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INVENTORY OF QUATERNARY GEOLOGY, SOUTHERN LABRADOR: AN EXAMPLE OF QUATERNARY GEOLOGY - TERRAIN STUDIES IN UNDEVELOPED AREAS

R.J. FULTON
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CONTENTS CONTENTS

Page

Illustrations

Table

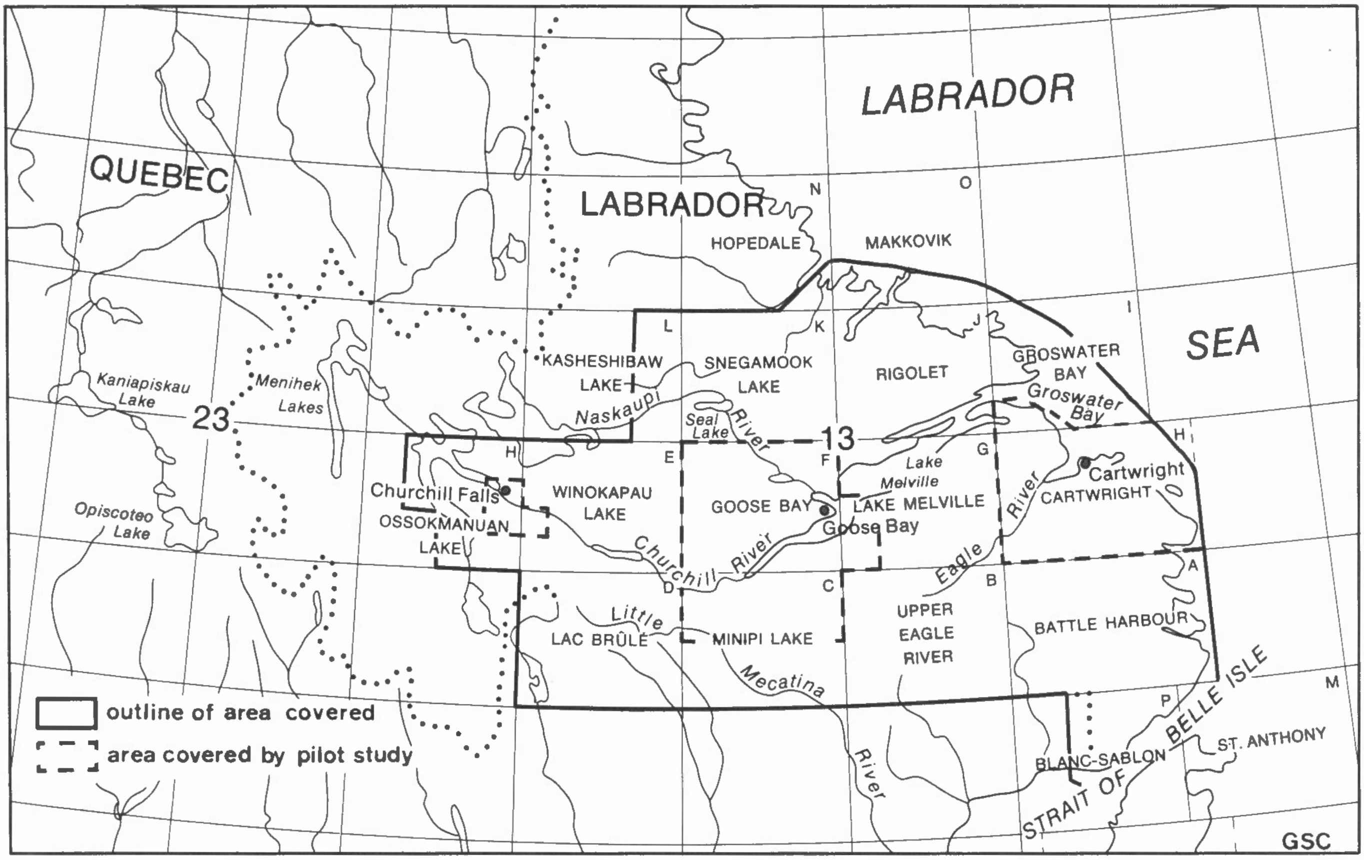

Figure 1. Area of study

(See Appendix II for open file numbers)

INVENTORY OF QUATERNARY GEOLOGY, SOUTHERN LABRADOR: A MODEL FOR QUATERNARY GEOLOGY-TERRAIN STUDIES IN UNDEVELOPED AREAS

ABSTRACT

The Quaternary geology inventory of southern Labrador was the first attempt at adapting helicopter field-mapping techniques, which have accelerated bedrock mapping, to the Quaternary geology-terrain mapping program of the Geological Survey of Canada. This description of the techniques used and the problems encountered is presented as a guide to the planning, execution and evaluation of future projects of this type.

A new method of describing deposits and terrain was devised owing to the sporadic distribution and variable quality of the basic data, the legend had to be flexible so that it could be applied to both general and specific information. This legend designates terrain units in terms of broad genetic categories, with implicated textural character, which can be subdivided in terms of geomorphic expression. If the actual texture of a deposit is known, this specific information can be used as a further stage of subdivision. Two basic assets of the legend are: 1) it can be used to depict information at a variety of levels of detail, and 2) it is descriptive and largely objective.

Certain inherent difficulties that should be given special attention are identified. These include problems in airphoto interpretation, difficulties in the collection of pertinent field information, and the problem of obtaining the necessary time and resources. The concluding section describes a model plan for this type of project which is designed to handle such problems more efficiently.

RESUME

C'est au cours de l'inventaire géologique du Quaternaire du sud du Labrador qu'on a tenté pour la première fois d'appliquer les techniques de cartographie par hélicoptère, permettant d'accélérer les levés de la roche en place, au programme de cartographie de la géologie du Quaternaire entrepris par la Commission géologique du Canada. Ce document présente une description des techniques utilisées et des problèmes soulevés, et constitue un guide pour la planification, la réalisation et l'évaluation des programmes du même genre qui seront mis sur pied dans l'avenir.

Une nouvelle méthode de description des dépôts et des terrains a été mise au point. En raison de la répartition sporadique et de la qualité variable des données fondamentales, il fallait que la légende soit suffisamment souple pour se rapporter à la fois aux données générales et aux données à caractère plus spécialisé. La légende classe les unités de terrain en fonction de facteurs génétiques d'ordre général comportant les éléments de structure; ces catégories peuvent renfermer des sous-divisions basées sur des caractères morphologiques. Lorsqu'on connaît la véritable texture d'un dépôt, on peut ranger cette information précise à un niveau de classification plus détaillé. Cette légende possède un double avantage: 1) elle classe les données selon différents degrés de précision; 2) elle est descriptive et amplement objective.

Certaines difficultés inhérentes à ces travaux ont été soulevées afin qu'on puisse leur apporter une attention particulière. Mentionnons, à titre d'exemple, les difficultés auxquelles on se heurte lorsqu'on interprète les photos aériennes ou qu'on recueille les données pertinentes concernant le terrain, ainsi que le problème de ne pas pouvoir disposer du temps et des ressources nécessaires. Le chapitre final décrit en quoi pourrait consister un programme conçu pour résoudre de tels problèmes de façon plus efficace.

INTRODUCTION

Surficial geology maps at a scale of 1: 50 000 have been produced for an area of approximately 60 000 square miles in southern and eastern Labrador. This survey was requested in 1969 by the government of Newfoundland as a basis for a forest land capability study to be carried out by the Forest Research Laboratory, Canada Department of the Environment in St. John's, and the then Newfoundland Department of Agriculture, Mines and Resources. As the field work phase of this land inventory was to be completed by 1973 and thus exceeded in scope and shielding any previous terrain study of the Geological Survey of Canada, it was necessary to depart from standard techniques of gathering and presenting surficial geology information and to devise rapid techniques which could be employed with a minimum of both systematic field checking and time spent on drafting and the preparation of written text. As a prelude to the companion forest inventory, in July 1968 the provincial government conducted a pilot study in a 500-square-mile area east of Goose Bay, following a pattern recommended by the subcommittee on Bio-physical Land Classification (Lacate, 1969).

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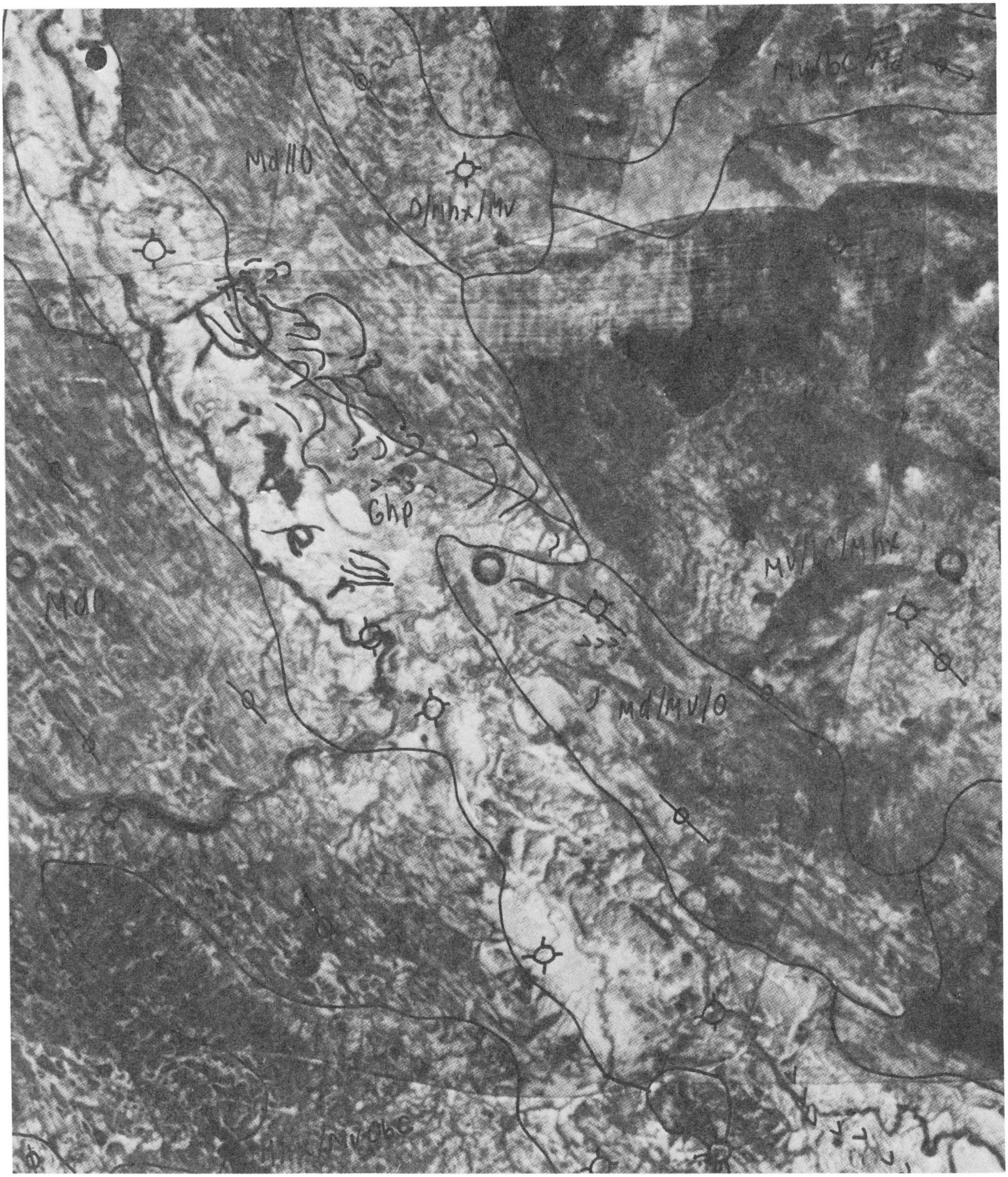

Figure 2. Manner of presenting basic map information.

D. R. Grant of the Geological Survey of Canada provided the geomorphological information necessary for identifying land systems in the area (Grant, 1969, 1971; Bajzak, 1969).

In 1969 a Geological Survey of Canada pilot project was initiated to see if rapid mapping of Quaternary deposits and landforms was feasible (Fulton and Hodgson, 1970); the main field program was conducted in 1970 (Fulton *et al.*, 1971). An attempt was made to keep map compilation in pace with the field operation to ensure that all basic map information be available to the public by the end of 1972.

The irregularly shaped area mapped encompasses the eastern two-thirds of southern Labrador (Fig. 1). Because of its diversity of deposits, physiography, and vegetation, this area is well suited to testing mapping schemes and developing logistical techniques. It stretches 300 miles north from the Strait of Belle Isle, from the Atlantic Coast to 450 miles inland, and rises from sea level to an elevation of 3900 feet. The diversity in physiography has resulted in a wide variety of Quaternary erosional and depositional landforms. The vegetation of the area ranges from the tundra and bare rock of the coastal region and mountains to thick stands of marketable black spruce and balsam fir in the lower Churchill River valley.

CLASSIFICATION OF LAND AREAS

Earlier systematic studies of landforms in southern Labrador relied on airphoto interpretation with a limited amount of field work. Maps produced by Hare (1959) at 1: 4 000 000, Henderson (1959) at 1: 633 000, and Blake (1956) at 1: 350 000 plot the locations of selected landform elements (drumlins, eskers, moraine ridges, etc.) rather than attempting to classify the entire landscape areally. This is understandable in view of the (small) scale of mapping, the emphasis on interpreting the glacial history of the region, and the apparent lack of any requirement for greater detail. The only large-scale maps known to the authors are those of surface deposits in the Churchill Falls area compiled by L. A. Rivard for the Churchill Falls power project at a scale of 1: 9600. This required low-level photography and great detail (e. g., boulder fields only 100 feet across are drawn out as units).

The Forest Land Inventory, which was instrumental in initiating this project, was itself an outgrowth of the Bio-physical Land Classification program of the National Committee on Forest Land. Hence the scale of work and attention to detail of the Quaternary inventory mapping were designed to be compatible with the recommendations of the Subcommittee on Bio-physical Land Classification (Lacate, 1969). Of the four levels of classification considered by this committee (land regions, districts, systems, and types), it was recommended that the land system be the working level for surveys of this type. A land system is an area of land throughout which there is a recurring pattern of landforms, soils, and vegetation (Christian and Stewart, 1952); 1: 125 000 or 1: 50 000 have been suggested as useful scales for reconnaissance mapping of units of this size.

A working level of 1: 50 000 was adopted for the Labrador project because: 1) the area is complex and as one objective was to develop a terrain classification as work progressed, it was necessary to use a scale that would permit retention of detail through preliminary levels of interpretation, 2) 1: 50 000 is the approximate scale of much of the available aerial photography and thus transfer of information is facilitated by using airphotographs and work sheets of the same scale. The information is being released at this relatively large scale in the interests of speed, although the reconnaissance nature of the operation probably does not warrant data presentation at a scale larger than 1: 250 000.

QUATERNARY GEOLOGY-TERRAIN CLASSIFICATION IN SOUTHERN LABRADOR

The nature of the terrain mapped, the operational limitations, and the objectives of the project were such that no available landform classifications were adequate. Hence it was necessary to develop a classification which not only would adequately describe complex landforms and provide scope for presentation of detailed information (where such is available), but also would allow for a generalized description where detail was lacking. Even though this classification was developed to meet the needs and restrictions of Quaternary geology inventory mapping in Labrador, its framework can be adapted equally well for use in other areas.

Operational limitations

Scale of operations

The requirement for the information was immediate and the area to be covered was large, hence mapping of the area had to be based on airphoto interpretation. Thus only landform elements that could be defined in terms of properties discernible from airphotos could be used.

Complexity of landforms

As mentioned above, the area is characterized by great diversity of materials and morphology. In most areas materials and landforms, which may be unrelated in origin and composition, are mixed so complexly that using basic elements of the landscape as the map-units would introduce such fragmentation that regional patterns would be masked. At the same time, supplementing the description of general standard legend units with qualifying statements that would adequately cover the main variations from the basic unit would cause confusion regarding the composition of the terrain in any specific area. For this reason a system was devised which provides both a way of referring to a map-unit as a single unit as well as a way of indicating the proportion of each specific landform type that was presproportion of each specific landform type that was present in a composite landform-unit.

Nature of terrain

Most of the southern Labrador is forested and there are few natural or man-made access routes. The forest cover makes ground traversing difficult, severely limits what can be seen on the ground, and renders access by rotary-wing aircraft difficult to impossible. Airphoto interpretation also is hindered by the forest cover, which masks details that might otherwise be used to recognize features and deposits.

Stratigraphic information

Natural exposures are rare; a few are present in major river valleys but these in general are restricted to fine-grained postglacial deposits. Cuts in coarse sediments soon develop an armour of boulders so it is impossible to see undisturbed material. Excavation of pits by hand work is difficult to impossible in most places because of boulders or a thick, cemented B soil horizon.

Primary level of subdivision

The objective of the primary subdivision was to set up several general classes of landform materials which could be delimited with a relatively high degree of certainty on airphotographs. This was done by grouping related sediments into eight broad materials, genetic categories. The categories used are: morainal, glaciofluvial, alluvial, lacustrine, marine, colluvial, eolian, and organic (each category is defined in Appendix I). The deposits of each of these general categories consist of a moderately limited range of materials. For example, areas falling in the morainal category (sediments deposited by the direct action of glaciers) probably would be composed of poorly sorted material ranging from clay to boulder in grain size. Areas mapped as alluvial (deposits formed by the action of streams) probably would consist of stratified, well washed and sorted sand and gravel. As each of the categories contains groups of genetically related sediments, a general understanding of the processes involved may permit prediction of the probable distribution of sediment textural classes. For instance, in an estuarine situation, coarse material tends to be deposited near the axis of the valley, whereas fine material settles out in quiet-water basins at the valley margins. The lower Churchill River valley contains a thick fill of alluvial and marine sediments which follow this pattern.

It is inevitable that some deposits will lie between genetic categories. One such group, which appears to have been formed by both morainal and glaciofluvial process, was recognized. These deposits generally consist of hummocks and ridges of loose gravelly till intimately mixed with features and deposits which suggest that meltwater played a major role in the formation and areal distribution of these basically till features. It was felt advisable to treat these deposits as special cases, thus a separate morainal-glaciofluvial genetic category was set up. Possibly other special categories should have been used for the estuarine deposits of the lower Churchill River valley (alluvial-marine) and the extensive "marine-kame" terraces at both the east and west ends of Lake Melville (marine-glaciofluvial).

Second level of subdivision

Most genetic categories have been differentiated into sub-units. Morphology was used as the basis of this second level of subdivision. A total of ten morphologic modifiers, such as hummocky, ridged, and plain were used (all are listed and defined in Appendix I). Certain genetic categories, such as colluvial and organic, were left essentially undifferentiated in this inventory study but if the area was to be remapped, additional morphologic modifiers probably would be used to permit subdivision of these categories.

Texture

As mentioned above, the general textural nature of a map-unit can be implied from the general category in which the unit is placed. In some places however specific field information on the texture of a deposit is available. Where this is the case, a textural modifier is applied. Textural terms used are boulder, gravel, sand, silt, and clay (working definitions are given in Appendix I).

Designation of landform systems

Landform system is the term used for the units mapped in the Labrador Quaternary geology-terrain inventory project. This term is used to indicate the similarity between the units outlined in this project and the "land systems" of the Bio-physical Land Classification (Lacate, 1969, p. 5).

The landform systems used are either pure single deposits or single-feature elements or they are heterogeneous complexes of pure elements. The single-element systems are identified on the maps by an upper case letter indicating the general category, followed by a lower case letter indicating the morphologic subdivision (letter designations are given in Appendix I and Table I). As examples: Mh would designate an area of hummocky moraine; At, an alluvial terrace; and Gr, an area consisting of ridges of glaciofluvial deposits. An upper case letter not followed by a lower case letter indicates undifferentiated landforms of the specified genetic category, e.g., O, undifferentiated organic material; C, undifferentiated colluvial material. The textural modifier, when used, appears as a lower case letter in front of the designator; hence, bMh would be used to designate an area of bouldery, hummocky moraine, stMp to designate a plain (or thick valley fill) of silty marine sediments and bC would indicate the presence of bouldery colluvium.

Landform systems that are complexes of pure-elements are identified by combinations of the pure-element designators. The approximate contribution of each pure-element to the landform system is indicated by the position of its designator in a three-part term. The element or elements in the first position constitute 60 per cent or more of the landform system area, those in the second position 15 to 40 per cent, and those in the last position from 5 to 15 per cent. A system designated as MdO would consist of approximately equal parts drumlinoid moraine and organic terrain. One identified as Mp/Mv/R would be more than 60 per cent morainal plain (thick till), 15 to 40 per cent morainal veneer (thin till), and 5 to 15 per cent rock. If a composite landform system does not have an element that falls in the 15 to 40 per cent category then the second position is left blank, e. g., Mp//O.

OPERATIONAL TECHNIQUES

This general account of operational procedure is of historical interest as this was the first Quaternary geology inventory project of this type conducted by the Geological Survey of Canada. Some of the techniques were chosen because they appeared to be the best possible way of doing the job, others were used because of time, material, or personnel limitations. The next section in this paper points out some of the problems encountered, and the final section contains recommendations of how future projects of this type might be organized and executed.

Pilot phase

A pilot project (Fulton and Hodgson, 1970) was necessary because the investigators lacked experience in this type of work and were unfamiliar with the project area. This study consisted of about six weeks of helicopter-supported field work by the authors. The final decision to undertake this project was made at such a late date that there was little time for planning. The main objectives of the pilot study were: 1) to gain familiarity with the area, 2) to determine the type of map-unit and legend best suited to this type of work, and 3) to develop field operation technique.

Preparation for field work

One of the first considerations was the selection of areas in which the pilot studies would be conducted. The study areas had to be chosen so that a cross-section of terrain types and vegetation cover would be present and so that each area contained a settlement where accommodation could be obtained. Three separate areas were selected; these were a coastal area, an interior plateau area, and a mixed area between the two (Fig. 1).

Field work

The field party was made up of two geoscientists, one compiler-draftsman, and a helicopter pilot. Transportation consisted of a Hiller 12E helicopter and also vehicles at Happy Valley and Churchill Falls. Much of the area was accessible only by air; the only roads available were a short network (about 50 miles) at Happy Valley and a few construction access roads in the vicinity of the Churchill Falls power development project.

Office work following field work

After field work had been completed the objectives of the project were reassessed to determine if they could be achieved realistically in light of field logistical problems and personnel shortages. A new legend was prepared which would accomplish the slightly revised objectives with the information that could be obtained from this type of operation. The map-units shown on the airphotos were altered and designated in terms of the new legend.

Main field phase

During the main phase of this Quaternary geology inventory project, the work objective was to collect data from an area of about 45 000 square miles in a maximum of three months' field work. This main mapping thrust was essentially an expanded version of the pilot phase with modifications so that the additional resources available in a larger party could be used to correct some of the shortcomings pointed out by the pilot study.

Preparation for field work

Once the approximate area to be covered was defined, campsites were selected and inspected during the pilot study phase. It was then possible to determine the type of aircraft required, the hours of helicopter and fixed-wing flying required, and the amount of aviation fuel necessary at each campsite. Arrangements were then made to obtain both contract and non-contract flying, and during March the required amounts of aviation fuel were cached at each campsite.

Available airphotos, airphoto mosaics, and topographic map coverage were ordered as soon as possible. Airphotos were indexed separately for each 1: 250 000 map-sheet and the mosaics were cut or joined so that each sheet corresponded to one-quarter of a 1: 50 000 map-sheet.

The three professionals assigned to this project divided the airphoto interpretation work such that all the area to be worked out of each map was assigned to one person. The legend developed during the pilot study was used for this preliminary airphoto interpretation and some cross-checking was done to ensure consistency in the application of the legend. Note was made of any localities where the interpretation was uncertain, where there appeared to be exposures or other features of special interest, and where good examples of specific legend-units appeared to occur. A compiler-draftsman copied the preliminary interpretation onto airphoto mosaics and following the completion of the area to be worked out of a camp, the original operator traced proposed traverse routes on transparent overlays which were attached to the mosaics.

In general a traverse was planned to give coverage of two 1: 50 000 map-sheet areas. The proposed route of the traverse was controlled by the nature of the terrain to be covered, the position of the area in relation to camp, and the position of localities noted for checking during the initial airphoto interpretation. It was originally planned to have the initial interpretation completed and plotted on airphoto mosaics before the start of field work. The late assignment of one professional to the project and commitments of the other professionals to other projects made this an impossible goal.

Field work

It was necessary to work from field camps because of the size and nature of the area covered. A Bell G-4 helicopter was at hand at all times for traversing; a Cessna 180 on casual charter was used for supply runs and caching fuel; a single-engine Otter, also on casual charter was used for moving camp. Four main camps and one fly camp were occupied, with between 5000 and 15 000 square miles being covered from each camp. Camp moves generally were completed in a day and were organized so that no helicopter traversing time was lost. The fly camp was fitted in with the longest camp move (220 miles, 2 days) so that the helicopter plus two scientists continued to work while the main party was involved with the move.

The field party consisted of three geoscientists, one graduate student, two undergraduates, two aircraft crew, and a cook. As helicopter traversing was split three ways, the geoscientists could use the two days between traverses to transcribe traverse notes, prepare for the next traverse, complete the mapping of areas already traversed, and handle logistical chores. Unfortunately much of the time between traverses had to be used to complete the preliminary airphoto interpretation. The graduate student and one assistant were used mainly for ground traverses which were run to gather detailed information on the relationship between landform-units, to solve special problems, and to obtain ground information on the nature of specific terrain-units. One undergraduate was used exclusively as a compiler-draftsman. By having him plot the information as it was collected in the field, it was hoped to have most of the map information available on open file at the end of field work. In fact, as the preliminary airphoto interpretation had not been completed before the start of field work, much of the compiler-draftsman's time was spent transferring the interpretation onto mosaics.

Helicopter traverses followed a pattern set during the pilot project. In this case, however, mosaics at 1: 50 000 scale were used for navigation and notation of data collection points rather than the 1: 125 000 scale mosaics used during the pilot study. Traverse lengths varied from 175 to 250 miles. The helicopter carried extra fuel, and on longer traverses made use of strategically located fuel caches.

The ground traverse team was set out and picked up by helicopter. They generally inspected their proposed traverse route from the air to detect any obstacles that were not apparent from an airphoto study of the traverse route.

The number of landings made during each traverse varied and generally depended on the complexity of the area traversed, the availability of suitable landing sites near the points under investigation, the presence of visible evidence that would permit solution of the problem at hand without landing, and the interest of the investigator in the area being traversed. Activities on the ground following each landing varied. Where natural exposures existed, notes were made on the stratigraphy and a search was made for material suitable for radiocarbon dating. In some places short ground traverses were made to obtain information on the general nature of the landforms present. Where possible, shallow holes were dug to obtain information on the nature of the near-surface materials. The greatest number of observations, however, were made from the air.

It was virtually impossible to write notes by hand while flying because of unsteady aircraft movements, the necessity of constantly observing the passing terrain, and the concentration required to keep track of the aircraft's position. Consequently, tape recorders were used for chronicling traverses. Each taped comment was keyed to a location number which was written at the appropriate position on a photo mosaic when the comment was recorded. After the traverse was completed, location numbers were marked permanently on both the front and back of the mosaic and the appropriate comment or an abbreviated and edited version of it was written next to each location number on the back of the mosaic.

Post-field office work

Following field work the information gathered had to be organized in forms that were appropriate for release. Three levels of information release were planned. The first level involved making available all the fundamental map information collected through release in the Open File system of the Geological Survey of Canada (*see* example, Fig. 2, Open File numbers are listed in Appendix II). The final interpretation information was copied from the airphotos onto airphoto mosaics at a scale of 1: 50 000 and organized so that each sheet covered an area 15 minutes of latitude by 30 minutes of longitude (the area of a standard 1: 50 000 N. T. S. map-sheet). These mosaics were photographed and halftone negatives placed on Open File, enabling interested persons to obtain paper prints. The information was unedited, drafting was unprofessional, and errors were present, but it was felt that making this raw information available to individuals involved in planning or developing projects in the area was sufficiently imperative to warrant release in this rudimentary form, thereby bypassing many production delays.

The second level of information release intended was to be a series of drafted 1: 250 000 maps showing more generalized terrain-unit subdivision than the basic information maps. These maps required the development of a new legend and the integration of small map-areas. The map-series would be aimed at those involved in planning or projects of a regional nature.

The third level planned for information release was to be a final report accompanied by 1: 500 000 scale maps. The report would contain detailed descriptions of terrain types, illustrated by oblique and vertical airphotos, descriptions of the legends used for the 1: 50 000 and 1: 250 000 maps, and a discussion of the geomorphologic and Quaternary history of the area. The maps would show the general distribution of terrain materials and the location of features and deposits which were used in deciphering the Quaternary history of the area. This level of information release would constitute a permanent document describing the terrain-units and legends and would provide a general overview of the terrain and the Quaternary history.

At time of writing the first level of information release has been achieved; competing priorities have postponed completion of the compilations.

PROBLEMS AND POSSIBLE SOLUTIONS

The accuracy and efficiency of the operation was affected by many factors. Some of these could have been minimized or alleviated by the use of different techniques and by better planning. Others are not as easily handled and must be accepted as factors which will always limit the effectiveness of this type of project.

Airphoto coverage

The airphotos used in this project were at four different scales, varied widely in overall quality, were taken over a time span of almost 20 years. In some areas coverage had to be pieced together from photographs at all four scales (varying from 1: 60 000 to 1: 25 000), arranged on flight paths that deviated from each other by up to 45 degrees. The time span factor led to differences in vegetation pattern (particularly where fires had occurred). The nonuniformity of coverage meant excess time in matching and correlating between adjacent photos and flight lines as well as handling large numbers of airphotos. This nonuniformity also reduced the quality of airphoto interpretation as it introduced significant problems in maintaining consistent interpretation standards.

Of the photography available for this project area the best quality prints at the most suitable scale were taken at an altitude of 30 000 feet with a 6-inch focal length camera. Larger scale coverages provided more detailed information but the detail generally was greater than was required and considerable extra effort was necessary to handle the large number of photos. Airphotos at 1: 50 000 scale, taken from 20 000 feet with a super wide angle (3.5-inch) lens, were available for parts of the area. They were inferior to the higher altitude photographs in resolution, contrast, and edge fidelity.

These difficulties could have been overcome if aerial photography could have been taken specifically for this project. Future projects of this type should be planned far enough in advance to obtain optional airphoto coverage.

Photo mosaics

Airphoto mosaics were used as manuscript and field maps and for presenting the basic airphoto interpretation data. The only available mosaics for the project area were uncontrolled mosaics prepared for early topographic mapping programs. In many places adjacent pieces of mosaic were poorly fitted, gaps were left, and there was no overall matching of tone and contrast. These deficiences made the mosaics difficult to work with and left some gaps in the information presented.

It was felt, however, that the advantage of using even second-rate mosaics was sufficient to warrant their use. They were convenient as a manuscript map medium, as the transfer of information from airphotos could be done more accurately by less experienced assistants and with less supervision and checking than would have been possible if conventional map bases had been used. Using the mosaics as field traverse maps was more convenient than carrying complete photo coverage of the traverse route, and at the same time provided a more accurate medium than a map for navigating and determining station locations. For presenting basic map information, the mosaics had the following advantages: 1) transfer of information from airphotos could be done by less experienced staff, and checking of the information was easier than if a conventional topographic base had been used, 2) the photographic base imparted an impression of the nature of the terrain-unit in addition to showing the unit shape and location, and 3) it provided the information in a form that is convenient to users who commonly replot the information on their own airphotos. It is felt that the time, effort, and cost saving made possible by the use of mosaics are sufficient to warrant having partly controlled mosaics made for the area to be covered by other projects of this type. The new series of 1: 50 000 photomaps, which include contours, would be an ideal base.

Problems related to field work

As already noted, forest cover made both airphoto interpretations and ground checks difficult. This problem was particularly aggravating for where forest cover is thick, airphoto interpretation is most difficult and consequently ground checks would be most advantageous. Even where landings could be made, in many places it was difficult to obtain the critical information required to answer the problem at hand. Much of the overburden is stony, or has a cemented soil B horizon. Penetration with a conventional soil auger almost always was impossible and great effort was required to dig pits down to undisturbed parent material. Even if it was possible to determine the nature of the unconsolidated material at a spot location, generally it was not possible to determine the thickness of the deposits or how typical the small sample was of the regional surficial material. In addition to these physical problems, the size of the project area and the short time allowed for its coverage made it difficult to justify spending much time in one area resolving local complications.

These problems could have been reduced if the project had been planned and executed over a longer period of time. The commitment to provide terrain information for a large area in a short time forced the project to adopt a rigid logistic pattern at too early a stage and little was known of the real difficulties of gathering information in the field before the full-scale program was in operation. The final section of this paper suggests ways in which a project of this type might be organized to minimize these field problems.

Airphoto interpretation accuracy and consistency

As has already been stressed, because of the dense forest cover, inaccessibility, and lack of exposures, airphoto interpretation was the only practical means of obtaining areal terrain information. Many of the factors which affect the accuracy of airphoto interpretation (quality of photos, vegetation cover, ground checking, etc.) have been mentioned already. The consistency or lack of variation in interpretation between different parts of the area is an important consideration when assessing the quality of airphoto interpretation. Consistency of interpretation was a major problem in this project as the work was done by three operators over a period of three years. The work was divided up according to map-sheets with each operator given responsibility for separate map-sheets. This method of partitioning the airphoto interpretation was an inferior one as the only place two operators were required to compare interpretations was at the map-sheet boundary. If the operators had been compelled to compare their interpretation more frequently, not only would the interpretation have been more uniform but there would have been more pooling of knowledge and insight. In future projects this might be accomplished by assigning operators alternate airphoto lines or preferably alternate rows of 1: 50 000 map-sheet areas.

Planning and timing

It has been noted that lack of adequate planning was a factor contributing to all the above mentioned problems. Thorough planning, made possible by adequate time, would have eliminated some of the difficulties and minimized others. There was insufficient time to have the area reflown to revised specifications, to have mosaics made from the new photography, to spend a field season testing different ways of obtaining data, to complete the preliminary airphoto interpretation before entering the field, and to obtain professionals who were not burdened by other projects.

If further projects of this type are to be run effectively and efficiently, it is imperative that sufficient time be made available so that the projects can be planned, prepared, and executed adequately.

SUGGESTED PROCEDURE FOR A QUATERNARY GEOLOGY-TERRAIN INVENTORY PROJECT

The following are suggested plans for a project on a similar scale to the work done in Labrador. These plans are designed to minimize many of the problems encountered in the Labrador project and to provide better results. In making these plans it is assumed that none of the investigators are familiar with the area and that there is little pertinent prior knowledge of the Quaternary geology or geomorphology. The permanent personnel are assumed to have been assigned to the project from its commencement and are assumed not to be encumbered by duties other than to this project. The project is set up to be operated by a full-time professional staff of three; one of these must have had prior experience at this type of work and one could be a junior professional (Bachelor level). An optimum area to be covered in two field seasons is chosen as 30 000 square miles. The project plans begin after the project area has been reflown so that recent airphotos, at a scale of 1: 50 000 and taken with a 6-inch camera lens, and photo maps or partly controlled mosaics would be available.

Preliminary assessment

The objective of this phase is to obtain a general overview of the project area, to determine the general physiographic breakdown, and to select areas where ground studies could be made of the various physiographic components.

Time: 8 months

Staff: three professionals, one general assistant
Work:

1. Reconnaissance flight around the area.
2. Gather all background information (e. g., shot hole logs, engineering reports, etc.).
3. Subdivide area into broad physiographic regions.
4. Scan airphotos and select one or two example areas in each physiographic region that appear to contain all pertinent terrain types.
5. Subdivide these example areas into their component parts and reassemble as map-units.
6. Select areas where map-units can be studied in detail in the field.
7. Plan logistics for the first season's field work.

Intensive field work

The object of this field work is to define the preselected terrain units in terms of their composition, variability, and their component parts.

Time: 3 months

Staff: three professionals, one senior assistant and three junior assistants

Logistics: one fixed-wing aircraft, vehicles, boats.

Work:

1. Set up fly camps on strategically located lakes in order to study all accessible map-units by means of ground traverses and possibly to conduct drilling.
2. Traverse roads and areas accessible by vehicle.
3. Make reconnaissance flights to check areal variability and continuity of features and units.

Preliminary airphoto interpretation

The object of this phase is to map all parts of the area by means of airphoto interpretation. The map-units used would be those defined during the intensive field work phase.

Time: 9 months

Staff: three professionals, one compiler-draftsman

Work:

1. Interpret airphotos for the entire area making note of points, areas, concepts, etc., that should be field checked.
2. Build up a preliminary Quaternary history and note critical areas and special problem areas that should be checked in the field.
3. Have preliminary airphoto interpretation plotted on airphoto mosaics.
4. Plan logistics for the next field season.

Field checking

The objective of this phase is to gather the information required for the finalized airphoto interpretation and the Quaternary history. Mainly this will involve visiting the areas noted for checking during the preliminary airphoto interpretation phase.

Time: 3 months

Staff: three professional, one senior assistant, one junior assistant, and one compiler-draftsman

Logistics: one helicopter, one fixed-wing aircraft, ground vehicles and boats (if necessary)

Work:

1. Run helicopter traverses to check points noted during preliminary airphoto interpretation.
2. Run minor short ground traverses to gather more detail on map-units and critical geologic history information.
3. Conduct further drilling, if feasible.
4. Upgrade preliminary airphoto interpretation.
5. Have finalized interpretation transferred to photo mosaics.

Information presentation

The objective of this phase is to make the results of the project available for distribution.

Time: 12 months

Staff: one professional, two compiler-draftsmen (the other two professionals could be released as soon as they have completed their parts of the finalized airphoto interpretation)

Work:

1. Have the finalized interpretation, on photo mosaics, made available for distribution through open file.
2. Group and recompile map-units at a scale of 1: 125 000 or 1: 250 000 for publication.
3. Prepare a report defining map-units and describing the terrain.
4. Prepare a generalized terrain type and special feature map (scale 1: 500 000 or 1: 1 000 000).
5. Prepare a report on the Quaternary and geomorphic history.

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DEFINITIONS OF TERMS USED IN LEGEND

Genetic categories

1. Morainal deposits - mainly till or unsorted to poorly sorted, unstratified to partially stratified clay, silt, sand, pebble- and boulder-sized material. These deposits are considered to be direct deposits of ice without intervening transportation by water but some of the in situ material may have had fines removed by meltwater. In southern Labrador the till generally is sandy with very little clay and in some areas contains or is overlain by large subangular boulders.

2. Glaciofluvial deposits - gravel and sand varying from well sorted to poorly sorted and from well stratified to poorly stratified. These deposits are considered to have been deposited by glacial meltwater in proximity to ice. Materials are placed in this category only if there is direct evidence of deposition in contact with or adjacent to ice. In the Churchill Falls areas, where exposures are abundant, glaciofluvial deposits are coarse bouldery gravel; in the southwestern part of the study area they are dominantly sandy.

3. Lacustrine deposits - silt, fine-grained sand and clay generally well sorted and well stratified. Lacustrine deposits are defined as materials that have been deposited in quiet fresh water. Lacustrine deposits in southern Labrador are dominantly silt and fine-grained sand with minor clay.

4. Marine deposits - silt, sand, clay and gravel, well sorted to moderately sorted, well stratified to moderately stratified, and in some places containing shells. Marine deposits are laid down in salt or brackish water. Differentiating marine deposits from lacustrine deposits, when fossils are not present, is difficult. The following operational definition was used: marine deposits are materials containing marine fossils or similar nonfossiliferous deposits located in an area that might reasonably be considered to have contained salt water at the time of deposit formation. The division between alluvial and marine deposits presents a problem at delta fronts as deltas are built into brackish water. To solve this problem, the term alluvial is restricted to areas apparently cut or planed by running water; unmodified slopes and areas obviously modified by wave action are referred to as marine. Sandy textures appear to predominate in marine deposits of the Lake Melville area but this conclusion is based on a limited number of observations.

5. Colluvial deposits - texture ranging from clay to rubble and boulders, generally poorly sorted, and massive to crudely stratified. The nature of colluvial deposits depends on the material from which they are derived. Colluvial deposits are defined as loose material accumulated on and at the foot of slopes by the various processes of mass movement. Areas mapped as colluvial deposits consist generally of rock-controlled slopes that appear to be underlain by a thin loose mantle and landslide deposits.

6. Organic deposits - peat, muck, and marl generally unstratified and locally containing inorganic detritus. Organic deposits are materials of organic origin which commonly accumulate in and around closed basins or on gentle slopes. The organic deposits of southern Labrador consist of sphagnum and sedge deposits, commonly 1 to 3 m deep, which in many places contain and interfinger with open water. Some of the areas mapped as organic deposits are merely wet sedge areas with very little accumulated organic material.

7. Alluvial deposits - sand, gravel, silt and clay, well stratified and sorted to moderately stratified and sorted. Alluvial deposits are defined as detrital material laid down by streams and rivers. Alluvial deposits in southern Labrador consist generally of sand. Locally they include gravel and boulder pavements, washed bedrock, bouldery channel deposits, and channel fillings of silt and clay.

8. Eolian deposits - sand and silt, generally massive to poorly sorted and moderately to well sorted. Eolian deposits are materials laid down by the wind. They have been mapped as a unit at a few places in southern Labrador and a symbol has been used to show the location of individual dunes.

Rock - R - is used to denote bare or moss covered bedrock and areas where near surface rock severely restricts the growth of trees. Areas with a covering mantle of up to 25 cm are included as rock.

Morphologic modifiers

1. Drumlinoid - streamlined hills, linear grooves, and ridges.
2. Plain - flat, undulating rolling.
3. Hummocky - rolling to steep and hilly with roughly equidimensional hills and hollows.
4. Ridged - rolling to steep and hilly with linear ridges and troughs.
5. Veneer - cover roughly 25 cm to 2 m thick.
6. Terraced - relatively flat surfaced and terminated by an abrupt change in slope on one or more sides.
7. Channelled - cut by a series of relatively closely spaced, deeply incised channels.
8. Eroded - dissected by a series of closely spaced gullies or a tightly knit dendritic drainage network.

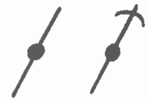
Table I. Letter designations used for the Quaternary deposits mapped in southern Labrador.

GENETIC CATEGORY / MORPHIC MODIFIER	M Morainal	G Glaciofluvial	L Lacustrine	*M* Marine	A Alluvial	C Colluvial	O Organic
d - drumlinoid	drumlinoid moraine						
p - plain	ground moraine thick till	glaciofluvial plain outwash plain	lacustrine plain thick lake deposits	marine plain thick marine deposits	flood plain		
h - hummocky	hummocky moraine disintegration moraine	hummocky glaciofluvial kame and kettle	hummocky lacustrine collapsed lake deposits			landslide deposit	
r - ridged	ridged moraine end moraine ribbed moraine	esker complex	lacustrine beaches	marine beaches		landslide deposit	
v - veneer	veneer moraine thin till		lacustrine veneer thin lake deposits	marine veneer thin marine deposits		colluvial veneer	
t - terraced		glaciofluvial terrace		terraced marine deposits	alluvial terrace fluvial terrace		
c - channelled	channelled moraine						
e - eroded	eroded moraine	eroded glaciofluvial	eroded lacustrine	eroded marine			
f - fan		outwash fan			alluvial fan	talus cone	
x - complex							

GSC

Symbols

Drumlinoid trends — long axis orientation of drumlinoid ridges, crag and tail, flutings, and other macrofeatures developed parallel to ice-flow direction. (direction of ice movement known, unknown)



Glacial striae (direction of movement known, unknown; where number used, 1 denotes the oldest)

Moraine ridge transverse to ice flow direction

Minor moraine ridges — washboard moraine, "annual" moraines, and other till ridges transverse to ice-flow direction

Esker — ridge of glaciofluvial material (direction of flow known, unknown)

Kettle hole — depression formed by the melting of ice buried in glaciofluvial or glaciolacustrine material (generally not used for depressions, possibly of similar origin in till)

Subglacial meltwater channel (used only where very positive evidence that channel was formed under ice)

Abandoned or underfit valley (large, small)

Limit of submergence

Abandoned strands

Dunes (active, inactive)

Palsas

Escarpment in unconsolidated material

Landslide scar

Cirque

Fault-line valley or trough

Observation (ground, from air)

9. Complex - a mixture of several morphologic elements.

10. Fan - shaped like a fan with a noticeable slope towards the fan toe.

Textural modifier

In some places it is desirable to show the texture in more specific terms than those implied by the genetic category. This is done by use of a textural modifier which is a lower case letter placed in front of the genetic category symbol. Six of these categories have been used:

b = boulder-material coarser than 256 mm
g = gravel-mixture of cobble-, pebble- and sand-sized material (256-1mm)
r = rubble - gravel that is angular
s = sand - 2-0.062 mm sized material
st = fine sand and silt - 0.25-0.062 mm sized material
c = silt and clay - material finer than 0.062 mm.

These textural modifiers are not used for most units mapped as the genetic category supplies as much textural information as is available.

APPENDIX II

Open File numbers of photo mosaic maps released. Copies may be obtained from Campbell Quick-Print, 85 Sparks Street, Ottawa, Ontario K1P 5A7.

Open File Number	Map-sheet
29	13 F
52	13 C
59	13 G
78	13 D
80	13 B
81	13 K
106	13 E
181	13 J
185	3 D, 13 A
195	12 P, 13 I
201	3 E, 13 H