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GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

BULLETIN 106

SURFICIAL GEOLOGY, NICHICUN-KANIAPISKAU MAP-AREA, QUEBEC

O. L. Hughes

MANUSCRIPTS UNIT
JUL 2 1964
G. S. C. 1964

Price $1.10

SURFICIAL GEOLOGY, NICHICUN - KANIAPISKAU MAP - AREA, QUEBEC

2,000-1963-5048

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By
O. L. Hughes

DEPARTMENT OF
MINES AND TECHNICAL SURVEYS
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ROGER DUHAMEL, F.R.S.C.
Queen's Printer and Controller of Stationery
Ottawa, Canada
1964

PREFACE

Early investigations of the surficial geology of Labrador-Ungava were concentrated on the relatively accessible eastern coast. Exploration and development of the iron deposits of the 'Labrador Trough', attended by the building of the Quebec North Shore Railway, stimulated study of the interior region. The surficial geology of the region west of the Labrador Trough received little attention until 1957, when the Geological Survey began Operation Fort George, a three-year program of reconnaissance geological mapping by helicopter covering a broad belt extending from Hudson Bay to the western edge of the Trough. This report completes the reconnaissance study of the surficial deposits in the area covered by Operation Fort George.

The author has described the glacial landforms and deposits, and their relation to retreat and disappearance of the last Pleistocene ice-sheet. He has also presented evidence to show that ribbed moraine, a glacial landform with wide distribution in the Canadian Shield, was formed beneath actively moving ice.

J. M. HARRISON,
Director, Geological Survey of Canada

OTTAWA, February 15, 1962

Bulletin 106 — Oberflächengeologie des Kartengebiets von Nichicun-Kaniapiskau in Quebec.

Von O. L. Hughes

Dieser Bericht beschreibt die glazialen Landformen und Ablagerungen in einem Gebiet östlich der Hudsonbai und deren Beziehung zu dem Zurückweichen und Verschwinden der letzten Eisdecke des Pleistozäns.

Бюллетень 106 — Поверхностная геология района карты — Ничикун — Каниапискау в провинции Квебэк.

Автор: О. Л. Юз.

Этот рапорт описывает ледниковые ландшафты и ледниковые отложения в районе на восток от Гудзонового залива и их отношение к отступлению и исчезновению последнего ледяного покрова плейстоцена.

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SURFICIAL GEOLOGY, NICHICUN-KANIAPISKAU MAP-AREA, QUEBEC

Abstract

The surficial geology of Nichicun-Kaniapiskau map-area was studied in conjunction with Operation Fort George, primarily a bedrock mapping project. The surficial geology map consists of an airphoto interpretation revised on the basis of field observations by members of the operation.

Ice-directional features, such as drumlins, crag-and-tail hills, *roches moutonnées,* and striae, all judged to be due to Wisconsinan movement, combined with the distribution of erratics from Labrador Trough, indicate initial ice-movement radially across the area from a dispersal area situated to the northeast, either over or east of the Trough. In a late stage of deglaciation, this radial movement gave way in the north and northeast to northerly movement, and in the east to easterly movement. The last remnant ice body of the area was an elongate mass lying along a belt between Lac Guyot in the northwest and Lake Opiscoteo in the southeast.

Ribbed moraine, which is widespread in the Lake Plateau region of Labrador-Ungava, and which consists of a series of arcuate to irregular ridges oriented roughly normal to the direction of last ice-movement, was found to be transitional laterally into drumlinoid topography. Fabric studies in till forming the ridges showed a preferred orientation parallel with the direction of last ice-movement, supporting the hypothesis that ribbed moraine is an ice-moulded form and that individual ridges do not mark successive positions of a retreating ice-front.

Résumé

Les dépôts meubles de la région représentée sur la carte Nichicun-Kaniapiskau ont été étudiés dans le cadre de l'opération Fort George, qui portait avant tout sur la cartographie de la roche en place. La carte des dépôts meubles consiste en une interprétation des photos aériennes revisée à la lumière des observations faites sur le terrain par les membres de l'équipe.

Les caractéristiques de la direction des glaces, comme les drumlins, les traînées de débris en aval, les roches moutonnées et les stries, qu'on attribue toutes au mouvement wisconsinien, et la répartition des blocs erratiques provenant de la fosse du Labrador indiquent que le premier mouvement des glaces à travers la région a été de forme radiale à partir d'une aire de dispersion située au nord-est, soit au-dessus ou à l'est de la fosse. Vers la fin de la déglaciation, le premier mouvement est devenu au nord et au nord-est un mouvement vers le nord, et, à l'est, un mouvement vers l'est. Le dernier lambeau de glace dans la région était une masse allongée le long d'une zone comprise entre le lac Guyot, au nord-ouest, et le lac Opiscoteo, au sud-est.

Une moraine *(ribbed moraine)* consistant en une série de crêtes tantôt arquées, tantôt irrégulières, et disposées à peu près perpendiculairement à la direction du dernier mouvement des glaces, se retrouve en plusieurs endroits de la région du lac Plateau (Labrador-Ungava). Elle se transforme graduellement, en direction latérale, en une topographie apparentée à celle des drumlins. Les

études de la texture du till qui forme les crêtes ont permis de reconnaître une orientation de préférence parallèle à la direction du dernier mouvement des glaces, ce qui tend à accréditer l'hypothèse suivant laquelle la moraine *(ribbed moraine)* serait une forme imprimée par les glaces et suivant laquelle également les diverses crêtes ne constitueraient pas les positions successives d'un front de glace en régression.

INTRODUCTION

The surficial geology of Nichicun-Kaniapiskau map-area was studied in 1959 as part of Operation Fort George III of the Geological Survey of Canada. The resultant surficial geology map (Fig. 1) is an airphoto interpretation by the author, supplemented by ground observations by K. E. Eade, I. M. Stevenson, S. H. Kranck, and the author. The surficial geology of Sakami Lakes map-area, adjacent to Hudson Bay, which was studied as part of Operation Fort George I, has already been reported on by Lee (1960)[1]. Figure 2, showing the surficial geology of parts of La Grande, Lac Bienville, and Kaniapiskau map-areas, has been adapted from an airphoto interpretation by F. Kenneth Hare[2] and others, and is distributed with this report to provide information on the area lying between Sakami Lake and Nichicun-Kaniapiskau map-areas. The following descriptive notes refer specifically to Nichicun-Kaniapiskau map-area.

PHYSIOGRAPHY

Physiographic Divisions

The map-area has been divided into two physiographic divisions (*see* Fig. 3): 1) upland areas, in which the main features of moderate to high relief are controlled by bedrock, and drift is thin and discontinuous; 2) plains areas, in which relief is developed mainly on drift that is relatively thick and continuous. The latter includes areas, however, in which relief is low and the drift thin, so that bedrock structure is discernible in airphotos.

For the most part, areas shown on Figure 3 as 'Upland areas' and 'Plains areas' (Nichicun-Kaniapiskau map-area) correspond respectively with those shown as 'Topography controlled predominantly by bedrock' and 'Topography controlled predominantly by drift' (La Grande-Lac Bienville map-area). However, areas of low relief with bedrock structure discernible through thin drift cover are placed in the first division, i.e., 'Topography controlled predominantly by bedrock' of the La Grande-Lac Bienville classification, and in the second division, i.e., 'Plains areas' of the Nichicun-Kaniapiskau classification.

In places, as along the steep northwest front of the Otish Ranges, the boundary between the two physiographic divisions is sharp; elsewhere there are gradations from hilly uplands into lower drift-covered areas, with scattered bedrock hills, necessitating arbitrary placement of boundaries between the units.

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[1]Names and/or dates in parentheses are those of references listed in Selected Bibliography.

[2]Professor and Head of Department, Department of Geography, McGill University, Montreal, Quebec.

Upland Areas

The main upland area consists of a belt that encircles the upper Kaniapiskau drainage area except for narrow gaps leading to the southwest. Kaniapiskau River drains northeastward across the belt through a deep narrow valley.

The southern part of the belt consists of high rugged hills developed on pyroxene-bearing granite and gneiss (Eade, *et al.,* 1959). The eastern and northeastern part of the belt, which comprises part of the Kaniapiskau Massif of Hare (1959, p. 48), is likewise developed mainly on pyroxene-bearing granite and gneiss, but the general character is that of a dissected plateau. Streams and narrow elongate lakes lie in valleys that are deeply entrenched along joint systems, and the valley walls rise sharply to gently rounded or nearly flat summits.

The western and northwestern part of the belt, which comprises part of the Western Plateau Belt of Hare (op. cit., p. 45), lacks in general the bold hills of the southern part, and the sharply incised valleys of the eastern and northeastern part; it consists rather of an area of gently rolling hills with few well-defined valleys.

The Otish Ranges in the southwestern extremity of the map-area constitute a second, smaller, upland area of distinctly different character. The rather weak quartzite of the Otish Group (Eade, *et al.,* 1959) is capped by thick sills of resistant diabase. These rocks dip gently to the south-southeast, and are repeated in the south by faults trending east-northeast, giving rise to steep north-facing cuestas and gentle south-facing dip slopes. Folding is virtually absent in rocks of the Otish Group, so that the classification by Hare (1959, p. 52) of the Otish Ranges as Appalachian-type uplands, implying a fold belt, is somewhat misleading.

Plains Areas

These areas of low relief, mostly drift-covered, constitute part of the Lake Plateau, a term adopted by Hare (loc. cit.) after Tanner. The surficial deposits differentiated on the map as glacio-fluvial deposits, hummocky moraine, ribbed moraine, and bog, are restricted almost exclusively to this area. Lakes occupy abundant depressions in the drift surface, and locally, broad expanses of irregular drift topography are drowned to form large lakes with myriad low islands, e.g., Nichicun, Naococane, and Kaniapiskau Lakes.

DESCRIPTIONS OF MAP-UNITS

Unstratified Drift

Definition

Unstratified drift includes lodgment till deposited at the base of moving ice, and ablation till, deposited irregularly over the land surface as the ice melted. Ordinarily, the former is distinguished by its compactness and relatively high content of silt- and clay-size material, as contrasted with ablation till, which is comparatively loose and relatively low in silt and clay because of washing by meltwater. Within the map-area, however, the drift was derived mainly from crystalline rocks and coarse-grained sediments, which yielded little silt- and clay-size material; hence, the lodgment till is relatively free of silt and clay, and is not readily distinguished from the ablation till, except by inference from the forms of the deposits.

Unstratified drift is relatively thick and continuous in the plains areas, relatively thin and discontinuous in the uplands areas. Only those areas of unstratified drift classified as hummocky moraine or ribbed moraine have been differentiated as map-units. Drumlins and drumlinoid ridges, and the tails of crag-and-tail hills, may be distinguished from the remaining undifferentiated unstratified drift by their respective symbols (Fig. 1).

Ribbed Moraine

Ribbed moraine (unit 1a, Fig. 1) in its most distinctive form consists of arcuate ridges of bouldery till up to a mile or more long, 30 to 90 feet high, with crests 300 to 1,000 feet apart (Pls. I, II). Typically the depressions between the ridges are occupied by elongate or multifingered lakes, which serve to accentuate the pattern of the ridges. The ridges are rather consistently oriented normal to the direction of last ice-movement. Elongate fields of ribbed moraine occupy shallow depressions in the drift plains or the bottoms of valleys that cut through the hilly uplands.

Ribbed moraine, or moraine having all or most of the outward characteristics of ribbed moraine, has been reported under various names from numerous localities in the Canadian Shield. The term 'ribbed moraine' is used here in preference to names previously used for reasons as follows:

Wilson, Douglas, and Drummond (1953) used the terms 'ribble till' and 'ribble formation' for ribbed moraine in Kaniapiskau map-area and other map-areas in Quebec-Labrador. 'Ribble' is a coined term of doubtful value; further, the writer prefers North American practice of reserving the term 'till' for glacial sediment, and the term 'moraine' for landforms (Elson, 1960); 'formation' should not, of course, be used except in its accepted sense, to designate a mappable lithologic unit. 'Rippled till' (Ives, 1956, p. 26) and 'ripple-till' (Hare, 1959, p. 53) meet similar objection. Ritchie (1960, Fig. 3, p. 215) has used the term 'washboard moraine' for what appears to be ribbed moraine northeast of Caribou Lake, Manitoba, but this

PLATE I. Ribbed moraine, west of Cow Lake; left half of plate same area as shown in Figure 4. Fluted ribbed moraine grades at upper left into drumlinoid ridges; ridges of the ribbed moraine have hummocky ornamentation near esker (left of centre). (RCAF A12954-452)

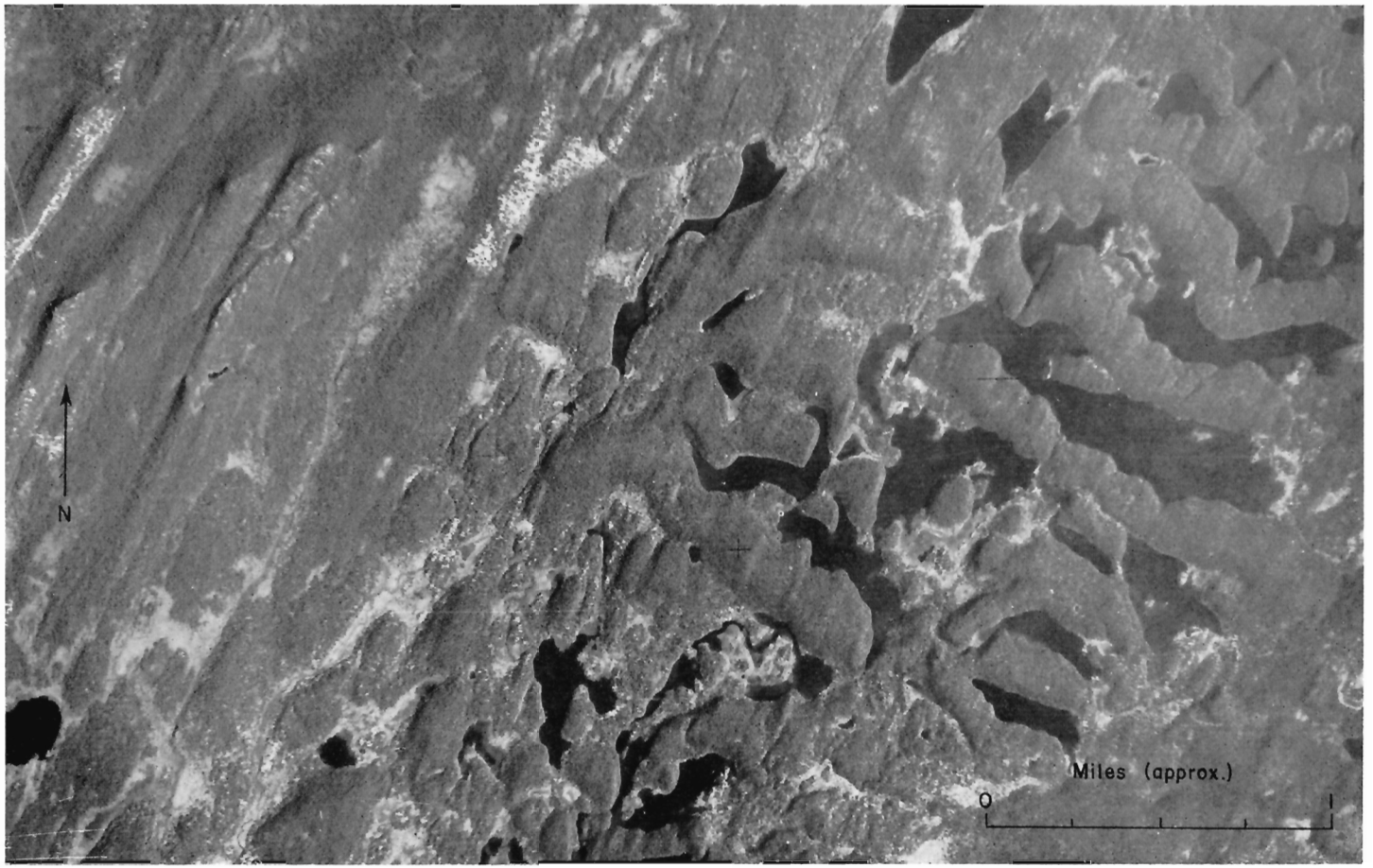

PLATE II. Ribbed moraine about 12 miles south-southwest of Lac Conflans (lat. 52°12′N, long. 70°43′W). Fluted ribbed moraine (right) grades into drumlinoid ridges and crag-and-tail hills (left). (RCAF A12798-35)

term is preoccupied for distinctive straight-ridged minor moraines originally described by Mawdsley (1936), and since reported by Lee (1959, Fig. 4, pp. 9, 13; 1960a, p. 1610; 1960b) from southern District of Keewatin and from Sakami Lake map-area, New Quebec. Henderson (1959, pp. 18-26) considered the individual ridges of ribbed moraine to have been formed by deposition in an annual cycle, and accordingly termed them 'cyclical moraines'. The writer disagrees with the mode of origin suggested by Henderson, and suggests use of a descriptive rather than a genetic term until the question of origin is settled. Lee termed similar forms in southern District of Keewatin 'ribbed minor moraines' (1959, p. 12). The term 'ribbed moraine' is used in this report to emphasize the collective rather than the individual character of the ridges. It should be noted that whereas the term 'moraine' in North American usage is restricted to landforms, it is not necessarily restricted to individual linear accumulations of glacial debris (end moraines, terminal moraines, marginal moraines, etc.).

Over large areas the ridges bear distinct flutings on their sides and crests (Pls. I, II). The flutings are everywhere parallel with the direction of latest ice-movement. From fluted ridges there is a continuous series of forms through oval-shaped drumlins aligned in rows to form transverse ridges, through groups of ridges with only a suggestion of alignment into rows, to ordinary drumlins and drumlinoid topography. At many localities there is lateral gradation through the entire series of forms, the well-developed transverse ridges typically occupying shallow depressions and the drumlins occupying low swells.

Ives (1956) did not mention fluting on similar ridges near Esker Lake, although he noted drumlins in close association with the ridges. However, ridges similar to those described by Ives but having distinct fluting occur 3 to 4 miles southwest of Esker Lake. Recently, Hare (1959, p. 54) described transitions between drumlin fields and 'ripple till' from Labrador-Ungava, which encompasses the present area, and stated "the impression grows, as one examines these areas, that ripple-still is as much a glacially moulded form as is a drumlin belt. . . ." The same impression prompted the writer to make till-fabric studies in a well-developed transverse ridge west of Cow Lake (Fig. 4 and Pl. I).

Till-fabric studies were made in short trenches (30 inches deep) at four points along the broad crest of a single ridge. A sharply curved ridge was chosen so as to show whether such preferred orientation as might appear would be, as expected, parallel with the flutings and with the latest direction of ice-movement, or normal to the trend of the ridge, as found by Hoppe (1957, pp. 4, 5) in certain minor moraine ridges in Sweden.

It was intended that the orientation of relatively smooth flattish elongate pebbles only (MacClintock, 1958, p. 6), which lay nearly horizontally in the deposit, would be measured. The ridge proved to be formed, at least near the surface, of compact sandy till with abundant pebbles, cobbles, and boulders. However, the pebbles, mostly of granitic and gneissic rock, proved to be predominantly subangular, and subequal in dimensions, necessitating acceptance of all distinctly elongate pebbles having both major and intermediate axes inclined less than 45 degrees from the horizontal.

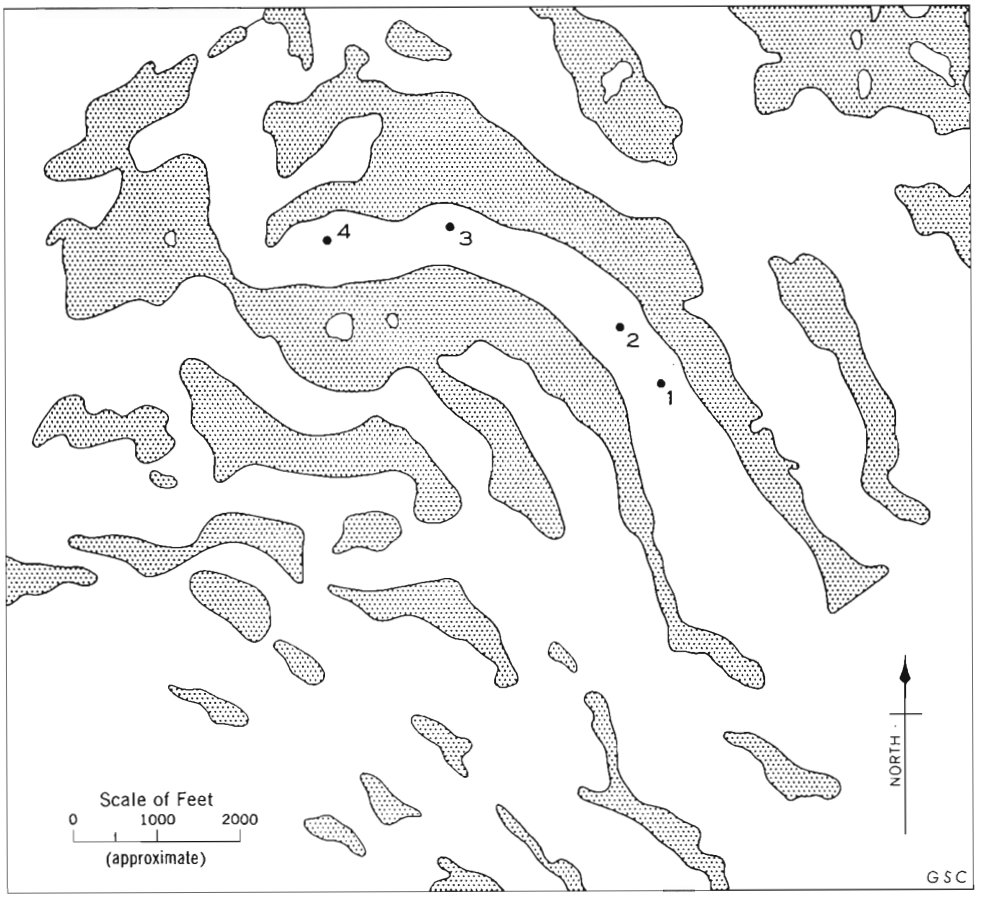

FIGURE 4. Sketch map showing location of pits for fabric analyses, on ridge between two unnamed lakes west of Cow Lake (lat. 52°32′N, long. 70°29′W). Numbers assigned to pits correspond to respective till fabric diagrams in Figure 5.

The results, plotted in Figure 5, show some scatter in individual diagrams, especially No. 1, yet each diagram shows a preferred orientation close to the direction of latest ice-movement rather than normal to the ridge trend. The fluting of the ridge crests, together with the till fabric, indicates that the final form of the ridges was moulded by active ice. There is no evidence of recurrent advance and retreat of the ice-margin in drumlinoid topography adjacent to the area of ribbed moraine. For that reason it is improbable that the transverse ridges are minor ice-marginal moraines that were over-ridden and modified during fluctuations of the ice-margin. There is obvious modification of some of the depressions between ridges. However, erosion by meltwater cannot have been a prime factor in formation of the ridge and depression topography because often fluting remains on the slopes, as well as on the rounded crests, of the ridges.

Hare (1959) did not offer, nor is the writer prepared to offer, a hypothesis as

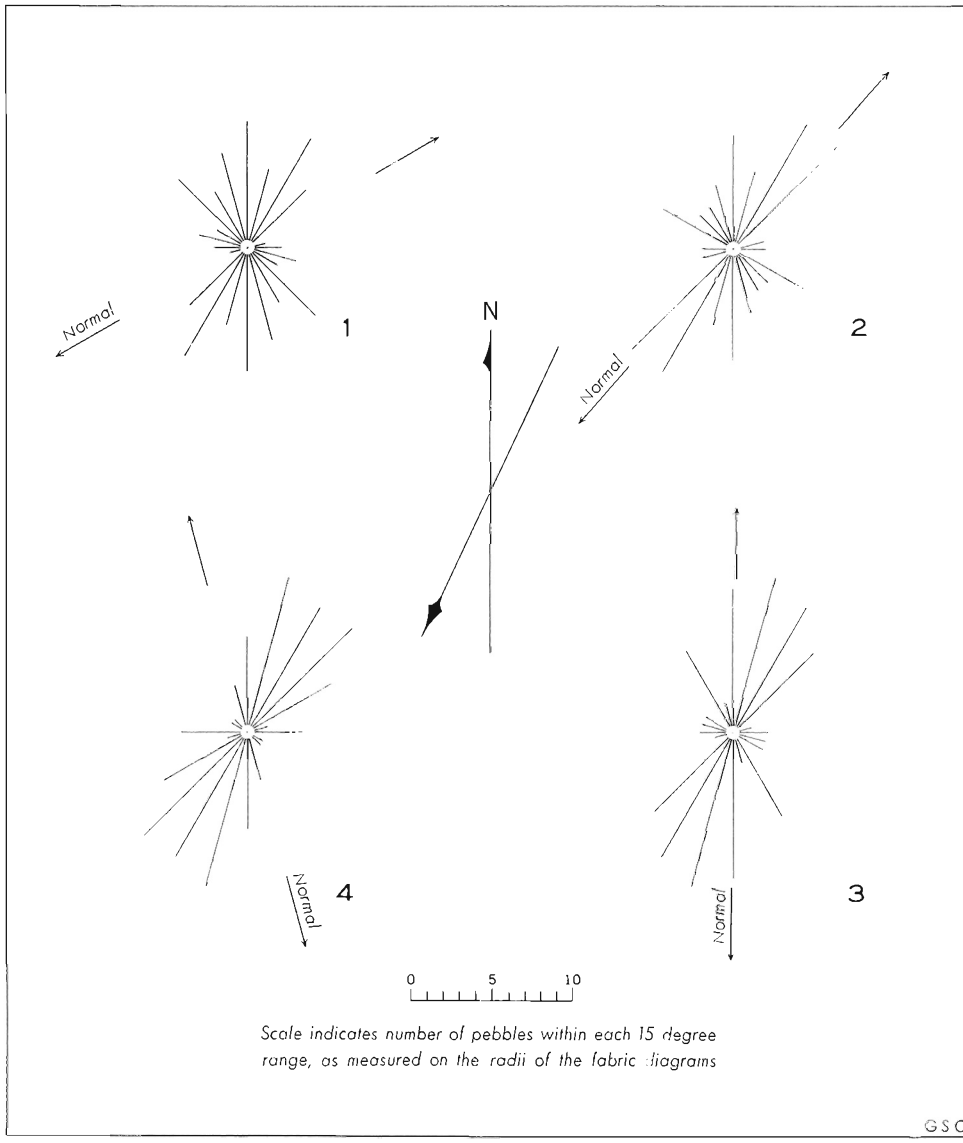

FIGURE 5. Till fabric patterns in an arcuate ridge in an area of ribbed moraine west of Cow Lake. Diagrams correspond to pits of the same number in Figure 4. Arrows at the periphery of each diagram give the trend of a line normal to the ridge at the point where the fabric was determined: double-headed arrow in the centre is parallel with the regional direction of latest ice movement.

to how ribbed moraine might have been deposited under actively moving ice. Esker complexes are commonly associated with areas of ribbed moraine in the Canadian Shield, as noted by several workers (including Hare). These complexes typically occupy the axes of the elongate depressions in which the ribbed moraine occurs (Pl. I).

Deltaic expansions along the esker complexes, with their upper surfaces typically tens of feet higher than the crests of the ridges of adjacent ribbed moraine, indicate the levels of proglacial lakes bordering the ice-margin when the deltaic expansions were formed. J. G. Fyles (pers. com.) has pointed out that the occurrence of ribbed moraine in areas where deltaic expansions indicate former proglacial lakes may be more than coincidental; that is, that hydrostatic pressure or buoyancy of water at the ice-margin may have been an essential prerequisite to the formation of ribbed moraine.

Hummocky Moraine

Hummocky moraine (unit 1b, Fig. 1) consists of closely spaced, irregularly shaped mounds of bouldery drift, 10 to 50 feet high. Most of the mounds probably consist of ablation till. The mounds and ridges and intervening depressions are profusely littered with boulders, many of which are 20 feet or more in diameter. The resulting topography appears as an irregular jumble from the ground, but some localities exhibit a discernible pattern from the air, with short ridges tending to be oriented normal to the direction of latest ice-movement.

As suggested by Lee (1960b), both deposition and erosion may have played a part in the formation of hummocky moraine. Much of it was deposited by slumping of debris from ice at the margin of a retreating ice-sheet; the dumps of debris would tend to be oriented parallel with the ice-margin, or with transverse shears in the ice in which debris was concentrated. However, much of the hummocky topography studied on the ground bears evidence of modification by stream erosion subsequent to deposition. The depressions between the mounds and ridges are commonly armoured by lag concentrates of boulders, and clearly have been occupied and deepened by meltwater streams.

On the east side of Kaniapiskau River (lat. 55°37′N, long. 68°06′W; Pl. III) the hummocks have very sharp crests immediately adjacent to a main meltwater channel, but become more rounded and subdued with increasing distance from the channel. Depressions between the hummocks form an intricate network of small channels, which are tributary to the main channel. The overall aspect of the topography suggests that the whole was deposited from wasting ice, and that the sharp-crested hummocks resulted from dissection by meltwater streams (possibly subglacial) or originally subdued hummocky moraine. In other places, the sharp crested hummocks and ridges occur in close association with subglacial chutes, without associated subdued hummocky moraine. Such topography may have been formed by erosion alone. Thus, hummocky moraine, as mapped on Figure 1, includes forms ranging in origin from purely depositional to mainly erosional.

Drumlins, Drumlinoid Ridges, Crag-and-Tail Hills

Drumlins, drumlinoid ridges, and tails of crag-and-tail hills (shown by symbols on Fig. 1) probably consist mainly of lodgment till, but may contain lenses of stratified sand and gravel; many of the drumlins and drumlinoid ridges may prove to have rock cores. The drumlins occur as discrete low ridges 100 feet to 2 miles long,

PLATE III. Hummocky moraine of erosional origin; east side of Kaniapiskau River, 3 miles below mouth of Goodwood River. (RCAF A11496-22)

25 to 3,000 feet wide, and 10 to 100 feet high, or in drumlin fields consisting of many closely spaced individuals. The drumlin fields grade into drumlinoid topography with ridges and depressions paralleling the direction of ice-movement but lacking discrete individual drumlins.

The drumlins and drumlinoid topography are restricted almost exclusively to the drift-covered plains and to major valleys within the uplands areas, which by chance were aligned in the direction of latest ice-movement. The crag-and-tail hills (Pl. II), which consist of rock knobs or crags with drift ridges extending from them in the downstream direction of ice-movement, are restricted mainly to the upland areas, although isolated examples occur where rock knobs project above the drift plains. Areas of drumlins and drumlinoid topography, or of crag-and-tail hills, are not delineated on Figure 1 but may be distinguished by their respective symbols.

Unusual, small drumlinoid forms were observed from a low-flying aircraft on both sides of Kaniapiskau River below Granite Falls, and have been studied from airphotos. Each form consists of a large boulder (large enough to be discernible on airphotos of scale 1 inch equals ca. 3,150 feet) with a drift tail as much as 950 feet long. The tails retain a uniform width about equal to the diameter of the boulder throughout their length until they die out in the drift surface.

Dyson (1952) examined very similar forms adjacent to the fronts of Grinnel and Sperry glaciers, Glacier National Park, Montana, and concluded that they represent "the fillings of subglacial tunnels which form in lee of boulders. Weight of overlying ice forces material upward into the tunnel, making a ridge, so that the ridge is a cast of the grooved base of the ice. In some cases tunnel formation occurs beneath actively moving ice with a thickness greater than 200 feet."

In the Granite Falls area there are three sets of the ridges: one centred 4 miles west-northwest of the falls indicates movement to the northwest; another centred 5 miles northwest of the falls indicates ice-movement to the north-northeast; and a third, north of the falls on the east side of the river indicates movement westward towards the river.

Glacio-Fluvial Deposits

Description

The glacio-fluvial deposits (unit 2 and esker symbol in Fig. 1) consist of material that ranges from coarse bouldery gravel to sand, which was sorted by glacial meltwater streams and deposited beneath the ice-sheet or at or near its margin. Within the map-area glacio-fluvial deposits occur mainly as simple eskers, esker complexes, and valley trains.

Simple eskers consist of single, typically sharp-crested, undulating, sinuous ridges with heights up to 75 feet, and with sides sloping at angles up to 30 degrees. The ridges are commonly broken by gaps, particularly where the trends of the ridges cross low local divides. At such points, the divide may be cut by a meltwater channel.

Esker complexes (one passing east of Lake Nichicun and west of longitude 70°00′ is typical) are larger features than the simple eskers, varying from a few hundred feet to a mile or more wide, and up to 125 feet or more high. Typically there is a prominent central ridge, bordered on either side by depressions which may be occupied by small lakes. The surface rises abruptly, laterally outward from the depressions to an elevation somewhat below that of the central ridge, then slopes gently to the general surface level. In places the central ridge is divided into two or more subparallel ridges separated by elongate steep-sided depressions. At intervals along the courses of the esker complexes are broad expansions, whose tops may be smooth and level but more usually are deeply pitted by steep-sided depressions (kettles). Although most such expansions are of irregular shape, usually elongated along the trend of the esker complex, a few have typical delta form. The surfaces of such expansions are in most places higher than the crests of the central ridges leading into them. The continuation of the ridge across the expansion may be marked by two parallel rows of elongate depressions. The simple eskers are considered to have been deposited in the channels of subglacial streams. The esker complexes are probably of compound origin, that is, the central ridge was deposited in a subglacial channel, but the flanking material was deposited into standing water on either side of the ridge at the point where the subglacial stream debouched at the ice-margin. Norman (1938) studied similar esker complexes in the Chibougamau district, Quebec, and accounted for the depressions bordering the central ridge by supposing that the subglacial stream channel became aggraded by deposition of sediment, while at the same time the channel shifted laterally to bury blocks of ice beneath the new, higher channel. The blocks later melted out, and collapse of overlying sediments formed the depressions. The remarkable straightness of parts of the central ridges is not compatible with the notion of lateral shifting of the subglacial channel in which the central ridge is presumed to have been formed. Possibly, burial of ice lateral to the central ridge took place when the flanking sediments were deposited at the mouth of the subglacial stream.

Valley train deposits consist of sand and gravel carried beyond the ice-margin by glacial streams, and deposited as fill in major valleys.

Distribution

Like the transverse ground moraine and the hummocky ground moraine, the glacio-fluvial deposits are confined mainly to the drift plains and to depressions within the hilly uplands. Simple eskers and esker complexes are almost exclusively confined to that part of the map-area southwest of a line passing southeasterly from Lac Guyot to Opiscoteo Lake. Thus, the area lacking eskers and esker complexes corresponds exactly with the area affected by late northward ice-movement and in a more general way with the Kaniapiskau Massif. Clearly, the lack of eskers and esker complexes indicates a marked difference in the amount of debris carried within the ice and/or the manner of its release from the ice in this northeastern region as compared with the southwestern region, but the underlying reasons for the difference are not yet understood.

Within the drift plains and valleys in which they occur, the eskers and esker complexes tend to follow shallow depressions parallel with the direction of latest ice-movement, and commonly traverse areas occupied by hummocky and/or ribbed moraine. Locally, however, they impinge against the sides of valleys, or are perched on the valley wall. Where the depressions in which the eskers and esker complexes occur are occupied by lakes, lower parts of the ridge crests may be submerged. Many such submerged crests are discernible on airphotos.

Valley train deposits are restricted to the valley of Kaniapiskau River below Eaton Canyon. The river has been entrenched into the deposits to leave sand and gravel terraces at an estimated height of 100 feet above river level.

Within the hilly uplands, the rare glacio-fluvial deposits consist of small kames, and deltas and fans associated with former meltwater channels.

Bog Deposits

Large areas of the poorly drained drift plains are bogs, most of which are the familiar string bogs characteristic of the northern fringe of the boreal forest (for description and discussion of origin of string bogs *see* Auer, 1920; Hamelin, 1957; and Allington, 1959). Palsa bog, indicative of at least local permafrost, occurs in association with string bog as far south as latitude 55°30′N. An isolated example is interpreted from airphotos at latitude 54°53′N, longitude 61°55′W. Northward from latitude 55°30′, palsa bog becomes increasingly more prevalent and predominates over string bog at latitude 56°00′N. Palsa bog is characterized by hummocks of organic matter 5 to 20 feet high, and 15 to 100 feet across. Elevation of the hummocks above general bog level is due to more or less permanent ice-lenses within the hummocks, which have heaved overlying organic material upward (*see* Thorarinsson, 1951; Sjors, 1959, p. 15).

Most of the string bogs are extremely shallow; typically, the open water between the strings of organic material is studded with boulders, 10 feet or less in diameter, which project above the bog surface. The strings are rather consistently oriented normal to the direction of surface drainage. Of possible significance as to the origin of string bogs is the observation that there is no obvious tendency for the strings to be draped downslope from projecting boulders, and hence, there can have been little downstream migration of the strings.

INTERPRETATION OF GLACIAL FEATURES

Although in the Torngat Mountains to the east of the map-area Ives (1960a) has inferred two glaciations (Torngat and a final Koroksoak), the surficial deposits and glacial features of central Labrador-Ungava, as known, record only the late retreatal stage of the classical Wisconsinan Stage. No record has been found of a warm interval of interstadial rank recorded by the Missinaibi beds of James Bay Lowland, or of a pre-classical Wisconsinan glaciation and a still older glaciation inferred from drift beneath the Missinaibi beds (Terasmae and Hughes, 1960).

The decipherable record of the central region then is one of general ice retreat, accompanied by both major and minor shifts in direction of ice flow, until final disappearance of perhaps several small remnant ice masses.

Ice-Movements

Most of the ice-directional features shown on Figure 1 are drumlins and drumlinoid forms composed mainly of drift, or crag-and-tail structures consisting of rock knobs with drift tails. The streamlined character of the forms is due almost entirely to moulding of the drift, rather than to the shape of the bedrock, and their trend is that of the latest ice-movement over the area. Any vigorous ice-movement in a new direction would have remoulded the forms quickly to conform to the new direction of movement. *Roches moutonnées* and small rock-inscribed features such as striae and glacial grooves indicate movements older than those shown by the streamlined drift.

Latest ice-directional features lying southwest of a line passing from Lake Opiscoteo in the southeast to Lac Guyot in the northwest, have a generally radial pattern, which, when produced to the northeast, has a centre to the east and north of the map-area. As pointed out by Fyles (1955, p. 3) "drumlins and related forms probably were made at different times in the peripheral part of the ice-sheet, by movement of ice towards successive positions of the glacial front. Thus they do not necessarily reveal paths of continuous glacial flow." However, at widely scattered points northeast of the Lake Opiscoteo-Lac Guyot line, there are striae that are older than the ice-directional features showing latest ice-movement, and these conform to the truncated radial pattern southwest of the line. Further, rocks from the Labrador Trough were found as erratics as much as 65 miles west of the Trough. The striae and erratics together suggest that the truncated radial pattern defines at least approximately a pattern of ice-flow to the west and southwest from a source area over the Trough at about latitude 56°00′N.

To the northeast of the Lake Opiscoteo-Lac Guyot line, ice-directional features indicate that latest movement was to the north and northeast. There is virtually no belt of indeterminate movement between these features and those produced by west

to southwest movement. At points immediately northeast of the line, features produced by the northerly movement are clearly superimposed on those of the west to southwest movement. For example, at a locality 2 miles west-southwest of the northwest extremity of Lac Bellin, a *roche moutonnée* trends west-southwest, and has west-southwest trending striae on its north side. The south side bears abundant striae and grooves trending north-northeast. The north-northwest trending striae are clearly the younger, because they could have been formed by ice moving northward across the trend of the *roche moutonnée,* leaving older striae on the lee (north) side, whereas if the latest movement had been parallel with the trend of the *roche moutonnée,* both sides would have been equally scoured, and only west-southwest trending striae would be preserved.

Henderson (1959, p. 64) stated that "on a reconnaissance between Fort Chimo on Ungava Bay, and Fort McKenzie on Swampy Bay River, evidence of ice-movement to the northeast and north only was found." Thus in the region north of the map-area, north-to-northeast movement may have prevailed throughout the last glaciation, continuing concurrently with west-to-southwest movement. Within the map-area, northward movement would have resulted simply from southward migration of an ice-divide belt separating the two movements. Southward migration of the ice-divide would have first slowed, then beheaded ice flowing to the west and southwest from the Labrador Trough. Final deglaciation of the map-area would then have consisted of decay of an essentially independent ice-body with decidedly negative economy.

At about the same time that northward flow was being extended southward into the map-area, eastward flow was developing at the eastern limit of the map-area. At about latitude 54°00′ to 54°20′, well-defined crag-and-tail hills, drumlinoid topography, and striae indicate eastward movement; the pattern of eastward movement extends easterly into the drainage of McPhadyen River (Henderson, 1959, p. 67). At localities around Lac Falaise two, and in some places three, sets of striae are superimposed or occur close together. These appear to indicate that southwesterly movement was superseded by easterly movement, which locally gave way to final northward movement.

The ice-directional features produced by the west to southwestward flow and by the northward flow form very regular patterns, with little evidence of marginal ice-movements controlled by local topography or by local irregularities in the surface gradient of the ice-sheet. Surface ablation could have reduced the thickness of the waning ice-sheet until a large remnant ceased activity rather abruptly.

An exception to the general lack of evidence of local, topographically controlled ice-movements is found in the valley of Kaniapiskau River north of the mouth of Goodwood River. Drumlinoid topography about 8 miles north of the mouth of Goodwood River indicates late westward movement towards the valley centre, and three sets of boulder-and-tail ridges near Granite Falls (*see* p. 11) indicate movement directly down valley as well as towards the valley centre. The strongly opposed movements from both sides of the valley towards the valley centre suggest that a deep re-entrant developed in the ice-margin along the line of the valley.

The position of the periphery of the ice-sheet when activity ceased is not

known. Such features as marginal moraines, which signify former margins of active ice, would by their extent show the minimum recession of the ice-margins prior to stagnation; none however is known from the area, if the writer's interpretation be accepted that the ridges of ribbed moraine found in the area were formed *within* rather than *at* the ice-margin.

Disintegration of the Ice-sheet

At stagnation the maximum diameter of the ice remnant probably lay approximately along the Lake Opiscoteo-Lac Guyot line. It is not known whether this ice remnant became separated before or after stagnation from a similar one inferred by Ives (1960a, Fig. 5, p. 334) in the Kivivic Lake area of Labrador Trough, nor is it known which of the remnants persisted longer. Ives plotted the positions and directions of drainage of abundant meltwater channels in an area centred by Kivivic Lake, and drew a 'theoretical ice-divide' between channels draining northwestward and those draining southeastward. The meltwater channels of the present area, though less abundant, form well-defined patterns, which conform in general to the patterns of latest ice-movement. Exceptions to this general rule occur west and south of Lac Malapart, and on the south flank of the Otish Ranges.

In the Lac Malapart area, channels draining southwesterly occur up to 16 miles northwest of the Lake Opiscoteo-Lac Guyot line, where latest ice-movement was to the north. Meltwater channels, particularly subglacial ones, may locally drain towards rather than away from the centre of an ice-mass before finding their way to the margin. However, the pattern of southward drainage in the Lac Malapart area is extensive enough to indicate that at the very latest stage of disintegration the southern margin of the residual ice-mass lay some 16 miles north of the Lake Opiscoteo-Lac Guyot line, which is a theoretical ice-divide determined on the basis of latest ice-movements. Although the discrepancy is not great, it is important to note that theoretical ice-divides, as determined from meltwater drainage on the one hand and from latest ice-movements on the other, do not necessarily coincide.

On the southeast slope of the Otish Ranges are numerous abandoned channels that drained normal to or even against the direction of latest ice-movement. However, all such channels are integrated with major glacio-fluvial channels (delineated on Figure 1 by extensive glacio-fluvial deposits), which drained southward or southwestward, and the anomalous drainage resulted from local topographic control.

During its active stages, the ice moved obliquely across the Otish Ranges with little deflection. In the waning stages of glaciation, some of the ridges of the Otish Ranges may have stood as nunataks above the ice-sheet. There is, however, no marked development of felsenmeer on ridges to suggest a long-continued nunatak stage.

Glacial Lakes

During shrinking of the ice-sheet, glacial lakes were impounded at levels that locally are 100 feet higher than those of present day lakes. Shorelines of the glacial

lakes are visible on airphotographs as faint lines, but are readily discernible on the ground only where they occur on drift-covered ridges that extended as points into the lakes. No lacustrine silt or clay deposits were noted in association with the glacial lakes; the absence of such deposits and the weak development of shorelines indicate that the lakes were short-lived.

Glacial lakes inferred from shorelines in the area 55°30′N to 56°00′N and 70°00′W and 71°00′W clearly owed their position to blocking of local southward drainage by ice lying to the south. Lakes near Lacs D'Esperey and Dolu appear to have been similarly impounded. Glacial lakes near Lacs Cognac, Lemaitre, and Clairambault appear to have been dammed by ice lying immediately to the north, suggesting that as in the Lac Malapart area, the southern margin of the ice had receded to north of the Lake Opiscoteo-Lac Guyot line after the ice-sheet had become stagnant.

ECONOMIC CONSIDERATIONS

Knowledge of the surficial geology of the area will have future economic application in two fields: 1) prospecting, using the techniques of boulder tracing, heavy mineral analysis, and geochemistry; and 2) engineering, particularly in construction of roads, railways, airfields, and hydropower installations.

All the surficial materials (bog deposits excepted) have at some stage been transported by ice, hence any interpretation of the distribution of boulders, heavy minerals, or trace elements must take into account the effects of ice transport in one or more directions. South of the Lake Opiscoteo-Lac Guyot line where ice-movement, at least in late Wisconsinan time, consisted of radially outward flow, the effects of ice transport should present no problem. Northeast of the line, however, where latest movement was to the north, allowance must be made for earlier southwest transport, and near Lac Falaise allowance must be made for intervening easterly movement.

The writer suggests that future locations of roads and railways would best be restricted to areas with topography controlled predominantly by drift (in the La Grande-Lac Bienville map-area) or plains areas (in the Kaniapiskau-Nichicun map-area), where the necessity for rock-cuts should be at a minimum. Within these two types of terrain, the pronounced 'grain' produced by late Wisconsinan ice-movements will also influence the choice of road and railway location. Relatively easy routes are available parallel with the grain, along the crests of eskers and drumlinoid ridges. In a direction normal to the grain, the ridges of ribbed moraine offer well-drained ground, but individual ridges are not continuous enough, nor are the areas of ribbed moraine extensive enough, to provide continuous routes. Road or railway construction in hummocky moraine would necessitate much cutting and filling regardless of direction.

Expansions along esker complexes offer numerous sites for airfields. The expansions are typically elongate parallel with the grain, and with rare exceptions would permit only short landing strips except in the direction of elongation. Glacio-fluvial deposits, mainly in the form of esker complexes, offer widely distributed and abundant sources of sand and gravel, except in the dissected plateau region of the northeast; there sand and gravel are found in small widely scattered kame deposits, which are mostly too small to permit recognition from airphotos.

The bog deposits though extensive are mostly shallow, and lie on coarse till. Construction of roads and railways across short stretches of bog should present no special problems.

Permafrost occurs very locally in palsa bogs of the northern part of the map-area. Polygonal ground on a ridge 5.4 miles southwest of Granite Falls, Kaniapiskau River, indicates the presence (now or formerly) of permafrost. In the northern part of the map-area permafrost may exist beneath the crests of bare high ridges that normally are blown free of snow in winter, a distribution noted by Ives (1960b) near Schefferville.

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