of line also is used to outline areas for which no data are available.

Another important symbol on the map traces faults. A fault is a break in rocks along which movement has taken place. The movement along faults in the Ottawa-Hull area appears to have been mostly in the vertical direction. This movement, coupled with subsequent erosion, has left rocks of different ages abutting each other across the fault. A number of large faults are present in the area, the three most important being the Hazeldean Fault in the west which brings up the Precambrian to form the Carp ridge, the Gloucester Fault running from the heart of Ottawa towards the southeast, and the Eardley Fault separating Ottawa Valley from the Gatineau Hills northwest of Hull.

It is more realistic to consider the lines on the map as representing fault zones rather than fault lines. Commonly a fault is not a sharp break in the rock but in fact is a series of breaks and bends that may affect the rock for a width of from a few feet to half a mile. This fact is particularly important with regard to water flow into excavations or tunnels across or near fault zones (Brandon, 1961, p. 10).

The bedrock geology map classifies the rocks in the study area into 20 units. This classification is achieved by visualizing the rocks as though they were exposed in the wall of a quarry in the sequence in which they were deposited (youngest at the top, oldest at the bottom). This enormous rock face then is divided horizontally into formations based upon changes in rock type (lithology). If every subtle change was considered, the column could be divided and subdivided until each bed was named. Obviously such fine subdivision would not be useful in regional mapping; therefore, division is based on a series of major breaks, for example where some interval of geological time is not represented by deposition (an unconformity). Commonly however, there is a slow change in the environment of deposition represented by a slow change in lithology. In this case three units may be defined, one each for the initial and final lithology and one for the transition rocks. No matter how skilled the stratigrapher is in dividing the rock column, only rarely is it possible to define a formation in terms of time and still have completely homogeneous lithologic units. Therefore, although a formation may be characterized as limestone, it may include some sandstone or shale beds.

Map units 1 to 9 (Fig. 1) were formed during Precambrian time and as described in the introduction are the highly deformed and altered roots of an ancient mountain system. Description of such rocks is often highly technical, requiring an extensive knowledge of mineralogy and silicate chemistry to understand. As a result, with the exception of a few common and familiar terms, the terminology used to describe the rocks does not convey much meaning to the nongeologist. Also, unless the reader is interested in mining the rock or in some specific application, the characteristics used to differentiate one unit from another at this map scale are not pertinent to most land use planning or geotechnical problems. Not only the complex mineralogy but also the complex structure of the units reduce the value of a detailed description to the nongeologist. For most purposes, therefore, the Precambrian rocks can be treated as a single unit. This is not to say that valuable information concerning route planning, excavation, groundwater, etc. cannot be obtained from the bedrock geology of areas underlain by Precambrian rocks. Such information, however, should be obtained from the more detailed original maps upon which Figure 1 is based. The main reason for grouping Precambrian rocks into one unit is that they are "hard" rocks as opposed to "soft" rocks. The geological slang differentiating between igneous and metamorphic rocks and sedimentary rocks is based on the greater difficulty in drilling, blasting, excavating, and crushing the hard rocks. Hard rocks, in this case Precambrian rocks, also are more resistant to erosion and are very dense, therefore less permeable.

The ten remaining formations are composed of essentially flat-lying layered rock which has been broken in places by faults. The lowermost of these units, the Nepean sandstone, is the unit that overlies the unevenly eroded Precambrian rocks in areas where they do not occur at the surface. The Nepean Formation everywhere underlies younger Paleozoic rocks except in the northwest, south of Constance Bay, where younger Paleozoic rocks lie directly on the Precambrian rocks and over knobs that project through the Nepean Formation cover in a few localities. Above the Nepean Formation is the March Formation which represents a transition period from the sand deposition of the Nepean Formation to the dolomite of the Oxford Formation. This transformation is accomplished by the progressive introduction of more and more dolomite beds. The bottom of the unit arbitrarily is defined as the first occurrence of a dolomite layer and the upper limit by the last occurrence of a sandstone layer. The Oxford Formation, although primarily dolomite, does contain some limestone beds and in places dolomite grades laterally into limestone. The upper surface is marked by the abrupt transition from dolomite to shale of the Rockcliffe Formation. This abrupt change is attributable to the retreat of the sea from the area, a period of erosion, and resubmergence (Wilson, 1946).

During and following resubmergence fine grained sediments were deposited to form the Rockcliffe Formation. No apparent break in sedimentation occurs between the Rockcliffe and St. Martin formations, but the introduction of limestone and dolomite suggests a decrease in the supply of fine grained material, perhaps as the water deepened. West of Ottawa the St. Martin Formation is absent, and the Ottawa Formation lies directly on the Rockcliffe Formation. The Ottawa Formation is primarily limestone although of a somewhat different colour and texture than the Rockcliffe Formation. The contact is difficult to recognize in outcrop. The Eastview Formation grades upward into black shale of the Billings Formation, which is overlain by grey shale of the Carlsbad Formation. Outcrops are scarce, and even in boreholes these two units can be extremely difficult to differentiate. The youngest formation in the area is known only from exposures in a few shallow wells north and east of Russell. This rock unit, the Queenston Formation, is a red shale that can be separated from the Carlsbad Formation by a thin unit named the Russell Formation (Wilson, 1946), which does not outcrop in the area.

Approximately 10 per cent of the map area does not show the uppermost rock unit because of a thick mantle of unconsolidated (Quaternary) deposits and the lack of borehole data; the letter Q designates these areas.

Geotechnical Characteristics of Rock Formations

Figure 2 presents a simplified version of the basic geology map (Fig. 1). Unlike the abbreviated legend of the bedrock geology map, however, Figure 2 has an extensive legend providing information of a different type. In preparing this information for publication it would have been possible to combine the two maps and their legends. Although this would have provided for a very compact format, it was difficult to use, therefore, so as to benefit from the colour coded legend-map system a separate map and legend were prepared[1]. The rocks are grouped according to rock type rather than their stratigraphic and age relationships. In general it is more important to the planner and engineer to know the nature of the material rather than its age or place in the stratigraphic column.

The legend is designed to group the information about each rock type (rows) into specific categories or areas of interest (columns). In addition, at the bottom of the matrix are a series of boxes which define in numerical terms the descriptors used in the legend. The first explanatory box gives the range of values for joint spacing. Observations made in a quarry or cliff, particularly one of sandstone or limestone, would show that in addition to bedding planes the rock is broken by sets of subparallel fractures, or joints, which commonly are nearly vertical where the rock is flat lying. Generally there are two sets of joints, with the second set commonly intersecting the trend of the first at nearly 90 degrees. The combination of two sets of joints and the bedding plane weaknesses divides the rock mass into rectangular blocks. This fact is exploited extensively in quarry operations for dimension stone.

Joints also play a major role in groundwater flow because they provide passage through the rock mass which is independent of the intact rock permeability (Brandon, 1961).

[1] The original map and legend were prepared by J. Code and F. Morin in 1972 as part of an internal document (Geological Survey of Canada).

Thus wells may be developed in a rock type that has a very low permeability by tapping water moving through the joint system. Unfortunately no systematic study has been done of the jointing of the rocks in the Ottawa area. The information on joints presented in this legend is based on general field observations rather than on systematic measurement.

Mentioned above but not defined, bedding planes are surfaces parallel to the depositional surface that divide the rock into units. Obviously, if a sandstone unit overlies a limestone unit, the contact between the two rock types is an easily recognized bedding plane. Not so obvious are the bedding planes that occur in what appears to be homogeneous rock. These might be caused by either the presence of a thin layer of a different material or simply a break in sedimentation. In fine grained material this weak plane parallel to the surface of deposition commonly is developed because the plate-like particles of clay tend to align themselves parallel to the surface of deposition. Bedding planes may be so close together that the resultant rock is composed of a series of paper thin layers. Some black shales of the area may be described this way. Very thick bedded units also are common in the area, particularly in sandstone, limestone, and dolomite.

The information on grain size and bedding thickness is self-explanatory and does not need further discussion here. As noted above, the geotechnical characteristics of rock formations map (Fig. 2) is derived directly from the bedrock geology map (Fig. 1) by classifying each formation as primarily shale, limestone, dolomite, sandstone, or metamorphic and intrusive rock. Such a classification has some inherent difficulties arising primarily from the fact that it is a two step process. The first step is to designate formation boundaries, and the second step is to group the formations according to rock type. As previously discussed, in designating formation boundaries it is often necessary to include within the formation several rock types. In most cases one of these is predominant and the others are secondary. Obviously a much more accurate map of rock type could be produced if the rock column initially was divided strictly on the basis of rock type and a rock type map prepared directly. Undoubtedly this approach is highly desirable but would require a complete remapping of the area. As remapping was beyond the scope of this study, the procedure followed to produce Figure 2 was to classify the formations on the basis of the predominant rock type, keeping in mind that within areas mapped as limestone, for example, some beds of sandstone or shale (Ottawa Formation) may be present. Two departures were made in this scheme from a pure rock type classification: (1) a mixed unit, sandstone/dolomite, was introduced because it would be misleading to classify the March Formation as dominantly one or the other and (2) the shale category has been split into two units to emphasize the important swelling characteristics of the Carlsbad and Billings formations.

Column 1 of the legend (Fig. 2) lists the rock type categories; column 2 groups the formations in which each rock type is predominant and of secondary importance; and column 3, lithology, provides a description of the rocks within each rock type unit. The first three columns, therefore, provide the same basic information as the legend of Figure 1 but in a different format.

Formation thickness, column 4, provides an estimate of the maximum thickness that might be expected in the Ottawa area. The thickness of a formation is given by the perpendicular distance between the upper and lower surfaces that bound the formation. This value changes from location to location, and near the edge of the depositional basin will thin to zero; therefore, no minimum values can be given. If a certain thickness of a formation is encountered at the surface, this does not give any indication of the actual formation thickness because the upper bounding surface and an unknown quantity of rock may have been removed by erosion.

Column 5 gives general information on the structure of the rock mass, i.e. bedding thickness, attitude, and jointing. Columns 6 and 7 record general observations on the mode of weathering and on strength characteristics, two important considerations when rock is used either for foundations or as a construction material. Column 8 provides much the same information by recording past and present users of these materials. Column 9 is information originally published by Brandon (1961) concerning the water supply potential of the rock type units; Brandon's original study area was smaller than that covered by this report but contained the same rock types so that extrapolation to a larger area is considered justifiable.

Column 10 gives values of the specific gravity of the rock (Saxov, 1956). This information is useful in the computation of weight and volume relationships for fill, riprap, and crushed rock.

The average sonic velocity of P-waves, column 11, provides data on the properties of intact rock. Essentially this is the speed at which energy in the form of compression waves will travel through the rock. The velocity at which energy is transmitted by rock gives a measure of some of its properties. This velocity can be measured either in the laboratory using individual samples or in the field where energy is put into the ground at one location and the time taken to reach a second site is measured. Velocities measured on individual samples in the laboratory usually are somewhat higher because the velocity in the field is slowed by faults, fractures, joints, and bedding planes.

To obtain the data presented in column 11 two to eight samples were selected from each formation for laboratory testing. In general an attempt was made to select the test specimens at spaced intervals through the sample. Data obtained from these samples, however, may not be representative for two reasons: Firstly, only one drillhole was made in each formation and therefore the data are from one location. Secondly, and more seriously, core can only be tested if it is recovered from the drillhole intact. In many cases, particularly within shale formations, only a portion of the core was sufficiently strong to survive recovery, packing, shipping, etc. The material tested, therefore, is biased towards the stronger, better cemented, less fractured units within the formation.

Given these limitations, however, some general conclusions can be drawn from the data. Most significant perhaps are the low velocities of the Billings and Carlsbad shales. These values, in the 6000 to 9000 ft/s (1800 to 2800 m/s) range, are comparable to velocities found in glacial till and, in some cases, marine clay. Therefore, a field seismic survey, since it depends upon the velocity of energy transmission through the material, would not differentiate between unconsolidated materials and shale bedrock, and a calculation of depth to bedrock would be in error. This difficulty was encountered in the seismic survey undertaken as part of the present study. Depth to bedrock yielded values indicating depth to the top of the unit underlying the shale. Because of a lack of velocity contrast, the shale could not be differentiated from the overlying till and marine clay. This error was discovered when seismically determined depths to bedrock were compared to drillhole logs.

The considerable difference between the sonic velocity of P-waves of, for example, the Ottawa Formation (20 369 ft/s, 6210 m/s) and the Nepean Formation (13 562 ft/s, 4135 m/s) suggests that they might be differentiated in the field using seismic equipment. Differentiation by sonic velocity may be possible in certain

Table 1

Sources* of information for the Surficial Materials and Terrain Features Map (Map 1425A)

NTS 1:50 000	Map area	Portion	Reference
31 F/9E	Quyon	Southeast quarter	Richard, 1976
31 F/8E	Arnprior	Complete	Richard, 1976
31 F/8E & W	Arnprior	Complete	Minning, 1972
31 F/1E	Carleton Place	Complete	Richard, 1976
31 G/12W	Wakefield	South half, west of Gatineau River	Richard, 1976
31 G/12	Wakefield	Gatineau Park	Buckley, 1968
31 G/5	Ottawa	Complete	Richard, 1976
31 G/5	Ottawa	Complete	Gadd, 1963
31 G/5	Ottawa	Complete	Johnston, 1917
31 G/4	Kemptville	Complete	Richard, 1976
31 G/12E & W	Wakefield	South half, east of Gatineau River	Vincent, 1976
31 G/11W	Thurso	South of Ottawa River	Richard, 1976
31 G/11W	Thurso	South part, north of Ottawa River	Vincent, 1976
31 G/6W	Russell	Complete	Richard and Gadd, 1976
31 G/3	Winchester	Complete	Richard, 1976
		Outside Area	
31 G/6E	Russell	Complete	Gadd, 1976a
31 G/11E	Thurso	South of Ottawa River	Gadd, 1976a

*All publications originate from the Geological Survey of Canada.

areas where it is important to trace the contact between two units buried under a cover of unconsolidated deposits. For general mapping purposes, however, the variation in seismic velocity within formations often exceeds the difference between the mean velocities of different formations.

SURFICIAL MATERIALS AND TERRAIN FEATURES

The Surficial Materials and Terrain Features Map (Map 1425A) provides information on the distribution of unconsolidated deposits, the legend gives some indication of the history and stratigraphy of these materials. The map also provides data on some of the more prominent terrain features. The term "unconsolidated deposits" is used here to refer to all the material between the surface and the underlying rock. Engineers commonly refer to this material as soil; however, this term is not used here because in geology and agronomy the term soil refers only to the upper portion of the earth's surface that supports plant life.

When this study of the Ottawa-Hull area first was initiated in 1970, only Johnston (1917) and Gadd (1963) had mapped in the Ottawa area and Buckley (1970) in the Gatineau Park region. Projects initiated as part of this project include work by Richard (1976), Richard and Gadd (1976), Vincent (1976), as well as work to the east and west of the study area by Minning (1972) and Gadd (1976b). Table 1 lists the basic information used to compile the Surficial Materials and Terrain Features Map at a scale of 1:125 000. The map provides an overview of the entire region. It was necessary to eliminate some detail at this scale; users interested in problems requiring more detailed information are urged to consult the original material (Table 1) which was prepared at a scale of 1:50 000.

Unlike the maps shown in Figures 1 and 2 where large areas of a single formation are bounded by relatively straight lines, this map is more complicated, with complex boundaries and numerous small units. In order to obtain a clearer overview, a simplified version of Map 1425A is given in Figure 11 which shows the area divided into physiographic regions. The following discussion of the surficial geology is organized according to these physiographic regions.

Precambrian Bedrock

Precambrian bedrock, as shown in Figure 11, occurs in three areas: the Gatineau Hills north of the Ottawa River, Carp ridge west of Ottawa, and part of the Frontenac Arch on the southwest edge of the study area. These regions are characterized as standing above the surrounding country and having a thin to absent cover of unconsolidated deposits. The surface topography is rolling to rugged with numerous lakes and swamps, particularly in the Gatineau Hills and Frontenac Arch areas.

The Gatineau Hills west of Hull are separated sharply from the lowlands by the Eardley Fault; this dividing line contrasts strongly with that east of Hull where the marine clays extend well into the Precambrian area along valleys. The area of Precambrian rock lying between the Eardley Fault and Gatineau River is appreciably higher than that to the east, although both surfaces are rugged and contain numerous small discontinuous deposits of sand and gravel and pockets of marine clay. Several larger sand and gravel bodies are localized in large valleys, particularly in the upper reaches of LaPeche Sud Creek, Blackburn Creek, and along Rivière Blanche. Areas of marine clay extend into the region up major valleys, the most extensive areas being found along Gatineau and Rivière Blanche valleys. A number of landslide scars (designated L on Map 1425A), can be identified in the clay of Gatineau Valley.

Carp ridge stands about 100 feet above Carp River but is at about the same elevation as the flat-lying Paleozoic rocks which border this broad valley on the south. The ridge, therefore, is not a prominent feature comparable to the Precambrian hills to the north, although the steep scarp marking the south side is readily identified. The scarp marks the trace of the Hazeldean Fault, and the change in elevation across the fault probably is attributable to the more resistant Precambrian rocks which lie on the north side. Carp Valley is developed in a trough in bedrock which may mark a preglacial drainage route developed in response to the alignment of the fault. Precambrian rock does not outcrop along the entire ridge. The southeastern one third is composed of gently dipping Paleozoic rock, which forms a thin cover over the Precambrian rock. A large part of the ridge is mantled by unconsolidated material to a depth of less than 3 feet (1 m) and, therefore, has been mapped as rock. A number of low areas within this bedrock high have been filled with clay or organic matter (swamps).

Along the southwest edge of the map area a small portion of the Frontenac Arch is exposed. The arch is a broad topographic high on the Precambrian surface which connects the Canadian Shield with the Precambrian rock of the Adirondacks in New York. The flat-lying Paleozoic rocks become thinner near the flanks of the ridge and are absent west of the Mississippi Lakes. There is no dramatic change in elevation across the transition from Paleozoic to Precambrian rocks although, like the Gatineau Hills, this area is rugged and contains numerous lakes and swamps.

Paleozoic Bedrock

Bordering the latter area of Precambrian rock and stretching east is a broad area best characterized as nearly flat-lying Paleozoic rock overlain by a thin to absent cover of unconsolidated material. This area abounds in broad shallow swamps covered by cedar trees. Large expanses of bare rock are common. Numerous shingle beaches have been developed on promontories by the waves of the Champlain Sea during the late stages of the marine occupation when the area was subjected to wave erosion. Small discontinuous sand deposits are numerous in the centre of the area and in some cases are associated with beaches. Although the area is characterized as predominantly thinly covered bedrock, a number of large till areas are present, particularly along the line joining Richmond and Carleton Place.

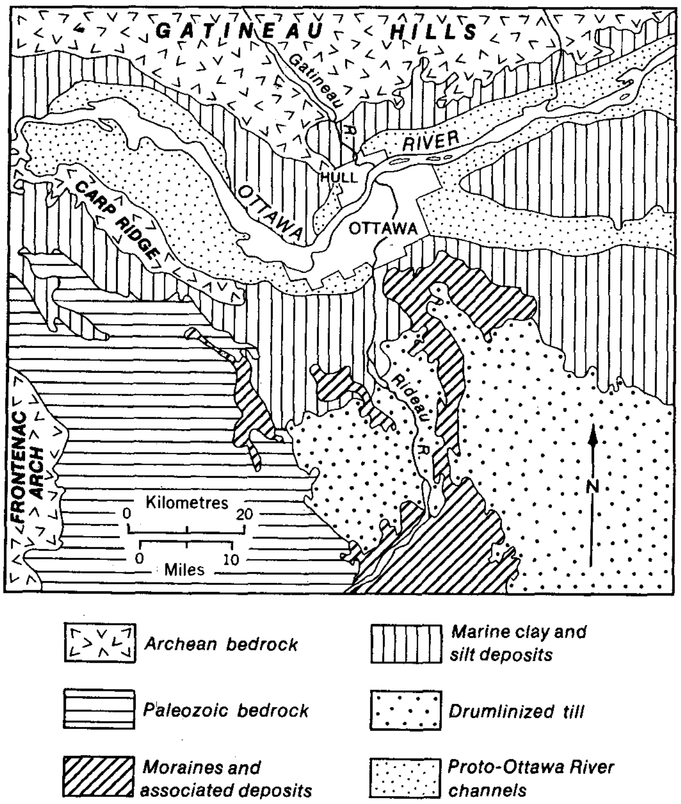

Figure 11. Simplified map of the surficial geology of the Ottawa-Hull area.

Drumlinized Till

During glaciation the ice flowed over the Ottawa area from the north. The ice deposited at its base an unsorted, nonstratified mixture of debris which it had eroded from the rocks farther north. This material, or till, then had its surface moulded by ice flowing over it to create landforms called drumlins: streamlined elongate rounded hills with the long axis in the direction of ice flow and commonly with a steep 'nose' on the stoss or up-ice direction and a tail in the lee or down-ice direction. Drumlins generally occur in groups and viewed from above resemble a herd of enormous whales on the surface of the sea. After the ice retreated from the Ottawa area the land remained depressed for a time, and the sea inundated the region. Clay was deposited in the low areas around the drumlins, and now only the summits protrude through the flat clay plain. The drumlinized till outlined in Figure 11 can be characterized as having areas of till, commonly drumlinized, over which a discontinuous cover of marine clay has been deposited. In addition areas of bedrock and swamp are common.

Moraines and Associated Deposits

As the glaciers retreated from the area, a number of complex sand, gravel, and till moraine ridges were formed at the margin of the glaciers. Ottawa International Airport is situated on a wave-modified moraine (Bowesville moraine; Johnson, 1917) composed primarily of bedded sand and gravel but including masses of till (Gadd, 1963). Several other bodies of sand and gravel might be of morainic origin; the largest two are a deposit northeast of Richmond and another that trends northwest from Stittsville. Smaller exposures near Bells Corners, Merivale, and Gloucester also may represent fragments of wave-eroded sand and gravel moraines.

These exposures consist typically of a core of sand and gravel flanked by sand and some gravel washed from the core and draped down the sides of the deposit. The flanking deposits commonly occupy a larger area than the core itself which may be blanketed by up to 10 feet (3 m) of reworked sand and gravel. Fine sand that was carried into the deep water beyond the flanks covers clay over a considerable distance beyond the core and flank deposits. During marine wave erosion of these deposits, bars and spits of sand were built out from the main deposit. A large recurved spit more than 7 miles long was constructed by wave action from material eroded from the Bowesville (Ottawa International Airport) moraine. This feature is composed primarily of fine sand. Only the major moraines and their associated features are shown in Figure 11.

Marine Clay and Silt Deposits

From the planning and construction point of view the most important unit is clay. Until recently this material, variously called Leda Clay, Champlain Sea clay (Gadd, 1976b), or the Hochelaga Formation (Elson, 1969), has been treated as a relatively homogeneous deposit. Recent detailed investigations, however, indicate that the deposit varies both areally and in section (N.R. Gadd, pers. comm., 1976). The area designated marine clay and silt in Figure 11 represents only a portion of the clay in the study region since clay also underlies much of the area designated proto-Ottawa River channels and also some of the sands associated with the moraines. The clay and silt unit outlined in Figure 11 characteristically forms a flat to gently undulating surface with steep gullies in areas marginal to major rivers and streams. Over large areas, particularly east of Ottawa, the clay has a thin sand cover. The clay varies from a few feet thick in pockets on bedrock to large continuous units in excess of 200 feet (60 m) in thickness.

There are insufficient data to discuss the variation of clay properties with respect to location; however, a simplified view of vertical variations can be given. Assuming a core is taken in the deeper portion of what was the Champlain Sea, at the base of the fine grained sequence one would expect to find freshwater silt and clay (Gadd, 1963). This unit is composed of pairs of alternating silt and clay rich bands. Each pair, or varve, is thought to represent deposition during one year. Varve deposition can only occur in freshwater so it is likely that the Champlain Sea was preceded, at least for a short time, by a freshwater lake phase. Above the varves and separated from this unit by a transitional zone is a massive soft, blue clay and silty clay with bands of grey sand. This soft clay is responsible for many of the landslide and foundation problems in the study area. This is a true marine clay and commonly is referred to as Leda Clay. In some places this unit is overlain directly by sand, but usually it is capped by a stiff, grey to brownish grey clay that is considerably stronger than the underlying grey clay. In some reports this upper clay is considered part of the Leda Clay and represents a zone of leaching and desiccation. Gadd (1963) considered the upper clay to be reworked material eroded by river action during and following emergence of the land above marine limit. The depositional environment was one which encompassed the transition from marine conditions, through a shallowing estuarine environment, to the beginning of fluvial erosion (Gadd, pers. comm., 1976). Thus the clay would be contemporaneous with sand washed from the moraine ridges by wave action and might explain the absence of the upper clay unit under the sand.

Proto-Ottawa River Channels

As the crust of the earth slowly rebounded from the depression caused by the weight of glacial ice, relative sea level dropped; as the region rose above sea level Ottawa River re-established itself and a sequence of environments migrated eastward across the area. First was the transition from deep to shallow water; then an estuarine environment of long leads and broad flats, perhaps covered by brackish to freshwater; then a subaerial delta environment; and finally a period of fluvial erosion. Erosion during the last two stages of this sequence, particularly the last, created a series of channels in the area. Figure 11 outlines the areas of major channels which are bounded by scarps. In the western half of the study area the proto-Ottawa River had approximately the same course as the present Ottawa River but was wider. In the east flow was by two routes, the present channel and to the south through the area of Mer Bleue swamp. Downcutting in the present Ottawa channel finally resulted in the Mer Bleue route being abandoned.

Proto-Ottawa River channels are characterized by bounding scarps on both sides. Where the channels have downcut into marine clay, the channel bottom is composed of clay commonly mixed with sand and having numerous sand bars. In some locations large sand bars or islands were built in the channel (Map 1425A). Four such former islands can be seen south and west of Mer Bleue swamp. Some sand deposits have been eroded since deposition, as indicated by the scarps cut into them.

Probably the most important fact to be noted with respect to proto-Ottawa River channels is their influence on the distribution of landslides (Map 1425A). During development of the channels scarps commonly were cut in marine clay. The steep banks promoted the development of landslides, some of which occurred while the channel was still occupied and some after the river ceased flow at the foot of the scarp (N.R. Gadd, pers. comm., 1974).

A second important characteristic is that once abandoned, a series of shallow lakes was left in the deeper portions of the channel. These lakes have infilled with organic material to form swamps. In a number of locations the swamps have been infilled and structures have been erected on the surface. Continuing consolidation of the organic material in the swamps has resulted in settlement of and structural damage to buildings whose foundations are not designed for such conditions.

Landslides

Areas of landslides are not shown in Figure 11 because they are individually small, but they are evident on Map 1425A. Large landslides have occurred in marine clay since retreat of the Champlain Sea. These landslides, even if they are old and covered by vegetation, are readily recognized on aerial photographs. The areas of landslides shown on Map 1425A have been identified primarily by this means. Each landslide area mapped includes both the source area of the slide material and the resultant slide deposit where present. In some cases the landslide material was deposited into a stream and has been eroded away.

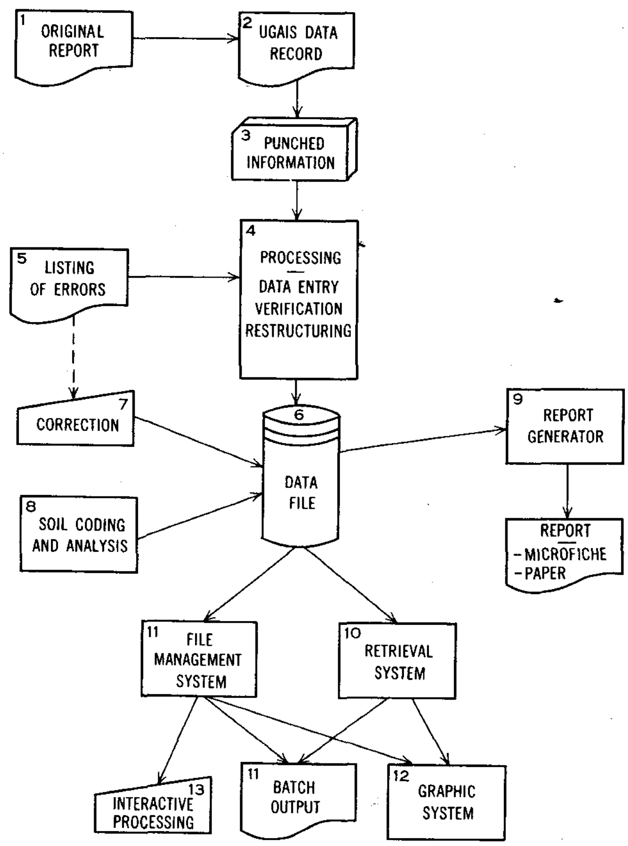

Figure 12. UGAIS (Urban Geology Automated Information System) flow chart.

The majority of landslides identified occur in association with scarps cut into marine clay (Klugman and Chung, 1976). As landslides are not present everywhere where scarps are developed in marine clay, obviously other factors also must be at work to localize this phenomenon. Probably one of the most important is the flow of groundwater. Gadd (1976a) noted the relationship between permeable sand lying on top of the clay and the occurrence of landslides. Gadd (pers. comm., 1976) has evidence to support the division of marine clay into a number of different units (facies) with different properties. Facies differences represent yet another factor localizing landslides.

Ideally, if all factors favouring landslide occurrence were known, maps could be prepared outlining areas of landslide danger. Since this is not possible, at each site where potential landsliding represents an important planning consideration, a separate investigation must be conducted. The surficial materials map provides an indication of where some of the known landslide conditions are present and thus where a more thorough investigation is warranted.

Smaller landslides are not shown on a map of this scale. Many smaller landslides have been noted along gullies and streambanks. Although slides commonly occur in marine clay, other materials may be involved.

Thus, to summarize, the Surficial Materials and Terrain Features Map provides a broad overview of the area as well as data on the type of materials to be encountered at the surface.

DATA PROCESSING – UGAIS

Description of the System

The Urban Geology Automated Information System (UGAIS) (Fig. 12) has been designated to handle the three-dimensional aspects of geological information as it pertains to the urban environment. The system was created in the hope of providing earth scientists and planners requiring subsurface information in an urban area with ready access to large quantities of data often already existent. The initial stage of the system centralizes, homogenizes, and systematizes this otherwise diffuse body of information. The central file so created then can be used in a number of ways: selected records may be retrieved and listed; the entire file may be listed on either paper or microfiche and appropriate locate maps can be created to make future access independent of the computer; or certain aspects of the data, such as drift thickness, may be displayed in the form of a contour map.

UGAIS was designed as a modular system, with each module being independent of the others. With this approach, it is possible to modify each module without affecting the entire system and to interface the UGAIS with other data processing systems. This kind of flexibility allows for changes reflecting the users' needs and adjustments to new technical developments, a frequent occurrence in the computer field. The system is divided into three modules: input, processing, and data retrieval.

Data Input

The data input module is used to compile geological and geotechnical information gathered from engineering surveys, and well drilling, seismic, and other survey reports. For the purpose of initially gathering the data a compilation sheet (2)[1] was developed which could contain the various kinds of information provided by the original documents (1) in a format compatible with computer processing. The compilation sheet serves both as a source for data entry into the computer and as an original record that can be stored for future reference.

[1] The numbers in the text refer to the flow chart in Figure 12.

In the preliminary phase of the project, the format of the data compilation sheet was adapted to the recording techniques normally used in electronic data processing. These techniques involve the use of mnemonic codes and fixed length fields in order to facilitate the task of computer programmers and to lower electronic data processing costs. In order to enter the data on the form, it is necessary to analyze the original documents and to classify each component according to a pre-established coding system. Once the information has been analyzed thoroughly, the parameters are assigned mnemonic codes and are entered on the form in the appropriate location.

Unavoidably, this method produces numerous errors both in interpretation and data coding, particularly when the person doing the compiling is not a geologist trained in computer processing techniques. Because the number of entries and the mnemonic codes have to be established in advance, any new information that does not fit the adapted format must be rejected or the list of codes must be modified periodically. It is difficult therefore to adapt this system to varied sources or levels of information or to normal variations in types of information as encountered in different regions of the country. Another source of difficulty is data interpretation once the form has been filled out; it is not the task of the key-punch operator to interpret the codes, and this leads to an increase in key-punch errors. Also when the data are retrieved, it is impossible to reconstitute the geological description as it appeared in the original document.

In 1974 and 1975 a number of studies were conducted in order to find a solution to the difficulties encountered during the preliminary phase. The main purpose of these studies was to make the system more readily accessible to individuals without data processing training and to improve the quality of information recorded on the data compilation form. The users and the data collection personnel, when surveyed, expressed two criticisms: (1) the mnemonic code list was cumbersome, and (2) the design of the data compilation form was too rigid.

To overcome these difficulties it was decided to abandon the use of mnemonic codes and to redesign the data compilation sheet. The new format is now similar to that of standard reports of borings prepared by most engineers. With this new approach it is possible to record all the information in the original documents and to preserve the terminology and the language used. Data processing rules regarding input format have been reduced to a minimum to simplify filling out the form and to reduce transcription errors. Further details regarding use of the data compilation sheets are given in a UGAIS training manual (Bélanger, 1975a).

Data Processing Module

The purpose of the data processing module is to create a computerized data file using the geoscientific information assembled by the input module.

First, the information on the data compilation sheet is transferred onto computer cards (3) so that it can be read by the computer. Next, the basic file (6) is created. The data input program (4) accomplishes this task by:

(a) reading the computer cards and verifying the sequence of the cards and record numbers; records containing errors are rejected, and a list of such records is produced (5);

(b) changing the card image into a record image. During this operation each field is verified, modified to meet data processing requirements, and then is recorded in the designated place. The output format of the record is divided into two sections: one section contains the information given by the original document, whereas the other is left blank and is used to enter mnemonic codes during a subsequent operation;

(c) creating an index (13) which is used to provide selective access to the data; indexing is based on the record number. This step enables the correction of errors detected by the data input program (4). Selective access to the data makes it possible for the operator to make the corrections interactively (7) and to validate the corrections through an automatic system that verifies each modification to the file. Records contained in the basic file can be retrieved according to the parameters of the header part of the records, but access to the records keyed on the soil type or description of the soil is not possible. It is necessary therefore to process the file further by a soil analysis and coding program (8) that isolates key words in the file. The program identifies each word in the sections reserved for soil type and description, compares it with a list of accepted words, and when the word in the record matches a word in the list it enters the appropriate code in the section of the record reserved for mnemonic codes. This coding enables the retrieval of data from the mass of information originally compiled in flexible format.

Data Retrieval

At present, data retrieval is performed according to three types of applications: (a) report generating, (b) batch retrieval, and (c) direct access processing.

Report Generator

The purpose of creating output in the form of a report (9) is to reproduce all the original information placed in the data base in a format similar to that of the original document. The program therefore generates only the information that appears on the data compilation sheet and ignores the mnemonic codes derived from the information.

Output is in the form of a paper printout or appears directly on microfiche when a COM (Computer Output Microfilmer) is used. Although microfiche requires the use of a special reader, this type of output presents numerous advantages in terms of production costs, durability, and format.

Batch Retrieval

Batch retrieval (10) is used in the case of processings that do not require a sustained dialogue with the basic file. Output is usually of large volume and is in the form of listings (12) or machine language for subsequent processing by computer. Output listings (12) are used primarily in specific studies requiring custom-made programs, such as statistical studies as well as verifications and systematic updating of the data base.

Output in machine language requires the intervention of an intermediate data processing system (11) that analyzes the basic information and generates instructions for the graphic output equipment. While the graphic output system was developed to meet the requirements of the UGAIS system, it is independent of it and constitutes a self-contained module. The graphic system (11) can receive different types of information in various forms and can be used for the production of a variety of maps (Bélanger, 1975b).

Interactive Processing

Interactive processing implies direct access of the data by the user. When operated in this mode, UGAIS utilizes a standard file management system (14).

Attempts have been made to handle the data through SYSTEM 2000. This system is highly effective in performing data retrieval operations, but necessitates a restructuring of the original basic file. The creation of the new file causes numerous problems, particularly in terms of updating, because the data base used by SYSTEM 2000 is not compatible with the other modules of UGAIS. SYSTEM 2000 therefore has been used on an experimental basis only.

Other file management systems, such as QUERY UPDATE and IS/ATHENA have been tested. The advantage of these systems is that they use the existing file to generate index tables without modifications to the file structure. It is possible, therefore, to update the UGAIS data base while maintaining compatibility with other modules. This approach has proven more successful than data base management systems (e.g. SYSTEM 2000).

BOREHOLE AND SEISMIC DATA

Introduction

The system described in the previous section evolved over a period of several years. This system and its predecessors were used to process information on subsurface geology obtained from more than a dozen sources. These sources can be classified into three categories: engineering boreholes, water well records, and seismic surveys. Engineering borehole data were obtained primarily from government agencies (Department of Public Works, Corporation of the City of Ottawa, Voirie du Québec, etc.) and private geotechnical consulting firms. Data on water wells drilled within the study area were provided by the Ontario Water Resources Commission; seismic information was obtained from a survey conducted as part of this study. Data from 9897 locations within the study area were used to construct a data bank which is stored both on magnetic tape and microfiche.

The location of each data point used to generate the other computer drawn maps (Fig. 3 to 6) is shown in Figure 7. Figure 7 indicates whether the data are derived from engineering, water well, or seismic sources and whether, in the case of boreholes, the drilled hole reached bedrock (cf. Table 2).

Engineering Boreholes

The engineering borehole data used in this report were obtained from boring records and laboratory tests made by various agencies to obtain information for design purposes. As the borings were made mainly to obtain subsurface data, the materials encountered, in most cases, were recorded with reasonable care by engineers or technicians with training in the field identification of unconsolidated deposits. In addition to providing reliable information on the type of

Table 2

Classification of Data Points in the Ottawa-Hull Data Bank

Source of data	Number of Boreholes Reaching Bedrock	Number of Boreholes Not Reaching Bedrock
Engineering boreholes	1189	686
Water well record	5839	640
Seismic survey	1543	–
	8571	1326
		Total 9897

material encountered and its depth, many engineering borehole records list values of penetration resistance, shear vane, and penetrometer tests, natural water content, and Atterberg limits. In this study it has been assumed that engineering borehole data are more accurate than either seismic or water well data. Where there was a reasonable density of engineering boreholes, therefore, no additional data were sought, and where the inclusion of seismic and/or water well data resulted in coverage too dense for the working scale, these data were deleted from the data bank.

Unfortunately engineering boreholes normally are made only for large structures: bridges, large buildings, overpasses, etc. Thus the majority of the engineering information in the Ottawa-Hull data bank is concentrated in the core of the urban areas or at overpasses along major highways. More than 90 per cent of the engineering borings lie in 20 per cent of the study area that is within 10 miles of downtown Ottawa. As a result, in the active residential growth areas outside the urban core less reliable data must be utilized.

As many as 40 borings may be made to obtain design information for one structure occupying an area of less than an acre. Such a large number of borings within a small area cannot be represented properly at the map scales used in this study; therefore, typical borings were entered in the data bank, usually four or five, representing the corners and middle of the structures, and the remainder were ignored. As a result of this procedure much more data actually were examined during this study than are represented by the 1875 engineering records used in the data bank.

Ontario Water Resources Commission

Since 1946 the Ontario Water Resources Commission (now Water Resources Commission, Department of Environment) has required that a log be filed with the Commission of every water well drilled within the province. Of the more than 200 000 (1976) water well records on file, more than 10 000 are from the Ottawa-Hull study area. These boreholes were drilled to develop a water supply, and any information on the strata penetrated is a byproduct of this primary function. As a result the quality of the water well records generally is considerably lower than that of engineering boreholes. This is because the information gathered often is not used by the driller and also because the personnel employed to drill water wells do not have the training in material identification that engineers or engineering technicians possess. Therefore, the stratigraphic information obtained from water wells must be used with caution.

Water well data was included in the Ottawa-Hull data bank in order to provide coverage outside the urban core. As mentioned above, few engineering boreholes have been drilled outside the core area yet there is a desperate need for information. Although the stratigraphic data must be used cautiously, some basic information such as depth to bedrock and borehole elevation has been found to be of acceptable accuracy. Available information is utilized because it would be prohibitively expensive to acquire subsurface data of the desired type and density of spacing solely for purposes of urban geology.

Of the approximately 10 000 water well records available 5839 were utilized in constructing the Ottawa-Hull data bank. Records were deleted from the bank if the particular area already was covered adequately by engineering data or if some piece of information on the record was incompatible with data from surrounding records. This incompatibility usually was identified on early versions of the drift thickness and bedrock contour maps. Anomalous values showed up on these maps as steep conical hills or depressions. Most records identified in this manner had errors in either location, well head elevation, or borehole depth. Once an anomalous record was located it was compared with nearby records to determine if indeed there was a deep depression or steep hill on the map at that location. Usually an incompatible stratigraphic sequence indicated that the boring was mislocated; a misplaced decimal in the elevation or depth revealed an error in compilation. As there was no way of determining what the correct values were for these records, they simply were deleted from the data base. Only the data required to generate the drift thickness and bedrock topography maps were used from the water well records.

Seismic Survey

Even using water well and engineering data, areas of the study region had an inadequate density of data. In these areas a hammer seismic survey was conducted to provide data on depth to bedrock, although in some cases limited stratigraphic information could be inferred from the records. Depth to bedrock was computed from seismic data at 1543 locations in the study region. These data points were compared to the engineering and borehole data; and some records based on seismic data were deleted from the data bank due to overlap or incompatibility with surrounding data. The majority of seismic data points deleted were in areas underlain by shale formations where the seismic velocity contrast between shale and overburden is insufficient to permit differentiation between the two.

COMPUTER DRAWN MAPS

Introduction

As part of the development of the UGAIS a set of programs were written to produce maps from information in the data bank. These maps are produced on a flat-bed plotter which uses input commands from a magnetic tape produced by computer. This portion of the UGAIS was developed to allow processing of large amounts of information, to provide an interpretation of the available data based upon a precisely defined mathematical algorithm (a set of mathematical relationships), and to permit easy and rapid updating of maps as new information is made available.

The automated cartography programs eliminate the tedious and time consuming job of contouring by hand the nearly 10 000 data points in the study area. The computer can produce a map in less than two hours. This ability to produce maps in a short time at relatively low cost has allowed experimentation with map scales, contour intervals, and types of information displayed. The five computer drawn maps (Figs. 3 to 7) in this report represent only a small portion of those that have been and could be produced. Maps that have been produced on an experimental basis include large-scale detailed maps of drift thickness and bedrock topography, maps showing all reported occurrences of clay more than 20 feet thick, and a map showing the first reported horizon for all drillholes in Ottawa.

The production of contour maps using a rigidly defined algorithm has both advantages and disadvantages. The primary advantage is that any bias that might be introduced into the contouring is consistent and completely known if the algorithm is understood. The user must be aware however that given a group of data points, there may be several ways of contouring the information, all of which agree with the data but may not depict the phenomenon as it appears in reality.

The maps produced by the ISAMAP package are intended to be used as basic documents rather than final products. Little attempt has been made, therefore, to smooth contour lines or to make adjustments for aesthetic purposes. The maps are intended for use as resource material, and it is expected that they will represent but one input into more complex derived maps created for special purposes. The contour maps in this package (Figs. 3 to 7) were generated by computer plotter, and only minor drafting changes have been made by the authors to improve clarity of data presentation in cases where confusion might otherwise result.

Manually updating maps as more information becomes available can be an expensive and time consuming job. Using the automated cartography package of UGAIS, it is a routine procedure. Even though a great number of new points would have to be added to the small scale maps accompanying this report before any appreciable change would be seen in the contours, as data are added it is possible to produce detailed maps at larger scale and smaller contour intervals. Also, although the contour lines are mathematically correct, their positions could be modified to some extent by changing the pattern of control points.

The disadvantage of computer drawn maps is that select information, such as fault lines and rock types, which might be known to a person contouring the data by hand, cannot be integrated in a graphic display program.

The set of programs in the automated cartography package of UGAIS used in the Ottawa-Hull data bank also is being used to analyze data from other urban areas as well as to contour other types of geological information. Although many interpolation-extrapolation algorithm programs are available for general purpose contouring (e.g., SYMAP, GPCP, SURFACE II) the contour package, ISAMAP, developed as part of UGAIS was created specifically to meet the needs of urban geology and particularly to provide a means of handling clustered data points. The automated cartography package also is capable of producing maps that display point data.

Details for use of the actual computer programs of the automated cartography package are given by Bélanger (1975b).

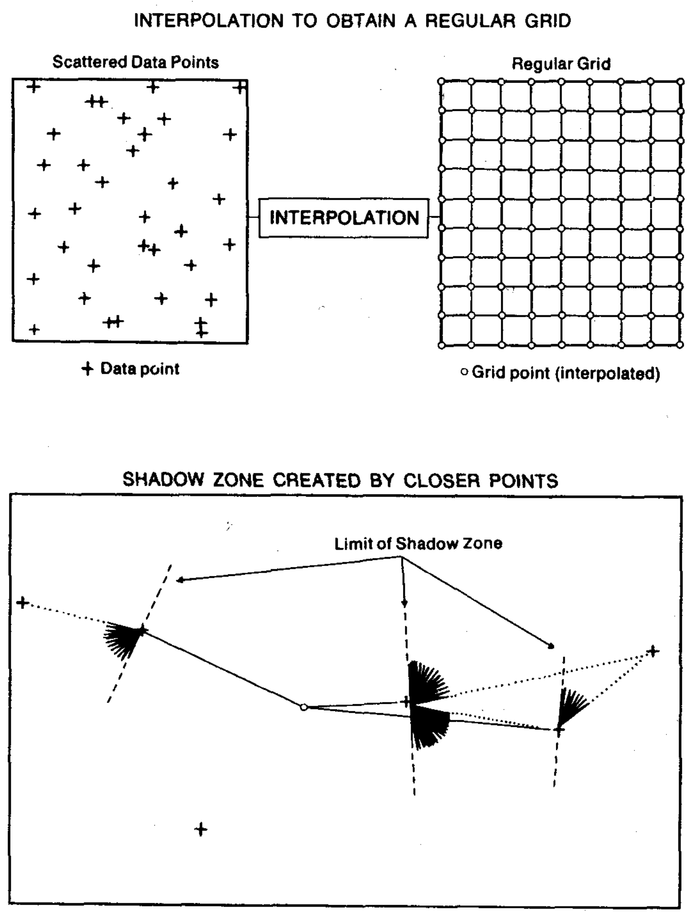

Figure 13. Interpolation of grid and shadow zone concept.

Point Data Maps

Point data maps provide, by the use of one or more symbols, information at a specific point. Figure 7 is an example of a point data map in which the symbols indicate the type of data and whether the borehole penetrated to bedrock.

A second type of point data map finding wide application is the locator map; the computer is programmed to print the data record number on the map with the centre of the first number at the location of the borehole or seismic data point. The resultant map, when placed over an appropriate base, can be used to locate specific data points by number. Where points are so close together that data numbers would overprint, thus destroying legibility, a series of separate overlays is made. The Ottawa-Hull data base has been prepared on microfiche and keyed to locator maps (Bélanger and Harrison, 1976).

Another type of point data map, which has been produced experimentally for the Ottawa-Hull region and has been produced for a study of the Hamilton area (F. Morin, pers. comm., 1976), is the flag map. To produce this map some condition or set of conditions is defined and the computer is programmed to print a symbol at each location where these conditions are met. An example of a flag map would be one that shows all occurrences of peat; the map then could be used as a warning that areas flagged should be examined more thoroughly before any development is allowed to proceed.

Contour Maps

Like the point data map the first step in the preparation of a contour map is the retrieval of information from the data bank. This information is processed and provides three values, x, y, and z, where x and y represent the location of the data point on the map and z the parameter to be plotted. On a point data map the value z either is plotted directly (e.g., record number) or is converted into a symbol (e.g., * represents an engineering borehole); on a contour map the value z, along with its position co-ordinates x and y, constitutes one control point. As the control points are not spaced uniformly throughout the map, a set of evenly spaced (grid) points must be generated from the control points (Fig. 13). This process is called interpolation and is accomplished using an algorithm (for details see Bélanger, 1975b).

The algorithm used to generate the grid values from the scattered data points is strictly an interpolation one, that is, no grid point is assigned a value beyond the surrounding maximum z values. The reason for using an interpolation algorithm, rather than one that generates values based on the slope of the surrounding plane, is to produce documents with a relatively "conservative" aspect.

Each grid point is evaluated from the surrounding control points. The search area either can be specified by the user or can be assigned automatically by the program. A minimum and maximum limit can be placed on the number of data points to be considered. The search for control points is

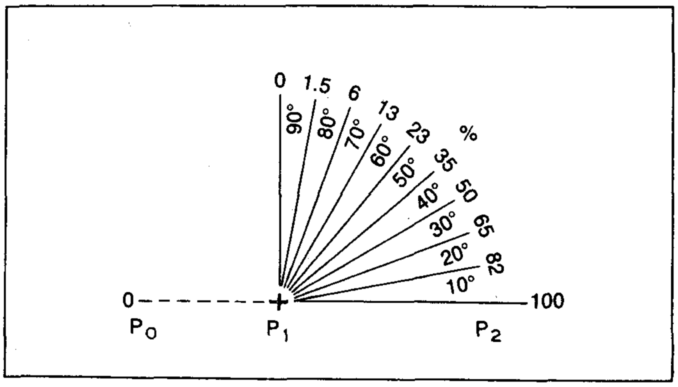

Figure 14. Incremental effect of the shadow zone.

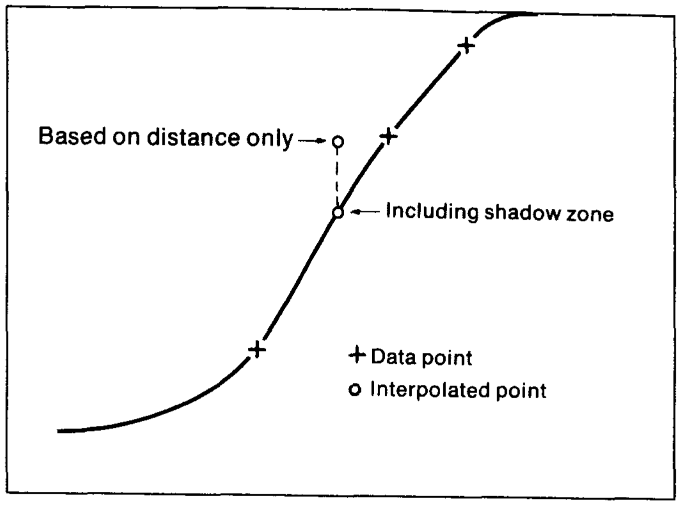

Figure 15. Necessity of a shadow zone.

done in the x and y directions independently (rectangular search), rather than a circular search, to permit the user to orient the search. When the area is not specified, the program calculates a standard search area, based on the density of the control points, in which an average number (specified or calculated) of data points should be found. If less than the specified number of points is found, the area is enlarged; if an excess number of data points falls inside the search area, only those closest to the grid point are used. The program allows a maximum of twenty control points and a minimum of one to be used for interpolation.

The values at the control points selected for use in the calculation of a grid point cannot be used directly; they must be weighted to take into account both distance and position. Points located farther from the grid point have less influence on its value than control points that are closer. To avoid sharp variations near control points an inverse squared distance is used in this algorithm rather than the more common inverse distance.

To overcome the problems caused by clustered control points located in the vicinity of the values to be interpolated, a shadow zone is created behind each data point from the grid point (Figs. 13 and 14). The influence of a data point that falls in the shadow zone of another data point is reduced as shown in Figure 14. The positional factor is defined by the cosine of angle P_0, P_1, P_2. A screening effect is essential in this algorithm because no slope factor is taken into consideration to overcome the shortcoming of a straight inverse distance interpolation (Fig. 15).

The contouring program reads the interpolated grid points and draws the contour lines. The grid surface first is subdivided into triangles by joining the four corners of the rectangles formed by the grid points (Fig. 16). The centre point formed by the intersection of the diagonals is interpolated as the average of the four corner points. The second step is to find the beginning of the contour line by linear interpolation between grid points, first along the edge of the map then throughout the entire area. Once a value equal to the contour line is found, the contour line is "followed" by searching in adjoining triangles. When the line crosses a boundary or reaches its point of origin to form a closed contour line, the process is repeated to find the next contour line. When a sufficient number of points along the line are found, or when the contour ends, the line is drawn and annotated as specified by the user.

Thus using the automated cartography package, any parameter forming a part of the borehole record may be contoured provided it can be expressed numerically and is continuous (e.g., a body of clay in the subsurface).

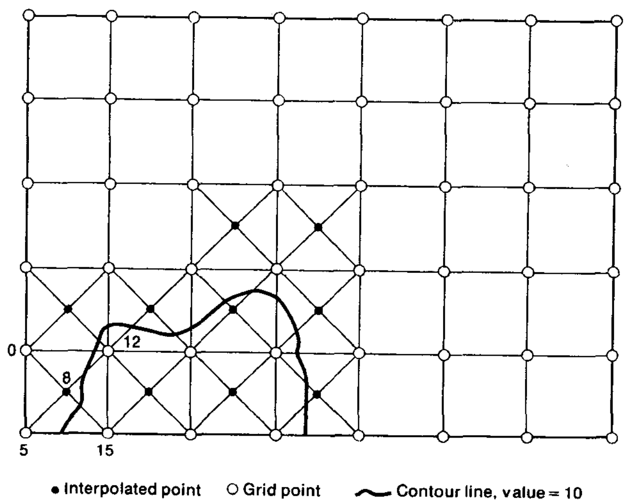

Figure 16. Contour generation.

DRIFT THICKNESS AND BEDROCK TOPOGRAPHY

Introduction

Two types of contour maps have been produced using the contouring facilities of UGAIS; drift thickness and bedrock topography (Figs. 3 to 6). The bedrock topography maps were produced by contouring the values given for the depth at which bedrock is first reported at each borehole or seismic data point. Drift thickness is generated by subtracting the bedrock elevation values from surface elevations and contouring the resultant data.

Two maps of each type were produced, one covering the entire study area at a scale of 1:125 000 and one providing more detail in the Ottawa-Hull urban area at a scale of 1:50 000. The bedrock contour maps have a contour interval of 25 feet, whereas the drift thickness map at 1:125 000 scale has a contour interval of 20 feet and the one at 1:50 000 scale has an interval of 10 feet. The larger scale and smaller contour interval of the detailed map are possible because of the greater density of data points in the urban areas and their higher reliability.

The degree to which the surface depicted by the contours of these maps is an accurate representation of the actual surface is difficult to assess rigorously. Standard techniques of statistics cannot be applied for three reasons: (1) the variability of the real surface is not uniform throughout the area, (2) the density of data is variable, and (3) the distribution of data points is neither random nor regular. A qualitative assessment of the data, however, can be made based on the following question: Can the feature of interest 'hide' between data points shown in Figure 7? For example, a square mile bedrock knob buried by thick drift could be hidden easily among data points, whereas it is unlikely that a major steep-walled preglacial valley could go undetected. In general, with an increase in variability of the surface and a decrease in the number of data points, the reliability of the map decreases. On a perfectly flat plain one point can provide all the data needed whereas on an irregular surface only an infinite number of data points will give an exact representation.

Where there is a large blank in the borehole or seismic data the computer will proceed to use the closest available information. In some cases this can mean reaching across the blank area for a bordering data point on the other side. An example of this occurs north of the village of Carp (UTM 420 000E 4502500N). The lack of data on the Carp ridge caused the computer to reach across the blank to the northeast side for a data point. The resulting contours were drawn based upon the data from borings in the thick drift southwest of the scarp marking the south margin of the ridge and the borings in drift on the north side. Without data indicating bedrock at the surface between these points, the computer assumed a continuous drift cover and generated a false drift-filled valley cutting the ridge. This example illustrates that a close examination of the distribution of data is mandatory in interpreting the contour maps, and that in this case knowledge of the position of the Hazeldean Fault and the Carp ridge (see Fig. 1) must be integrated into a final interpretation.

An interesting point can be raised: If it is known that the thick drift shown on Carp ridge does not correspond to ground truth, why is this error not corrected? This feature was left on the map for two reasons. Firstly, and most importantly, to correct this error it would be necessary to introduce information into the map that was not part of either basic data or the programming (only if all such departures from ground truth could be detected and connected would this procedure be warranted). Secondly, this obvious departure from ground truth serves as a reminder and an example that what is depicted here is a representation of the data which may not be adequate in some areas to provide ground truth information of sufficient accuracy for the user's need. The authors take the point of view that the best data available should be presented as clearly as possible, but the interpretation of the data depends upon the requirements of the user and that interpretation is the responsibility of the user.

Approximately 15 per cent of the map area across the north has been left blank. This area is in the Gatineau Hills where topography is rugged and data are scarce. Because of the variability of both bedrock topography and drift thickness it was impossible, given the data available, to produce meaningful contours in this area.

Bedrock Topography

The bedrock topography of the study area (Fig. 5) is more variable than the surface topography and has greater relief. This is to be expected since the glacial materials have infilled the deep valleys, and marine clay has been deposited in the low-lying areas.

A well marked major bedrock valley approximately coincides with the course of the present Ottawa River from in front of the Parliament Buildings downstream to the margin of the map area. The rock surface along most of the distance is less than 50 feet (15 m) above sea level. An arm of this deep bedrock channel extends up Gatineau River valley as far as Ironsides and may extend to Chelsea or beyond. A lack of data in this region has caused the computer to close the contours. Above Ottawa in the Aylmer area, bedrock is at about 175 feet (55 m) above sea level in Lac Deschênes and rises to 425 feet 9130 m) in the north and to 350 feet (105 m) in the south.

Farther up river at Eardley the map shows a low on the north side of the river indicating that the surface may be only 50 feet (15 m) above sea level. This low is based on nine seismic observations, and although a bedrock low exists at this location, it may not be as deep as shown. South of this location another depression is shown by the contours. This low is defined based on only two boreholes, and further subsurface information is needed to confirm the bedrock configuration. These two depressions align with the Constance Lake-Constance Creek valley which suggests that these features are located in a bedrock trough perhaps associated with faulting or other bedrock geological control.

Carp River flows in a broad bedrock trough from Carp to Kinburn. The river then turns north to cross a topographic high in the bedrock on the north side of the Hazeldean Fault. The bedrock valley however continues west to join the bedrock trough in which lower Mississippi River flows.

Rideau River through the city of Ottawa flows down the centre of a broad bedrock trough best defined by the 175 foot contour line. Between the south edge of the city and Manotick several elongate closed contours at 200 feet mark the low line of this portion of the bedrock valley. South of Manotick it is difficult to detect any marked linear depression in the bedrock except that the present course of the river is flanked on either side by areas lying above the 275 foot contour with the bedrock elevations near the present river course 25 to 50 feet (8 to 15 m) lower. This creates a weak north-south trough centred on the river.

From the map it appears that the present streams are flowing in broad linear depressions in the bedrock. Whether these were originally the result of fluvial erosion by preglacial rivers or are structurally controlled cannot be determined. Certainly Carp Valley must owe part of its origin to the Hazeldean Fault whereas the depression in which Rideau River flows cuts across structure.

The 1:50 000 bedrock topography map (Fig. 6) contains the same information as the larger scale map. It is provided because the data are better in the urban area, and therefore the contours can be treated with more confidence. An experimental map with a 10 foot contour interval provided only slightly more information but was extremely difficult to read in places because of line crowding.

Drift Thickness

Drift, a term left over from the 19th century concept of drifting icebergs depositing debris on the flooded continents, today refers to all glacially related unconsolidated deposits. A drift thickness trend map has been produced at 1:125 000 scale for the entire study region and another at 1:50 000 scale for the urban area. The two maps show the thickness of unconsolidated material using 20 and 10 foot contour intervals, respectively. No zero contour of thickness is given as this would be a very complex contour; bedrock outcrop information can be obtained more reliably from the Surficial Materials and Terrain Features Map (1425A).

The information depicted in these maps represents a simplified overview of the drift thickness data; the term "trend" was introduced because it embodies this concept of generalization. The term therefore is not used here in the rigorous mathematical sense.

The 1:125 000 scale map shows up to 220 feet (65 m) of unconsolidated material in the area north of downtown Hull with thickness of 120 feet (35 m) not uncommon along the north shore of Ottawa River from Hull to the east border of the map area. In the area west of Hull the south side of the steep scarp of Precambrian rock that marks the Eardley Fault has several locations of drift more than 200 feet (60 m) thick with deposits to 240 feet (75 m) thick north of Quyon. Other areas of thick drift include the north side of the Gloucester Fault, particularly in the vicinity of Ramseyville, and part of Carp Valley.

The 1:50 000 scale map provides more detail in the urban area and because of the smaller contour interval emphasizes the variations in drift thickness.

CONCLUSIONS

This report and maps represent a modest contribution to what is hoped will be a growing trend to provide more geoscience data for planning use in urban areas. This study should encourage planning authorities to become collectors and custodians of geoscience data as a matter of economic and social benefit. The availability of such information should result in it being incorporated into the urban planning process and being documented in case studies. With data freely available, the next step is to demonstrate their usefulness in practice which can be done only by those charged with the responsibility of planning the future of the region.

The kinds of geoscience information presented here are, in the opinion of the authors, essential ingredients in the drafting of a good plan for regional development. Planning that does not take into account the physical environment risks the senseless destruction of the environment and, in the extreme, risks the loss of human life and property.

Finally, it is hoped that this study contributes to an awareness by the general public of the composition and characteristics of the physical environment. With increasing emphasis on involving the public in the planning process, it is important that the public be well informed.

REFERENCES

Béland, R.
1954: Preliminary report on Wakefield area, Gatineau County; Quebec Dep. Mines, Prelim. Rep. 298, 7 p., 1 map.

Bélanger, J.R.
1974: L'axe géologique de l'environment; un système d'information automatise en géologie urbaine; GEOS, Hiver 1974, Ministère de l'energie, des mines et des Ressources, p. 16-17.

1975a: UGAIS data record instruction manual; Geol. Surv. Can., Open File 292, 11 p.

1975b: ISAMAP user's manual: An interpolation and contour package for continuous phenomena; Geol. Surv. Can., Open File 295, 38 p.

Bélanger, J.R. and Harrison, J.E.
1976: Ottawa-Hull subsurface information data bank, Part I and Part II; Geol. Surv. Can., Open File 383.

Bélanger, J.R. and Morin, J.M.
1972: Synagraphic computer mapping; in Manual of Detailed Geomorphological Mapping, ed. J. Demek; Czech. Acad. Sci.-Inst. Geogr.

Bostock, J.M.
1960: Drift-thickness contours, City of Ottawa; Geol. Surv. Can., map 39-1959.

Brandon, L.V.
1961: Preliminary report on hydrogeology, Ottawa-Hull area, Ontario and Quebec; Geol. Surv. Can., Paper 60-23, 17 p., map 31-1960.

Buckley, J.T.
1970: Surficial deposits and landforms of (a portion of) Gatineau Park and vicinity; Geol. Surv. Can., Open File 36.

Elson, J.
1969: Late Quaternary marine submergence of Quebec; Rev. Géogr. Montréal; v. 23, no. 3, p. 247-258.

Gadd, N.R.
1963: Surficial geology of Ottawa map-area, Ontario and Quebec; Geol. Surv. Can., Paper 62-16, 4 p., map 16-1962.

1976a: Surficial geology and landslides of Thurso-Russell map-area, Ontario; Geol. Surv. Can., Paper 75-35, 7 p., map 4-1975.

1976b: Geology of Leda Clay; in Mass Wasting, ed. E. Yatsu, A.J. Ward, and F. Adams; 4th symposium on geomorphology (1975), Geoabstracts Limited, Norwich, England.

Hogarth, D.D.
1970: Geology of the southern part of Gatineau Park, National Capital Region; Geol. Surv. Can., Paper 70-20, 8 p., map 7-1970.

Johnston, W.A.
1917: Pleistocene and recent deposits in the vicinity of Ottawa, with a description of the soils; Geol. Surv. Can., Mem. 101, 69 p.

Klugman, M.A. and Chung, P.
1976: Slope stability study of the Regional Municipality of Ottawa-Carleton, Ontario, Canada; Ontario Geol. Surv., Misc. Paper MP68, 13 p.

Legget, R.L.
1973: Cities and Geology; McGraw-Hill, New York, 624 p.

Livingstone, K.W.
1974: Geology, Arnprior, Ontario (Contributions by K.W. Livingstone, P.A. Hill, A.E. Wilson, and J.L. Kirwin); Geol. Surv. Can., map 1363A.

MacDonald, G.
1967: Geology of the Ottawa region: A compilation; Carleton University, Geol. Paper 67-1, 3 p., map.

McHarg, I.L.
1969: Design with Nature; National History Press, Philadelphia, 198 p.

Mathewson, C.C. and Font, R.G.
1974: The geological environment. Forgotton aspect in land use planning process; in Engineering geology case histories, No. 10, ed. H.F. Ferguson; Geol. Soc. Am., p. 23-28.

Minning, G.V.
1972: Surficial geology, Arnprior, Ontario and Quebec; Geol. Surv. Can., Open File 118.

Prest, V.K.
1968: Quaternary geology of Canada; in Geology and economic minerals of Canada, ed. R.J.W. Douglas; Geol. Surv. Can., Econ. Geol. Rep. 1, p. 676-764.

Quigley, R.M. and Vogan, R.W.
1970: Black shale heaving at Ottawa, Canada; Can. Geotech. J., v. 7, no. 2, p. 106-112.

Reinhardt, E.W.
1973: Geology, Carleton Place, Ontario; Geol. Surv. Can., map 1362A.

Richard, S.H.
1976: Surficial geology, Carleton Place (OF 361), Arnprior (OF 362), Quyon (OF 363), Winchester (OF 364), Kemptville (OF 365), Ottawa (OF 366), Thurso (OF 368), Wakefield (OF 369); Geol. Surv. Can., Open Files 361-6, 368-9.

Richard, S.H. and Gadd, N.R.
1976: Surficial geology, Russell, Ontario; Geol. Surv. Can., Open File 367.

Sabourin, R.J.E.
1965: Bristol-Masham area, Pontiac and Gatineau counties; Quebec Dep. Nat. Res., Geol. Rep. 110, 44 p., map.

Saxov, S.
1956: A Gravity survey of the vicinity of Ottawa; Dominion Observ., v. 18, no. 11, p. 257-286.

Scott, J.S.
1971: Environmental geology prototype study — Ottawa-Hull region; in Report of Activities, Part A, Geol. Surv. Can., Paper 71-1A, p. 156.

1974: Urban geology in Canada; Proc. Conf. Urban Engineering Terrain Problems; Nat. Res. Counc. Pub. ACGR/NRC T.M. 109.

Stockwell, C.H.
1968: Geology of the Canadian Shield, Introduction; in Geology and Economic Minerals of Canada, ed. R.J.W. Douglas; Geol. Surv. Can., Economic Geology, Rep. 1.

Vincent, J-S.
1976: Surficial geology, Thurso and Wakefield, Quebec; Geol. Surv. Can., Open Files 370 and 371.

Wilson, A.E.
1946: Geology of the Ottawa-St. Lawrence Lowland, Ontario and Quebec; Geol. Surv. Can., Mem. 241, 65 p.

Wilson, M.E.
1920: Geology of Buckingham, Hull and Labelle Counties, Quebec; Geol. Surv. Can., map 1691.

1924: Geological Survey of Canada, Map 1737.

Wynne-Edwards, H.R., Gregory, A.F., Hay, P.W., Giovanella, C.A., and Reinhardt, E.W.
1966: Mont Laurier and Kempt Lake map-areas, Quebec; Geol. Surv. Can., Paper 66-32, 32 p.