GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

BULLETIN 99

# SURFICIAL GEOLOGY OF EAST-CENTRAL DISTRICT OF MACKENZIE

B. G. Craig

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1964

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By
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1964

# PREFACE

During the 1955 field season the author was attached to 'Operation Thelon' to study and map the surficial geology in east-central District of Mackenzie. This operation was the third in a series of helicopter-supported geological surveys designed to complete, as rapidly as possible, the reconnaissance mapping of northern Canada.

This report describes the glacial landforms and their relation to glacial retreat, and outlines the extent of the glacial lakes formed during deglaciation. The distribution of these glacial lakes, their elevations as determined from abandoned strand lines, the directions of marginal flow, and the distribution of areas of outwash indicating pauses in the retreat of the ice, all provide evidence for determination of the overall pattern of retreat of the ice.

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

OTTAWA, November 16, 1961

Bulletin 99—Oberflächengeologie des östlichen Teils des mittleren Mackenzie-Distrikts (Nordwestterritorien). Von B. G. Craig.

Beschreibt die glazialen Landschaftsformen und ihre Beziehung zum Zurückweichen des Eises und gibt einen Umriß der Ausdehnung der eiszeitlichen Seen, die sich im Stadium des Rückgangs der Vereisung im östlichen Teil des mittleren Mackenzie-Distrikts bildeten.

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Бюллетень 99 — Поверхностная геология восточно-центрального района Макензи, Северо-западный край. Автор: Б. Г. Крэйг.

Объясняет ледниковые ландшафты и их отношение к ледниковому отступлению, а также описывает распространение ледниковых озер образовавшихся в период таяния ледников в восточно-центральном дистрикте Макензи.

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# SURFICIAL GEOLOGY OF EAST-CENTRAL DISTRICT OF MACKENZIE


## *Abstract*

The area was completely glaciated during Wisconsin time, as is shown by an abundance of glacial landforms and glacially deposited material, and by modification of the bedrock surface. As deglaciation progressed eastward glacial lakes were formed by differential isostatic depression west of the Mackenzie-Hudson Bay divide and by glacial damming of major eastward-flowing streams. The distribution of ice-flow features shows a discontinuity in flow characteristics along a line northwest from Dubawnt Lake. The area south of this discontinuity became ice-free before that to the north.

The first part of the map-area to become ice-free was around Artillery and Clinton-Colden Lakes where a glacial lake formed at an elevation of 1,300 feet above present sea-level. Further retreat of the ice-margin eastward allowed the initial stages of glacial Lake Thelon to form in the upper Thelon basin at about 1,250 feet. Later this lake lay in the north-trending part of the Thelon Valley at about 1,150 feet and extended into the northwestern part of the Dubawnt basin. In the southwestern part of the Dubawnt basin at 1,350 feet, another glacial lake formed which eventually joined with glacial Lake Thelon at about 1,100 feet. Finally glacial Lake Thelon lay along the Thelon Valley below Eyeberry Lake at 800 to 700 feet, and Hyper-Dubawnt lay west of present Dubawnt Lake at 900 feet. Marine water probably extended up the Thelon and Western River valleys and possibly up the Back River valley for a short time.

Final deglaciation was probably completed 7,000 years ago.

## *Résumé*

La région à l'étude a été entièrement recouverte de glaciers au cours du Wisconsin ainsi que l'attestent l'abondance de dépôts glaciaires de divers types et les formes d'érosion du socle. A mesure que la déglaciation a progressé vers l'est, des lacs glaciaires se sont formés en raison de la dépression isostatique différentielle à l'ouest de la ligne de partage des eaux du Mackenzie et de la baie d'Hudson, et de l'endiguement par les glaces d'importants cours d'eau coulant vers l'est. La répartition des vestiges glaciaires le long d'une ligne partant du lac Dubawnt vers le nord-ouest indique une discordance dans les caractéristiques d'écoulement du glacier. La région située au sud de la discordance en question a été déglaciée la première.

Dans la région à l'étude, les glaces se sont tout d'abord retirées des environs des lacs Artillery et Clinton-Colden, et un lac glaciaire s'y est formé à une hauteur de 1,300 pieds au-dessus du niveau actuel de la mer. A l'est, le retrait plus poussé du glacier a donné naissance au lac Thelon dans la partie supérieure du bassin Thelon, à environ 1,250 pieds. Plus tard, les eaux de ce lac ont inondé la section de la vallée Thelon orientée vers le nord à environ 1,150 pieds d'altitude et se sont répandues dans la partie nord-ouest du bassin Dubawnt. Un autre lac glaciaire s'est formé dans la partie sud-ouest du bassin

Dubawnt à une altitude de 1,350 pieds. Après un certain temps, ce lac s'est raccordé au lac Thelon à une altitude d'environ 1,100 pieds. Finalement, le lac glaciaire Thelon s'est encaissé dans la vallée Thelon, en aval du lac Eyeberry, entre 800 et 700 pieds d'altitude tandis que le lac Hyper-Dubawnt s'étendait à l'ouest du présent lac Dubawnt à 900 pieds. Les eaux de la mer ont probablement envahi la vallée Thelon et celle de la rivière Western et peut-être même la vallée de la rivière Back pendant une courte période.

La déglaciation s'est probablement terminée il y a 7,000 ans.

# INTRODUCTION

## Location of Area and Accessibility

The map-area (about 61,000 square miles) lies almost entirely in east-central District of Mackenzie, except for a small part in the northeast in the District of Keewatin (*see* Fig. 1).

The area has no roads or settlements. It is accessible by aircraft from various points in northern Canada, and is crossed by three canoe routes: along Dubawnt River; along Lockhart, Hanbury, and Thelon Rivers; and along the Back River system. During the 1955 field season a landing strip, which has since been abandoned, was maintained by Spartan Air Services just north of Pelly Lake.

## Previous Work

The earliest report on the glacial geology of the map-area is by Tyrrell (1898)[1]. His observations were confined to the shores of Dubawnt River and Dubawnt Lake. As aerial photographs became available for the virtually unknown parts of northern Canada they provided a basis for office compilation of easily recognized glacial features. From airphoto studies Wilson (1939) showed the distribution of eskers and beaches and the direction of ice movement in the west-central part of the map-area and westward, and later (1945) the distribution of eskers in an area north of that of his earlier work and west of this map-area. Dean (1953) discussed the drumlinoid landforms on much of the Canadian Shield west of Hudson Bay.

It was not until 1948 that any further field observations were made. Bird (1951, p. 16; 1953b, p. 218) reported on the glacial geology of a strip along the middle and lower Thelon River basin that extended through the map-area as far west as Hornby Point. He has since (1955b) extended his studies, which are mainly physiographic, on the basis of airphoto compilation and field work in other parts of the Northwest Territories (1953a, 1955a) to include much of the District of Keewatin and the eastern part of the District of Mackenzie. Lee (1959) and Fyles (*in* Wright, 1955, pp. 3-4) have studied the glacial geology of the area to the east of that covered in this report. Preliminary accounts of the surficial geology of the area are given by Craig (*in* Wright, 1957, pp. 4-5) and of the bedrock geology by Wright (1957).

## Present Work

This report embodies the results of the third of a series of helicopter surveys conducted by the Geological Survey of Canada in the southeastern part of the Northwest Territories. The field work occupied four months of the 1955 field sea-

[1] Names and/or dates in parentheses are those of References, page 40.

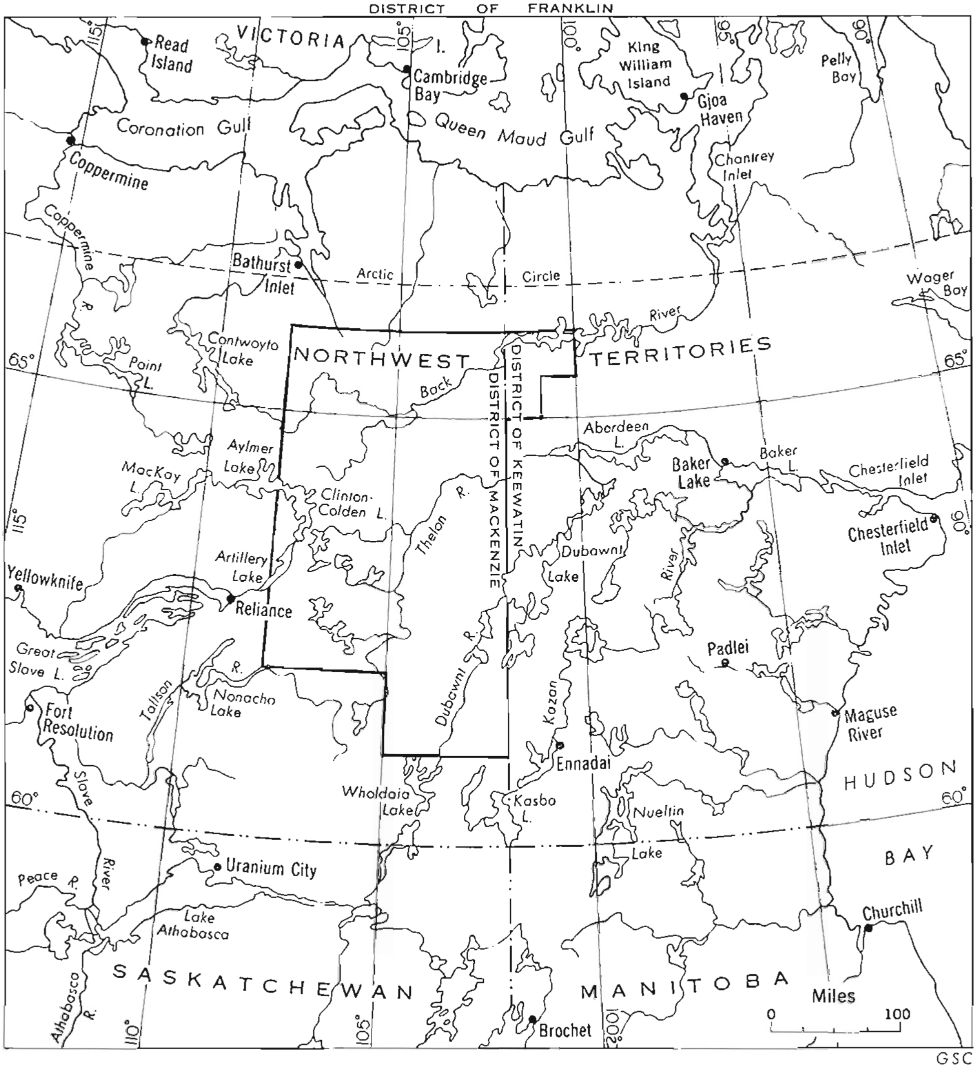


FIGURE 1. Index map showing location of area covered.

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For a detailed description of the bedrock geology *see* Wright, 1957, from which this summary was made.

wackes, and slates, with minor amounts of greenstone and acidic lavas. They occur along the west side north of Artillery Lake.

Probably younger than the Yellowknife Group is the Hurwitz Group, which is represented by white quartzite; and the Nonacho Group, which is composed of quartzite and greywacke, phyllite and schist, and conglomerate. Both groups are of limited areal extent; the former is found only in a ridge, a few miles long, northeast of Eyeberry Lake, the latter as a narrow, hook-shaped band between Tent and Whitefish Lakes. Most of these older stratiform rocks, which have been folded and contorted, range in age from Archaean to possibly early Proterozoic. Except for the east-central and northwestern parts, much of the map-area is underlain by granitic rocks, which are mainly gneissic but in part massive. These are possibly younger than the sedimentary rocks and may be in part Proterozoic. Dolomitic limestone of limited distribution, which underlies part of the shoreline and nearby islands in the southeast part of Artillery Lake, probably belongs to the Great Slave Group of early Proterozoic age. Sedimentary rocks of the Goulborn Group and the Dubawnt Group are probably of late Proterozoic age. The former underlie part of the northwestern corner of the map-area and consist mainly of quartzite and conglomerate with lesser amounts of limestone and slate. They have been moderately folded and tilted and form a series of high rugged hills. The Dubawnt Group consists mainly of sandstone showing varying degrees of induration, and minor amounts of conglomerate, volcanic rocks, and carbonate rocks. These rocks underlie the east-central part of the map-area north and west of Dubawnt Lake and are essentially flat lying and unmetamorphosed. Basic intrusive rocks occur as dykes, sills, and plugs throughout the map-area. The age of the plugs is unknown, but the dykes and sills appear to be no older than late Proterozoic. The youngest rocks in the map-area are restricted to the islands and shoreline of Nicholson Lake. They consist of well-bedded, gently dipping, fossiliferous limestone, probably of Ordovician age. These limestones were first described by Tyrrell (1898, p. 54F).

## Physical Features

The map-area lies entirely within the Canadian Shield. Elevations range from 300 feet where Thelon River leaves the area to about 1,350 feet on the Lockhart-Thelon divide (*see* Fig. 3) near Summit Lake. In general, the area is broadly trough-shaped, dipping towards the northeast. Around the southern, western, and northwestern sides of this trough elevations range from 1,200 to 1,350 feet; along the eastern side they decrease from nearly 1,200 feet at the south to the low point at Thelon River, increase to possibly 900 feet along the Thelon-Back divide, and then decrease to just over 500 feet in the northeastern corner of the map-area.

The character of the bedrock is the dominant control in the appearance of the landscape in most places, but the bedrock topography has been modified almost everywhere by glacial action. Eskers and drumlins are common throughout the map-area except in the northwestern part and the east-central part west of Dubawnt Lake. In much of the southeastern corner the ground surface is a rolling, ground-moraine plain covered with bouldery rubble. West of Dubawnt Lake the ground is a gently rolling, grassy plain and north of Dubawnt Lake it is a vast field of drumlinoid ridges. The large areas underlain by gneissic granite consist mainly of monotonous series of irregular rolling hills, frequently with bare rock exposed at the tops. Relief ranges from a few tens of feet to about 200 feet. Streams are generally shallow and follow an irregular course with many rapids, and lakes are numerous. Near Moraine Lake the banded structure has been greatly accentuated and the landscape has a pronounced grain. Drift is patchy or absent. Deep steep-walled valleys containing streams or long narrow lakes are common. The smaller areas of massive granite generally form dome-shaped hills or series of hills rising a few hundred feet above the gneissic terrane. Except in the northwestern part of the map-area the metamorphosed sedimentary rocks are of limited extent and have little effect on the appearance of the landscape. The quartzite assigned to the Hurwitz Group stands out as a ridge 300 feet high and several miles long. Elsewhere areas underlain by these rocks have much the same aspect as those underlain by granite gneiss. In the re-entrant north of Western River rocks of the Goulborn Group form a series of rugged hills rising abruptly to about 1,300 feet above sea-level. These hills are 300 to 400 feet above the lowlands to the east, south, and west. Drift is very thin and the rock structure is revealed as a series of gracefully curved rock ridges. The landscape of the east-central part of the area, which is underlain almost entirely by Dubawnt sandstone, is mainly the product of glacial action. A low gentle scarp between Granite Falls on Thelon River and Dickson Canyon of Hanbury River marks much of the western side of this region. Outcrop is scarce and over large areas absent. Lakes are rare and the small streams are few and sluggish.

# PLEISTOCENE GEOLOGY

Evidence of glaciation is abundant throughout the map-area, and deposits of glacial drift of various types and in various patterns are widespread. The bedrock surface has been modified, both in the shape of the outcrops and by their surface markings. In general, the drift is thin and intermittent except in the southeastern and east-central parts of the area where the drift mantle is very continuous. Locally, glacio-fluvial material in the form of outwash and eskers may attain thicknesses of 100 feet or more.

## Surficial Deposits

### Glacial Deposits

A mantle of till of varying thickness is found in most of the map-area. It is mostly sandy, buff, and reflects the nature of the underlying bedrock. In the outcrop area of Dubawnt Group dolomite and along Thelon River from Hornby Point to longitude 103°30′ the till is clayey and brick-red. Most of the till areas are covered with boulders, ranging from less than a foot to tens of feet in diameter. In many places the ground surface is entirely rock rubble, consisting mostly of boulders of local rocks but with sparse erratics. Much of the till is being modified by solifluction processes.

### Glacio-fluvial Deposits

The greatest concentrations of drift are found in the eskers and outwash deposits, which are composed almost entirely of sand, with minor lenses and beds of fine gravel. The esker sand contains many boulders, which in places completely cover the surface of the eskers.

### Lake Deposits

Most of the material resulting from lacustrine action is found as beach terraces along valley sides and around hills. It consists largely of gravel although there is some variation depending on its source; many beaches in the area of the Dubawnt sandstone consist of slabs of rubbly sandstone. No bottom deposits were noted and only a few small deltas composed almost entirely of sand.

### Alluvium

Along parts of Thelon and Back Rivers and the lower reaches of Clarke River flat terraces of sand and silt above the present flood plain levels of the rivers represent older alluvial deposits. The pingo previously described by the writer (1959) formed in material of this sort.

# Glacial Features

## Bedrock Surface

The surface of the bedrock has been modified on both a large and a small scale, in places concealed and probably in many places uncovered owing to the movement of glacial ice and the subsequent effect of meltwater as the ice-sheet disappeared. Furthermore, the configuration of the bedrock surface, especially of strongly lineated gneisses and metamorphosed sediments, influenced the pattern of movement of the ice and the direction of flow of many meltwater streams. In areas of massive rocks glacial action had a general rounding and smoothing effect; in areas of gneisses and other strongly banded rocks, especially where the direction of glacier flow was parallel to the strike of the bedrock, the lineation and local relief were accentuated. Many of the glacial features imposed on the bedrock give a clear indication of the direction of ice-movement. *Roches moutonnées* are common, especially in areas underlain by massive granitic rocks and along dykes. Smoothed rock knobs in combination with drift ridges form crag-and-tail hills of sufficient size to be easily discernible on air photographs. Although many of the rock types have weathered sufficiently since deglaciation so that striae are either no longer present or poorly preserved, larger grooves (*see* Pl. I) are still apparent in many places. Striae are not uncommon, however, and even on badly weathered rocks can still be found in protected places or crossing crystals of resistant minerals.

## Drumlinoid Forms

Possibly the most common and easily discernible features of the drift are those mapped as drumlins and fluting. Although there is a wide variation in their physical characteristics, they are all considered to have been formed by moving glacial ice in a zone a few miles wide near the ice-margin, and to be parallel to the direction of movement of that ice. They occur as true drumlins in fields of many square miles, as patches in drift-filled lows in areas that are mostly bedrock, and, in the Thelon basin, as a vast area of long, uniformly spaced ridges and grooves. The drumlinoid forms range from hills with relief up to 100 feet to 'trends' that are discernible on air photographs only by the variation in vegetation, which is more luxuriant and commonly only present in the low areas. There is a complete intergradation of these types.

The true drumlins are probably not more than 100 feet high and from a few hundred feet to about a mile long. Most of them are elliptical, but in any one area the ratio of length to width is variable. Some are symmetrical in long profile, but most are higher at the proximal end. In the Thelon basin, the fluting is more regular in appearance than most of the drumlin fields. There individual ridges are much longer and generally lower than the drumlinoid features elsewhere in the area. Typically they are from 10 to 30 feet high and up to 5 miles long. Ridge crests range from 400 to 1,200 feet apart, but are generally about 800 feet. The longer ridges are gently tapering at each end. The area of fluting roughly coincides with



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the outcrop area of the Dubawnt sandstone, and the drumlins occur within the outcrop area of the older crystalline rocks.

Most of the drumlinoid forms are composed of till, but some have been formed by ice overriding previously deposited glacio-fluvial material. The latter type is found in the region around latitude 64°20′, longitude 105°00′. An excavation in a drumlin south of Garde Lake revealed medium-grained sand and a few boulders. The surface of the ridges in much of the fluted area is composed of sandstone slabs.

Some drumlins have rock bosses at their 'upstream' end. These are called crag-and-tail hills and are reliable indicators of the direction of ice-movement.

BGC 6-6-55

PLATE I. Striated glacial groove on *roche moutonnées*, north side of Beechey Lake.

## Transverse Ridges

These features include all drift ridges formed at right angles to the direction of ice-flow and for the most part can be classed as minor moraines. Except for two small areas south of Pelly and Garry Lakes, they are found only in the southern part of the map-area, where they are very common (*see* Pl. II). These are similar to and probably an extension of the minor moraines near Ennadai Lake, about 50 miles east of the map-area, described by Lee (1959, p. 12) as follows:

> A ribbed type of landscape, produced by minor moraines, is discernible on air photographs of the region . . . from the air [the ridges] appear to be fairly regularly

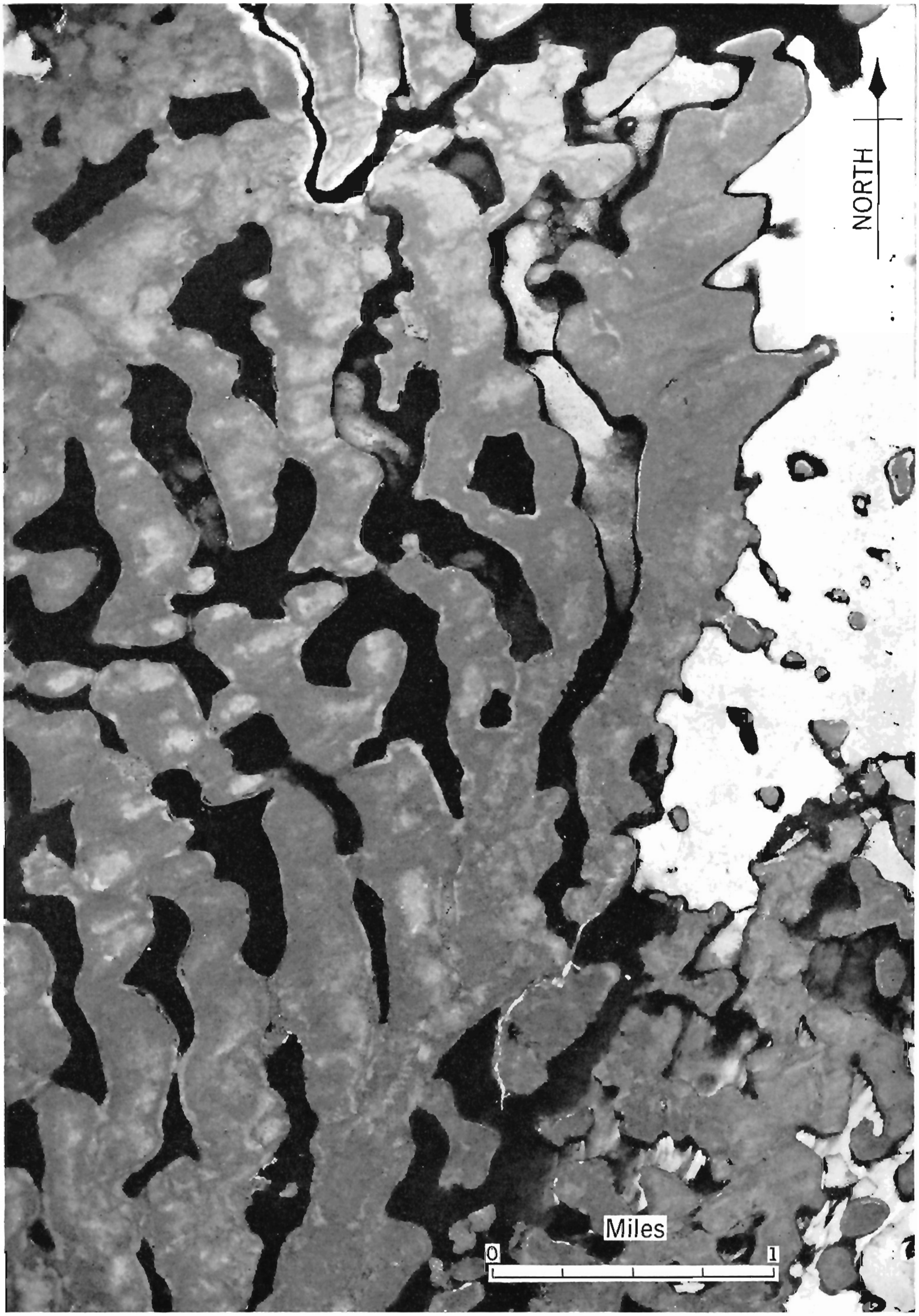


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PLATE II. Minor moraines and associated small drumlins, west side of Boyd Lake. Ice movement from right to left.

> spaced. When examined on the ground they are seen to be much less uniform. Individual ridges rarely exceed a few hundred feet in length and are up to 50 feet high; some are linear, some are arcuate, and others are irregular and hummocky. The interridge areas are boulder-covered with large perched blocks and boulders common on the surface of the ridges. Some of these boulders are up to 8 feet in diameter, but most of them are about 1½ feet.

Taylor (1960, and *in press*) describes a western extension of these features in the Penylan Lake—Firedrake Lake area, and a southern extension in the Snowbird Lake area. Henderson (1959, pp. 18-23) described cyclical moraines south of Dyke Lake in Labrador that closely resemble the writer's minor moraines, and summarized reports of the occurrence of similar features elsewhere in Canada.

In the east-central part of the map-area south of Thelon River near the 64th parallel some of the drumlins display a pattern of closely spaced, irregular ridges and mounds oriented at right angles to the long axis of the drumlin (*see* Pl. III). These features appear to be gradational between true drumlin ridges and minor moraines. They consist of short cross-ridges aligned in *en échelon* series parallel to and in places adjacent to drumlin ridges. Although they were not examined closely on the ground, their upper surface seems to be composed of slabs of Dubawnt sandstone—the underlying bedrock. They have a relief of 5 to 10 feet, which is less than that of most of the minor moraines. Because of their affinity to drumlins and minor moraines it seems most likely that these features were formed in the frontal part of the ice-sheet, and it is interesting to note that in this map-area they are found only below the limit of lacustrine submergence.

## Ice-block Ridges

A series of ridges that completely or partly surround irregular depressions is located near the west edge of the map-area, about 15 miles west of Ptarmigan Lake (*see* Pl. IV). These ridges cover an area of about 8 square miles and although they are very distinct, well-formed features they were not observed elsewhere in the map-area. Individual ridges are a few feet to 75 feet high, generally sharp-crested, and about 200 feet across the base. They enclose depressions from a few hundred feet to a half mile in maximum diameter. The surface of the ridges is bouldery, the composing material being till that is more clayey than is common within the map-area.

Similar features are widespread in southern Canada especially in Alberta and Saskatchewan, and have been described by Gravenor and Kupsch (1959) and Stalker (1960). The term "ice-block ridge" is used by Deane (1950, p. 14) for analogous forms in southern Ontario. There is a general agreement that these features were formed in cracks and crevasses between stagnant blocks of ice, either by a squeezing up of basal material into the open space by the weight of the ice-blocks or by sloughing down of ablation material as the ice-blocks melted. The bouldery nature of the till and the general thinness of the drift suggest that the latter process is more likely, but a combination of both may have taken place.

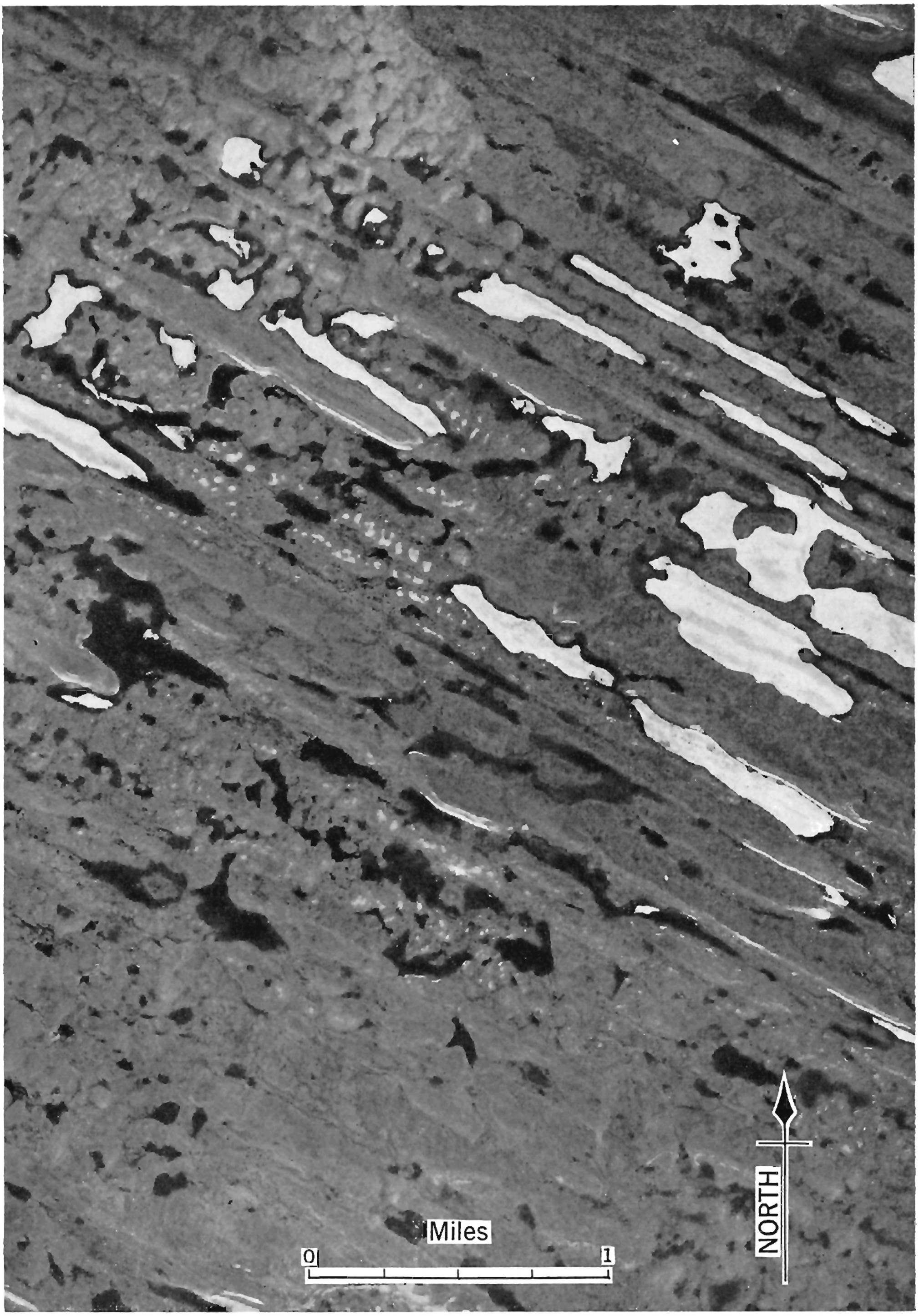


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PLATE III. Transverse ridges formed along northwest-trending drumlins, at latitude 63°54′, longitude 102°23′. Note beaches of glacial Lake Thelon in lower part of photo.

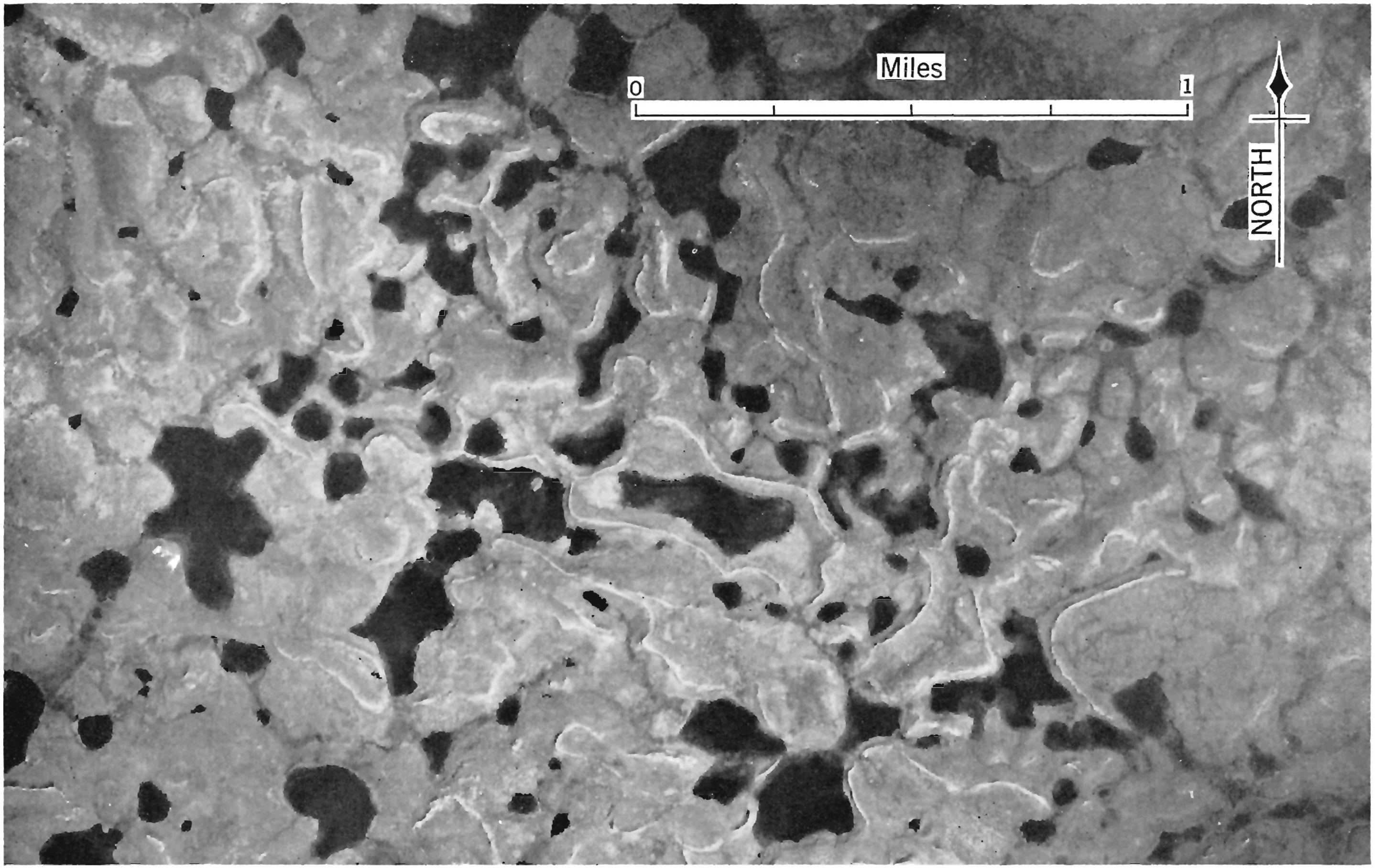


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PLATE IV. Ice-block ridges 15 miles west of Ptarmigan Lake.

## Glacio-fluvial Features

### *Eskers*

The network of eskers within the map-area is striking—and for the most part easily discernible—evidence of glaciation. These features are common in most of the map-area and generally are roughly parallel to the direction of glacial flow. Individual eskers vary greatly in appearance and form throughout their length, and the following descriptions do not necessarily apply to segments more than a few miles long. They range in size from single ridges more than 120 feet high and 1,500 feet wide across the base to those only a few feet high and a few tens of feet across the base. The longest esker can be traced almost continuously across the map-area from just west of Dubawnt Lake to north of Clinton-Colden Lake—a distance of about 250 miles. Preliminary airphoto study indicated that this esker continues northwestward for at least another 240 miles towards Great Bear Lake. In the southern part of the map-area eskers are generally larger in cross-section and longer than those in the northern part.

Most of the eskers are the familiar railway-embankment type. Many of the larger ones, however, have flat tops several hundred feet wide with steep slopes along the sides at the angle of repose of the composing material. A few have terraces along their sides, and in places many of them consist of three or four parallel ridges.

At irregular intervals along many of the eskers in the southern part of the map-area the ridges expand in both height and width to form 'knobs', the summits of which are as much as 200 feet above the adjacent plain. These knobs are characteristically two to three times as wide and twice as high as the adjoining esker ridges, and they exhibit varied patterns of ridges and valleys generally parallel to the course of the esker. Some have low cross-ridges dividing the valleys into segments (*see* Pl. V) and some have a reticulate pattern (*see* Pl. VI). Many are pitted with kettle holes at different elevations within the esker knob. Low scarps and narrow terraces that appear to be the result of wave action occur on the distal end of some knobs.

It is probable that these features were formed where the esker stream under considerable hydrostatic head issued from a subglacial tunnel into a body of standing water. Topographic conditions for such a situation are ideal west of Dubawnt Lake where the ice-front retreated downslope over a considerable distance. The great increase in size of the knob, especially in height, as compared with the esker ridge upstream from it precludes the possibility of the esker stream flowing in an open crevasse at the ice-margin. The pattern of ridges and kettles suggests that the stream flowed over stagnant ice-blocks and represents the fracture pattern of the dead ice at the ice-front.

An esker at latitude 64°19′, longitude 105°51′ terminates in a small delta that differs from the esker knobs. Its surface is at the same altitude as the upper surface of the esker; it is triangular and has a steep outer slope notched by a prominent wave-cut scarp.

As can be seen on Figure 10, most of the eskers are not single ridges extending for great distances but rather parts of esker systems that form a generally dendritic pattern. This pattern is most clearly seen in the southern half and the northern quarter of the map-area, where there was a regular retreat of the ice-margin to the east and south (*see* p. 29). In the central part of the map-area, however, the direction of ice-flow changed during the last phases of movement, and this resulted in an irregular arrangement of the eskers. There most eskers are short and discontinuous, many of them are not parallel to adjacent flow features, and some—notably those at latitude 64°18′, longitude 104°55′, and latitude 64°05′, longitude 105°15′— have been overridden and drumlinized.

GSC 3-1-55

PLATE V. Cross ridges in valley between larger longitudinal ridges in esker knob.

Most of the eskers have gaps of varied lengths at irregular intervals. In such gaps, however, there is usually evidence of the former existence of the esker stream. Because of the scale of mapping, parts of eskers consisting of short segments have been shown on Figure 10 as discontinuous over considerable distances, although the segments of the esker ridge may be prominent landforms. In places the action of the esker stream was erosional rather than depositional. Steep-walled channels, locally containing esker segments, connect longer esker segments. Gaps in eskers are often characterized by a zone washed clear of drift. At such places the structure of the bedrock shows clearly on air photographs whereas the adjoining ground has a smooth ground moraine surface. These localities are most common where the esker stream flowed over a slight bedrock high between two lower areas. The 'scoured' areas or esker scour channels are generally sharply defined along the edges (*see* Pl. VII) and in places occur beside esker ridges. In many areas of relatively thick or continuous drift they provide the only opportunity to examine the bedrock.

As a general rule the eskers follow topographic lows, and many are found in the bottoms of valleys that predate the last ice movement. Such a one occurs in the valley of Thelon River just west of the 104th meridian. Under-water extensions of esker ridges can be seen from the air in many of the lakes.

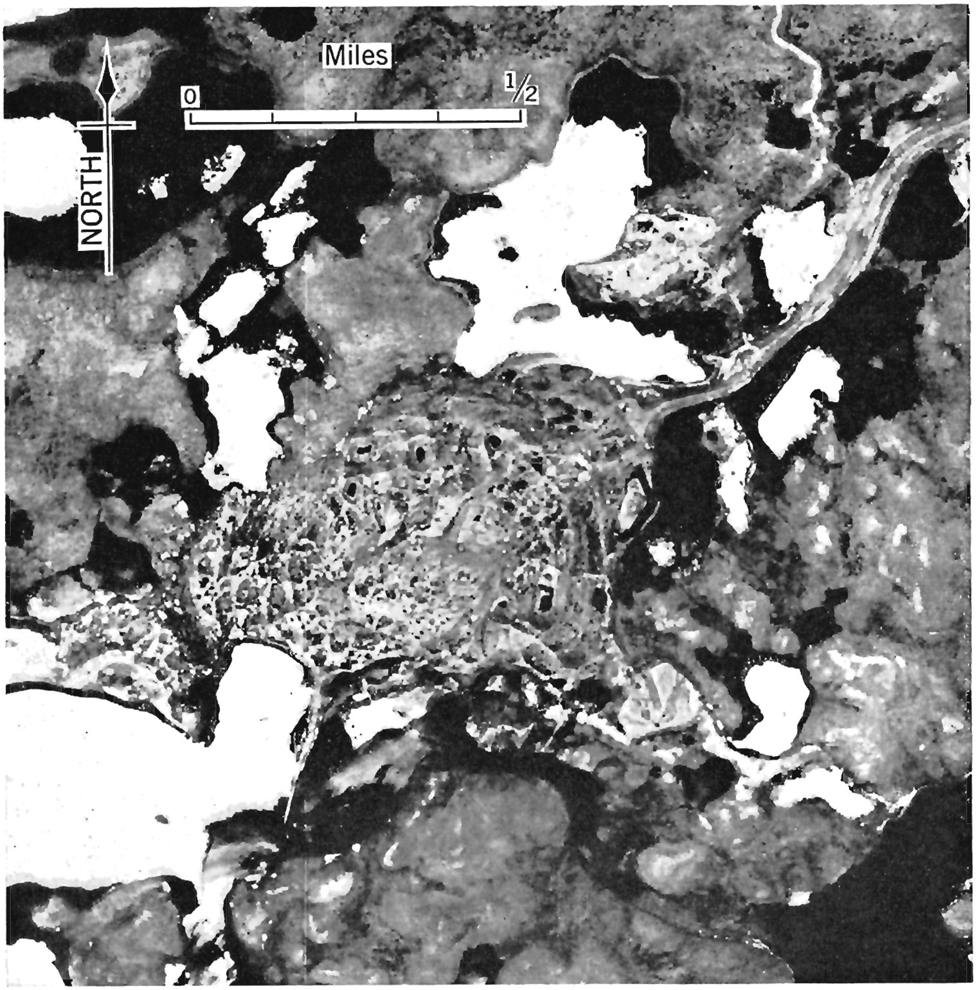


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PLATE VI. Reticulate pattern of ridges on esker knob at latitude 61°16′, longitude 102°25′.

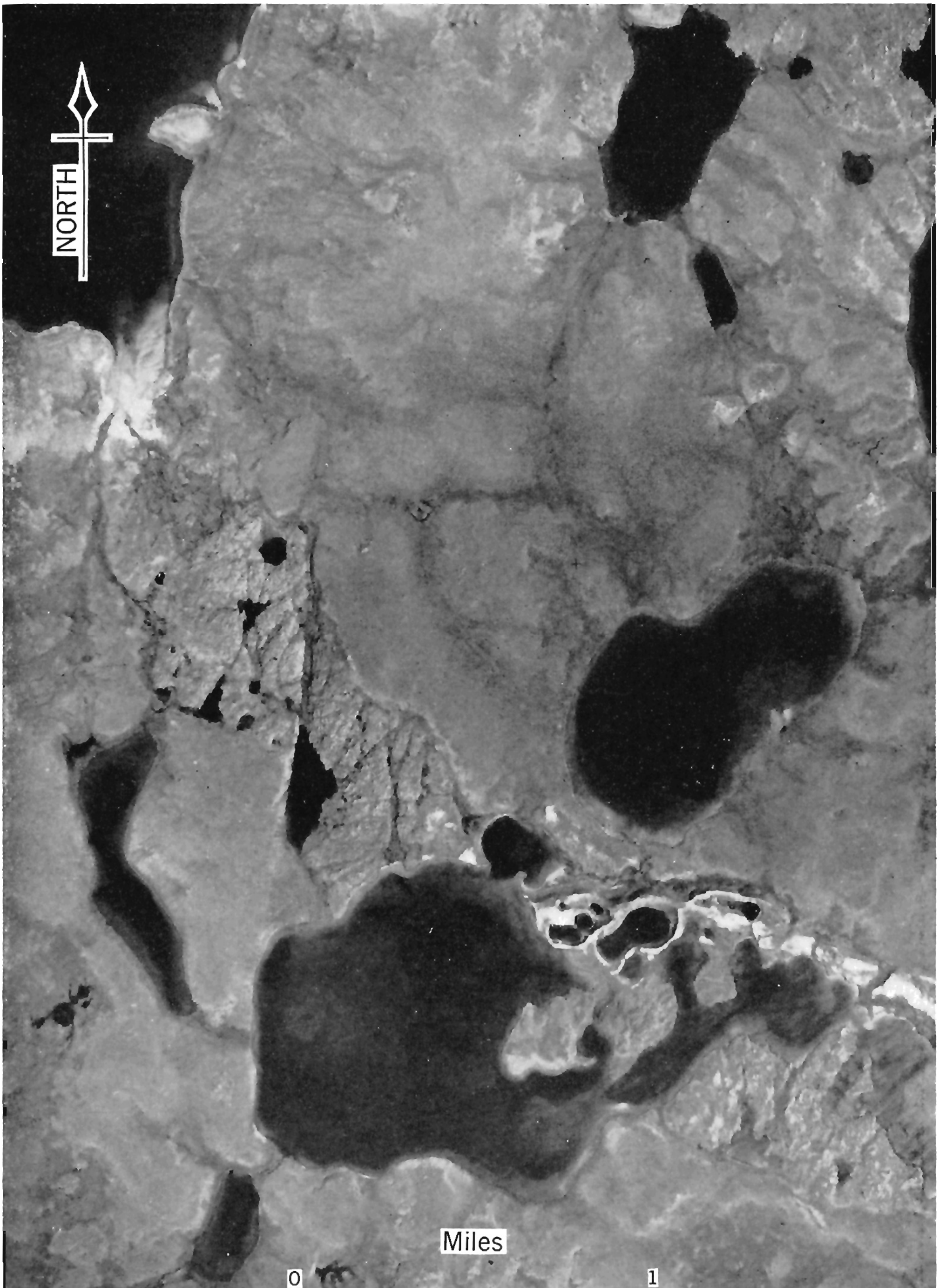


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PLATE VII. Esker scour channel, southeast part of Clinton-Colden Lake.

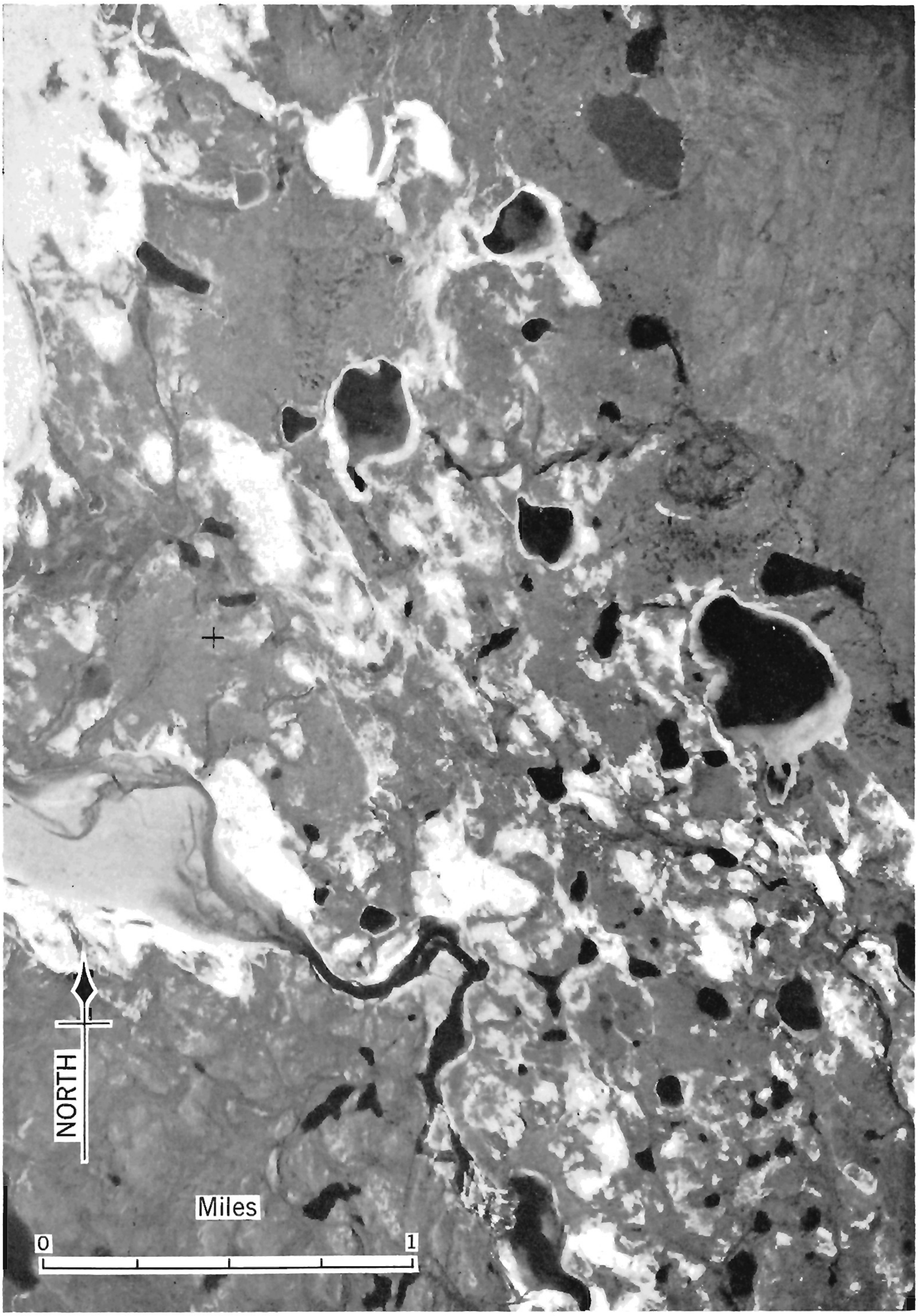


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PLATE VIII. Pitted outwash north of Macdonald Falls and Sandy Lake, Hanbury River.

*Outwash*

Sand and gravel has been deposited as outwash in front of the ice-margin, and in places forms bodies of great thickness and extent. It is found as high-level terraces, sometimes covering several square miles, and as valley train deposits. In some places braided channels of the glacial rivers are visible on the outwash surface, but often melting of buried ice-blocks has produced a pitted surface.

The largest high-level deposit occurs north of the lower reaches of Hanbury River and extends southeastward along Clarke River to about the 104th meridian. This zone appears to mark an ice-front position of the northern lobe of ice discussed on page 29. It is composed mostly of pitted outwash (*see* Pl. VIII), especially in the western part, but grades into deposits resembling kame moraine in the eastern part along Clarke River and may be of interlobate origin. Eskers with a general northern alignment lead into the western end of this mass of outwash from both north and south.

A second elongate zone of outwash extends intermittently from the lake at latitude 65°23′, longitude 105°50′ to about latitude 65°40′, longitude 104°20′. This band probably marks a pause in the retreat of the ice-margin. It consists mostly of high-level deposits of sand showing the braided pattern on their upper surface (*see* Pl. IX), but these are intimately associated with lesser amounts of pitted outwash. Both of these have subsequently been channelled by meltwater streams. Each separate segment of outwash is part of an esker or esker system that continues beyond the area of outwash, however, indicating that the still-stand of the ice-front in this region was of a temporary and minor nature.

A third zone of outwash west of Mary Lake extends southwesterly between Sid and Gravel Hill Lakes (*see* Pls. X and XI). Although smaller than the two zones already described, it is the most spectacular within the map-area. Apparently the outwash sand and gravel was deposited over an extensive area of stagnant and fractured ice instead of enclosing isolated ice-blocks as is common elsewhere. The ground surface consists mostly of ridges, crudely oriented normal to the direction of ice movement.

Most of the smaller deposits of pitted outwash that occur throughout the map-area are associated with eskers and are in part extreme phases of the esker knobs. North of Pelly Lake and Upper Garry Lake a zone of pitted outwash many square miles in extent is found. This outwash was probably deposited during a halt in the retreat of the ice-front, and may be contemporaneous with the outwash north of Hanbury River.

## Glacial Lakes and Marine Submergence

In many parts of the map-area abandoned strand lines indicate the former presence of glacial lakes. Small deltas commonly associated with eskers occur at many localities, but with beaches at latitude 64°10′, longitude 104°04′, and latitude 63°50′, longitude 102°10′. Many of the esker knobs show evidence of lacustrine action during their formation. No bottom deposits were mapped as such, but it is probable that more detailed work would reveal such sediments.

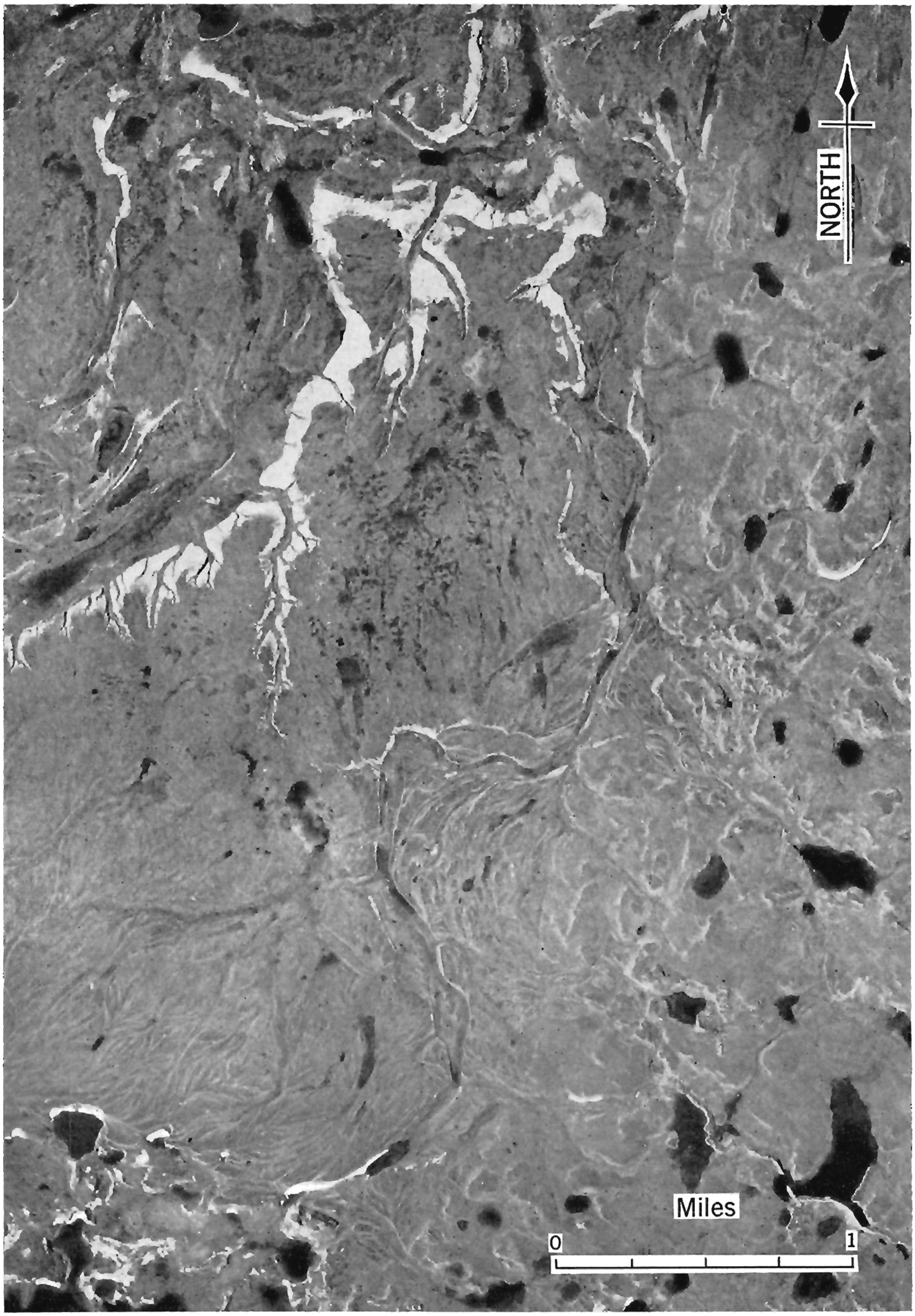


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PLATE IX. Braided and pitted outwash at latitude 65°31′, longitude 104°30′.

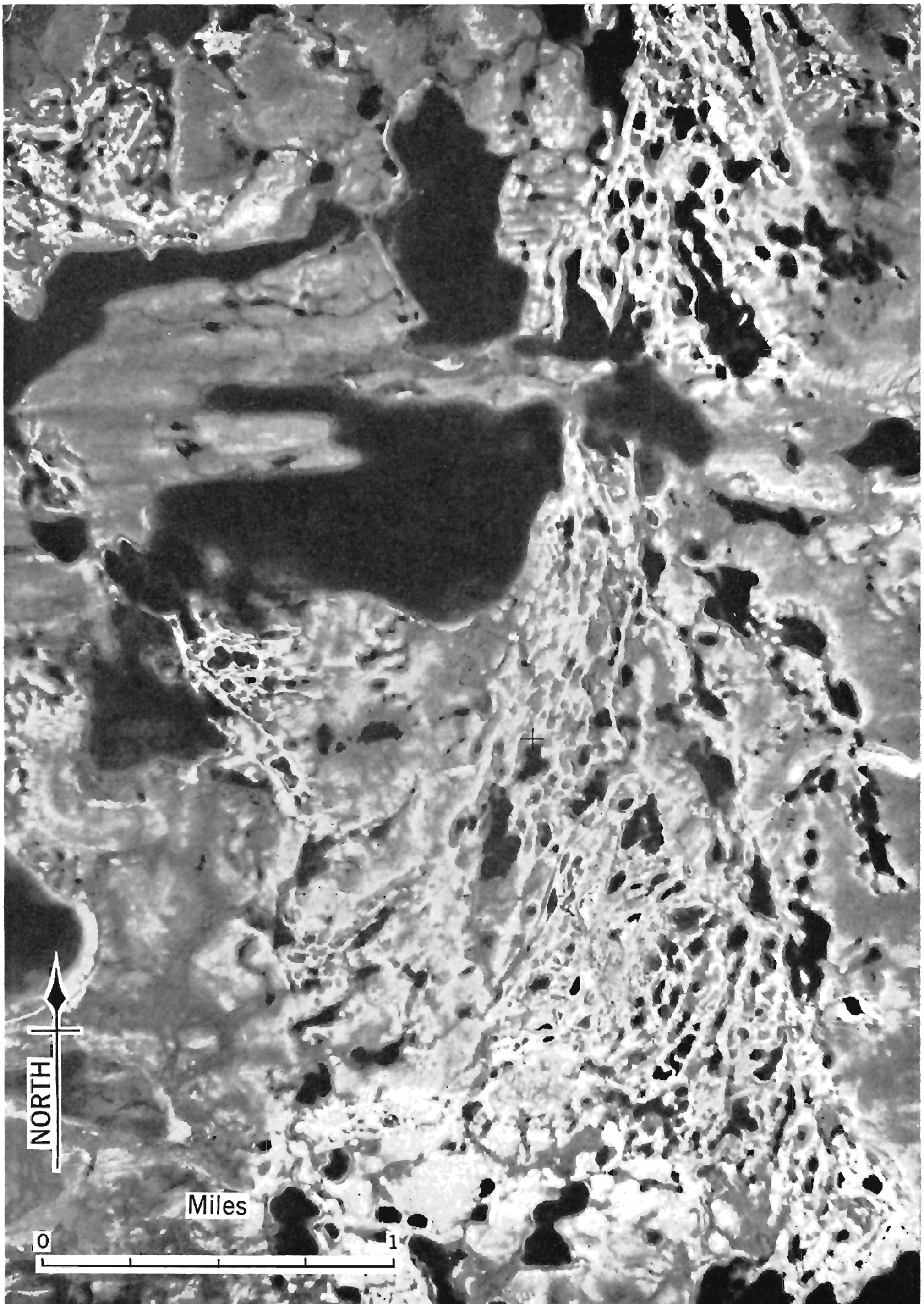


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PLATE X. Pitted outwash between Sid and Mary Lakes.

In some of the major drainage basins lacustrine features are extensive and have an accordance of elevation over wide areas, so that limits of former lakes can be determined and related to the general retreat of the ice-front; elsewhere the evidence is too fragmentary to be of great significance in deciphering the glacial history.

Most of the glacial lakes were formed by blocking of natural drainage lines by the retreating glacier. Some apparently were formed by differential isostatic depression of the land and were drained wholly or partly during the period of readjustment. In addition, this second process (differential isostatic depression of the land) may well have complicated the history of lakes formed by the first process (blockage of drainage lines by the ice). Insufficient data are available to determine the amount and direction of uplift that followed the retreat of the ice. However, if it is assumed that the isostatic readjustment took place progressively as the ice-margin retreated (as has been inferred by Craig and Fyles, 1960, p. 10), then uplift took place from west to east and from northwest to southeast. Furthermore, this region lies well within the central zone of the Laurentide ice-sheet as described by Craig and Fyles (1960, pp. 6-7), where the amount of rebound was probably about the same throughout the area, though not contemporaneous across it.

The principal glacial lakes were formed in the drainage basins of the major stream systems (*see* Fig. 3), the largest having formed in the Thelon basin. The first

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PLATE XI. Oblique view of pitted outwash between Sid and Mary Lakes. This is a low aerial view to the north-northwest of the ground shown in the upper part of Plate X. (Scale, 2,850 feet from left to right across centre of plate).

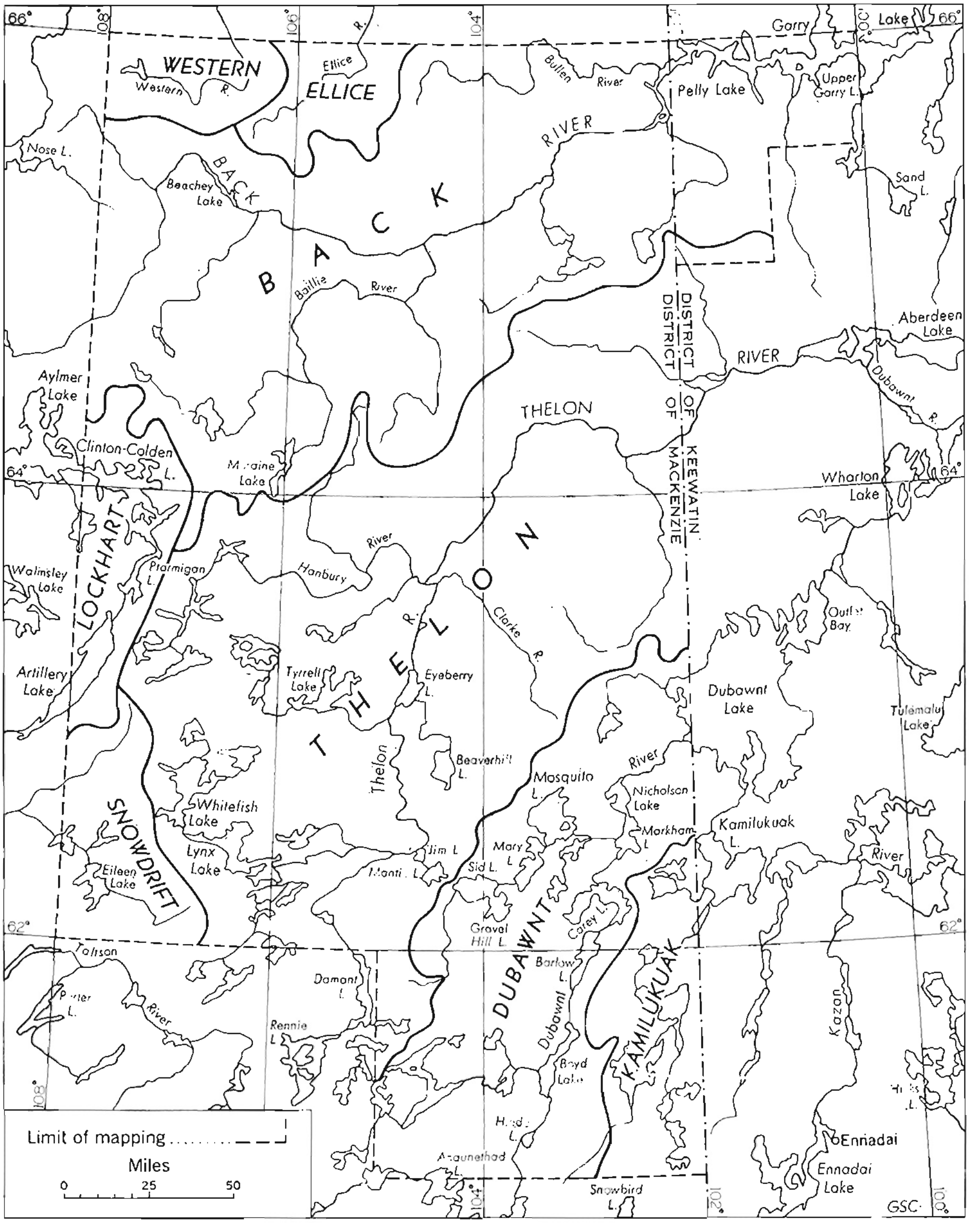


FIGURE 3. Drainage basins, east-central District of Mackenzie.

descriptions of this lake were by Bird (1953b) and Fyles (*in* Wright, 1955, p. 3), based on observations made largely east of the present map-area. Another large proglacial lake lay in the basin now occupied in part by Dubawnt Lake, although most of it was east of the present map-area. This lake has been described by Tyrrell (1898, p. 190F) who named it Hyper-Doobaunt Lake, and discussed by Fyles (*in* Wright, 1955, p. 3). The upper part of the Dubawnt basin near the southern limit of the map-area was also the site of a glacial lake. Sparse evidence indicates that one of some magnitude existed in the Lockhart basin near Artillery and Clinton-Colden Lakes and possibly a small one in the Back River basin.

## Glacial Lake Thelon

During the retreat of the ice-margin the eastern part of the Thelon basin was covered by the glacier while the western part was ice-free. The eastward-flowing Thelon River was dammed and a proglacial lake was formed. Several stages of this lake can be recognized and related to the relative time of retreat of different parts of the ice-front and to uncovering of successively lower outlets for the impounded water. At an early stage the lake was a body of water 25 to 35 miles wide along the Thelon River from near Jim Lake to the mouths of Hanbury and Clarke Rivers. With further retreat of the ice to the south and east the lake spread across the divide into that part of the Dubawnt basin now occupied in part by Sid, Gravel Hill, Mary, Mosquito, Ecklund, and Oman Lakes, and possibly into Carey Lake and upstream along the valley of Dubawnt River. Still later the lake expanded to the north and east along the valley of Thelon River from near Eyeberry Lake to the east side of the map-area.

The highest beaches formed by glacial Lake Thelon are west of the north-flowing part of the river. Near Cruikshank and Radford Lakes and the western part of Tyrrell Lake beaches were measured up to 1,250 feet above sea-level. East of these localities the maximum elevations of the beaches are lower and between Sid Lake and latitude 64° along Thelon River the highest beaches are at about 1,150 feet above sea-level. Just downstream from this point the elevation of the highest beaches drops sharply to about 800 feet above sea-level, and apparently decreases gradually eastward along the valley to about 700 feet above sea-level at the east side of the map-area.

The drainage routes of the early stages of glacial Lake Thelon are not obvious. It is not likely that the impounded water flowed westward over the divides into the Lockhart and Snowdrift basins, as any isostatic depression to the east would further increase the effectiveness of the divides. If, however, westward drainage had occurred, evidence of it should be apparent between Sandy Lake and the north-western arm of Whitefish Lake (elevations 1,165.4 feet and 1,165.8 feet above sea-level, respectively; unpubl. data, Topographical Survey) and at Hanbury Portage between Deville Lake and Ptarmigan Lake (elevations 1,196 feet and 1,199 feet above sea-level, respectively). The valley between Sandy Lake and Whitefish Lake is plugged by an esker that shows no indication of erosion. The divide at Hanbury

Portage lies along a drumlin only a few hundred feet wide and yet there is no indication of stream flow between Deville and Ptarmigan Lakes.

During the initial stages of the 1,150-foot level the ice-front is presumed to have stood along Hanbury and Clarke Rivers. At this time Lake Thelon probably extended far to the south and across the divide into part of the Dubawnt basin. No outlet for this stage has yet been found, but as the impounded water was held up by ice to the east and north and by high land to the west drainage could only have been southward. Later, the water probably escaped northward into the Back River basin through the complicated series of channels north and west of latitude 64°, longitude 104°.

The 800- to 700-foot phase of glacial Lake Thelon probably drained northward into the Back River basin. Three possible outlets are apparent: through the elongate lake at latitude 64°30′, longitude 103°53′; through the abandoned channel at latitude 64°35′, longitude 103°14′; and through the channel at latitude 64°37′, longitude 102°37′. It is not likely that all three were in use simultaneously, although the eastern two are tributary to a common channel.

## Hyper-Dubawnt Lake

A few small beaches occur on some of the hills west of Dubawnt Lake between latitudes 62°50′ and 63°10′ and for about 8 miles inland. These probably formed during a stage of Hyper-Dubawnt Lake, although there seems to be more evidence of its existence north and east of the present Dubawnt Lake (Fyles, pers. comm.). Lee (1959) made no mention of it south of Dubawnt Lake. Fyles (*in* Wright, 1955, p. 3) reported beaches up to 900 feet above sea-level just east of the map-area. The beach at latitude 63°02′, longitude 102°15′ was determined photogrammetrically to be 830 feet above sea-level, but it is probably not the highest beach in the area. The regimen of this glacial lake was controlled by events that occurred east of the map-area.

Near Boyd Lake and for a few miles to the west a series of altimeter measurements on small beach remnants indicated the former existence of a lake at about 1,275 feet above sea-level. Evidence is too fragmentary to outline this lake, but it seems most likely that water was impounded in this part of the Dubawnt basin by ice to the east and that the lake level dropped lower and lower as the ice receded, until the lake eventually became part of glacial Lake Thelon.

## Lockhart Basin

Well-defined beaches developed on an esker are found at Twin Buttes on the east side of Artillery Lake at latitude 63°08′, longitude 107°45′ (*see* Pl. XII). The highest beach is about 90 feet above the present water level and 1,267 feet above sea-level, as measured photogrammetrically. This is the only locality around Artillery Lake showing evidence of higher water levels but elsewhere in the Lockhart basin, mainly around Clinton-Colden Lake, beaches were measured by altimeter up to 100 feet above the lake or 1,300 feet above sea-level. Most of these strand

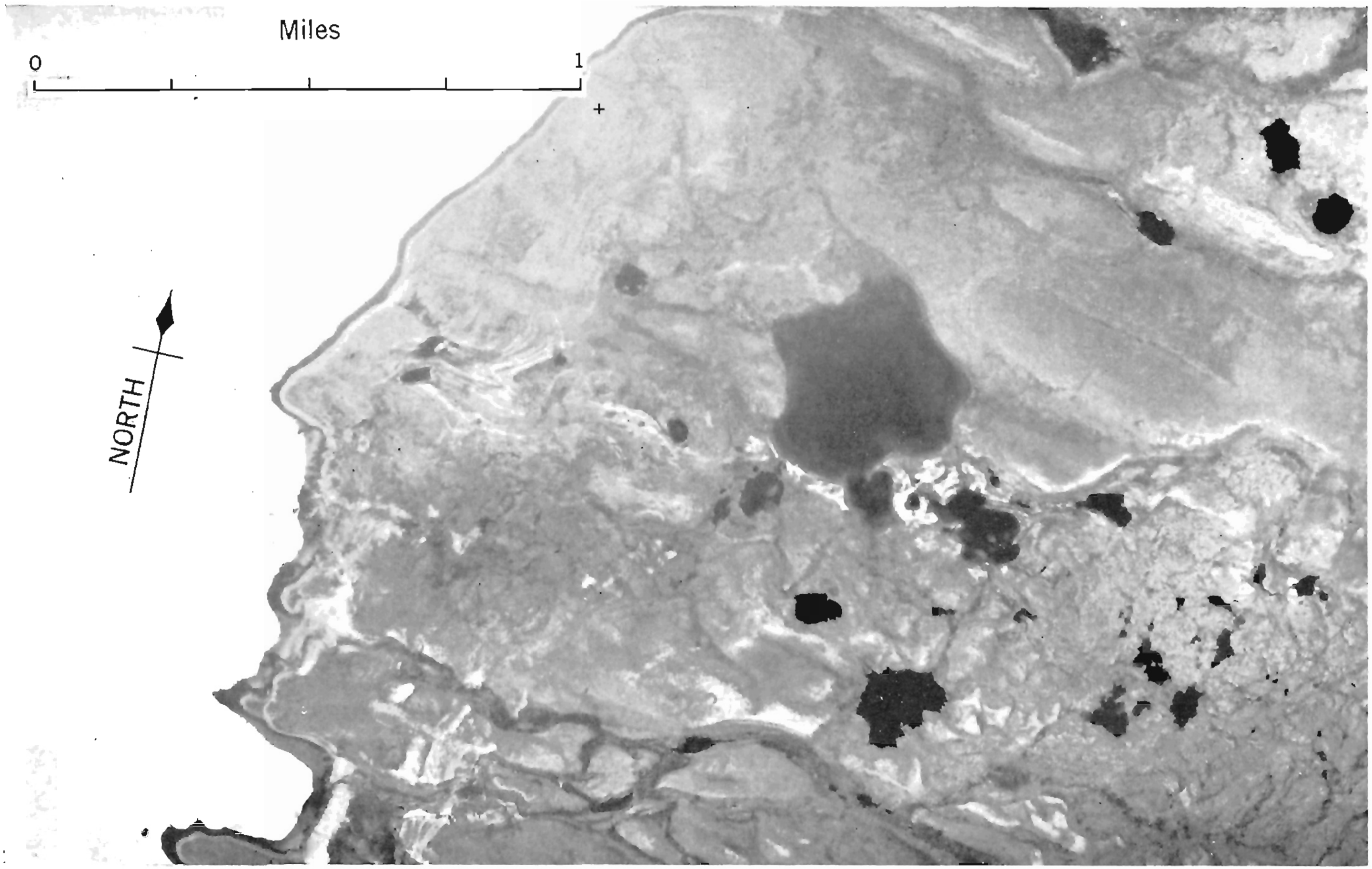


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PLATE XII. Lake beaches developed on esker at Twin Buttes, Artillery Lake. Esker scour channel in lower right.

lines occur as concentric rings around high parts of eskers and none is continuous for any great distance. They may not have been formed by a single water body although there is a general accordance of level at four localities within the basin. Since drainage of this basin is to the west it is possible that shortly after the retreat of the glacial margin residual isostatic depression was about 100 feet greater in the eastern part of the area of the lake than it was on its western edge. As beaches are found only in very favourable localities, the lake was probably short-lived.

## Back River Basin

There is sparse evidence that a glacial lake was formed or that an arm of the sea extended into the valley of Back River near Pelly and Upper Garry Lakes. Well-formed beaches are present near latitude 65°45′, longitude 101°00′, but their elevations are not known. Fyles (pers. comm.) noted patches of silt of either marine or lacustrine origin and poorly defined beaches up to about 550 feet above sea-level east of the map-area south of Macdougall Lake. Craig (1961, p. 3) stated "that an arm of the sea probably extended up the valley of the Back River" and showed a delta at 500 feet above sea-level near the mouth of Hermann River, 115 miles east of the map-area.

Farther up Back River south of Beechey Lake a small delta with a wave-cut scarp on its northern side indicates the former presence of standing water; this water was probably of limited extent and occupied this part of the valley for only a short time.

## Marine Submergence

No direct evidence of the former presence of the sea has been found within the map-area. However, submergence of 613 feet above present sea-level has been recorded east of the map-area at Chesterfield Inlet (Lee, 1959, p. 17), about 550 feet above sea-level northeast of the map-area south of Queen Maud Gulf (Craig, 1961, pp. 3-4), and 725 feet above sea-level northwest of the map-area at Bathurst Inlet (Bird, 1955a). On the basis of these figures it appears likely that an arm of the sea extended into the area along the valley of Thelon River and possibly along the valleys of Western and Back Rivers.

Fyles (*in* Wright, 1955, p. 4) reported that evidence of the highest stand of the sea at Baker Lake is at an elevation of about 430 feet. He also reported the occurrence of marine shells at an elevation of 360 feet near Beverly Lake, only 50 miles east of the map-area. However, as the highest occurrences of marine shells in coastal parts of the surrounding area are characteristically some tens of feet below the limit of marine submergence (Bird, 1955a, p. 9; Craig, 1960, p. 4) the sea probably stood higher near Beverly Lake than is indicated. Although the amount of post-glacial rebound was about the same throughout the area, rebound was not contemporaneous but took place progressively from west to east. Hence, a plane representing the upper limit of the arm of the sea west of Baker Lake would now be tilted down to the west, and any shoreline features formed at that time would now be found at successively lower elevations towards the west. Thelon River at the eastern boundary of the map-area is 330 feet above sea-level (unpubl. data, Topographical Survey) and increases to 400 feet above sea-level at longitude 103°08′. It seems probable that the sea extended westward to about this vicinity as a narrow arm or estuary.

On the west side of Western River, near the northern boundary of the map-area, a small delta indicates the presence of standing water during the time of its deposition. Bird (1955a) has determined the marine submergence in the Bathurst Inlet area a few miles farther north as slightly more than 725 feet and has indicated that an arm of the post-glacial sea extended up the valley of Western River into the present map-area. The delta is probably of marine origin but its elevation is not known.



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# HISTORICAL GEOLOGY

## Preglacial Aspect

It is not likely that any major changes were made in the overall appearance of the map-area during the Pleistocene epoch. Concerning northern Canada, Bird (1959, p. 152) stated "The major landforms already existed by the early Pleistocene and were in most areas developed during the Tertiary." All evidence of preglacial soil development has been removed. It has been suggested (op. cit., p. 157) that many of the boulder fields are products of interglacial weathering that were moved only slightly by the ice-sheet. Within the map-area, these boulder fields contain glacial erratics, however, and many are parts of constructional glacial landforms and the boulders cannot be distinguished from those produced by normal glacial erosion.

The Back and Dubawnt Rivers and the eastern part of Thelon River are flowing in old, possibly preglacial, valleys which in some places were of sufficient size to influence the direction of flow of the glaciers. The northward-flowing part of Thelon River above the confluence of Hanbury River lies, for the most part, within a young valley characterized by steep rock-walled canyons. The upper part flows mostly in a valley with an old aspect that, prior to glaciation, may have carried water eastward at Jim Lake through Mantic and Sid Lakes into the present Dubawnt system.

## Glacial History

### Multiple Glaciation

Stratigraphic evidence indicates only one glaciation. The oldest glacial features recognized are isolated south-trending striae in the southern part of the area. These striae do not conform to the general pattern of ice-flow features and must date from an early phase of the last glaciation or from a separate earlier glacial invasion. Tyrrell (1898) recorded striae trending in this direction along Dubawnt River and the west side of Dubawnt Lake within the map-area and Lee (*in* Lord, 1953) and Fyles (*in* Wright, 1955) have also observed striae with this orientation east and south of Dubawnt Lake. Concerning the general direction of striae in the area Tyrrell (1898, p. 177F) stated:

> . . . most of the glacial striae between Lake Athabasca and Doobaunt Lake point in a west-southwesterly, or westerly direction, but on Doobaunt Lake, and on the upper portion of the Telzoa [Dubawnt] River, there is an earlier set pointing southward.

Lee and Fyles also indicate that these southward-oriented striae are earlier than most of those recorded nearby. No other evidence of this earlier glaciation has been found, and the significance of these striae is largely conjectural.

## Pattern of Deglaciation

The regional ice-flow pattern is radial around a long narrow zone called the Keewatin ice-divide (Lee, Craig, and Fyles, 1957; Craig and Fyles, 1960, Fig. 4), which lies between the map-area and Hudson Bay. This pattern has been interpreted to record successive near-marginal directions of ice-movement as the ice retreated from its position at the climax of glaciation until it existed as a final remnant along the divide. Within the map-area ice-flow directions are northwest in the northwestern part, west in the western part, and southwest in the southwestern and southern parts (*see* Figs. 4 and 10). The ice is believed to have shrunk from northwest to southeast, west to east, and southwest to northeast across the area. This sequence is supported by lake levels and misfit river channels.

The distribution of surficial features shows a distinct discontinuity of flow characteristics along a line northwest from Dubawnt Lake (Fig. 4). Several lines of evidence indicate that the area south of this discontinuity became ice-free before that to the north, and also that the manner of retreat was not the same in the two areas. The flow features in a zone 40 to 50 miles wide north of the discontinuity show the ideal pattern of lines of flow in the lateral marginal part of a glacier lobe, whereas similar features south of this zone show a more or less straight line pattern expected in the interior part of an ice lobe. This suggests that lateral ice-flow could not take place south of the discontinuity because of the presence of glacier ice to the north. The ice-margin south of the discontinuity was probably straight or only gently curved, whereas north of the discontinuity it was very markedly curved. Evidence that the ice south of the discontinuity retreated in advance of that to the north is furnished by the relationship of glacial Lake Thelon to the ice-margin when the lake stood at the 1,150-foot level. At that time the impounded water extended well into the area south of the discontinuity but was dammed by ice across the valley of Thelon River north of the discontinuity at about latitude 64 degrees. Overridden eskers near latitude 64°00′ to 64°30′, longitude 105°00′ may have been formed originally by northward- to northwestward-flowing ice and then drumlinized by a change in the flow direction as the ice-mass in the area took on the lobate character of the ice north of the discontinuity. Lee (*in* Lord, 1953, Fig. 1) and Fyles (*in* Wright, 1955, Fig. 1) show the eastward continuation of the discontinuity and, based on observations of intersecting striae, confirm the age relationship outlined above.

Craig and Fyles (1960) extend the discontinuity to the northwest to about the 127th meridian, near the western limit of the area covered by the Wisconsin Laurentide ice-sheet. In a general way, the split into two lobes was caused initially by the emergence of high land above the lowering ice surface while the thinning ice continued to flow along either side, and later by accelerated flow into the glacial lake in the Great Bear-Great Slave Lakes basin on the south and into the sea on the north. Within the map-area, especially in the western part, the land south of the discontinuity is generally higher by 400 to 500 feet than that to the north. During deglaciation the ice over the lower ground to the north probably was still thick and actively flowing after the ice over the higher ground to the south had become thin



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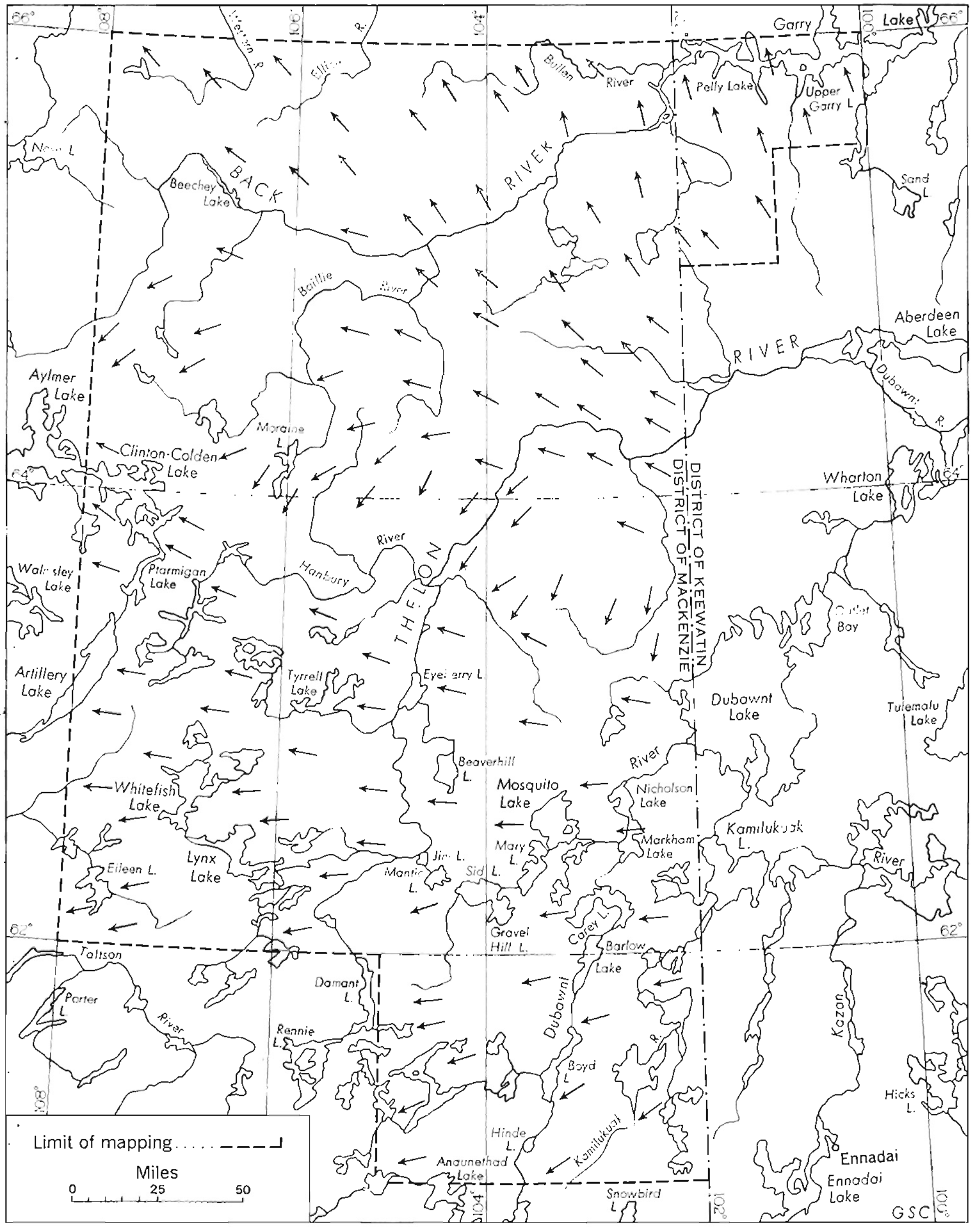


FIGURE 4. Generalized direction of glacial flow features, east-central District of Mackenzie.

and stagnant. The actively flowing northern lobe may have been further accelerated by the funneling effect of the deep channel through Bathurst Inlet and beyond, and by rapid melting of the north edge of the glacier where it bordered on a large marine embayment south of Queen Maud Gulf (*see* Craig, 1961; or Glacial Map of Canada).

Figures 5 to 9 show approximately the gross shape and position of the ice-margin at various times during the period of retreat and its relationship to the various glacial lakes. The lines depicting the positions of the ice-margin are based on two assumptions: first, the ice-flow features were formed close to the margin and show the direction of last movement there, and second, the ice-front everywhere was at right angles to adjacent flow lines. The ice-marginal positions shown in Figures 5 to 9 were chosen because they pass through localities where the relationship between the ice-margin and some significant event in the ice retreat is known. At some such localities elongate zones of outwash, commonly with steep ice-contact faces, trend at right angles to the direction of ice-flow, at others ice-dams must have existed in order to cause glacial lakes to be formed at the various levels that have been determined. Although the zones of outwash require a pause in the retreat of the glacier for a short period of time, the ice-fronts recorded in the diagrams generally are arbitrarily chosen positions of the glacial margin during regular retreat. Correlation of the ice-frontal position north and south of the discontinuity is partly conjectural as fewer flow features are present along this zone. However, near latitude 63°50′, longitude 105°00′ ice-contact deposits and outwash appear to mark one position of the re-entrant (*see* Pl. XIII). At this locality two steep, in places slumped, ice-contact slopes meet at a right angle and face to the northeast and southeast. In addition, eskers lead directly into this outwash complex from the north and the south and appear to have been formed on either side of the discontinuity.

The first part of the map-area to become ice-free and also the site of a glacial lake was that part of the Lockhart basin that now contains Artillery, Ptarmigan, and Clinton-Colden Lakes (*see* Fig. 5). Further retreat of the ice with the resultant uplift of the land to the east caused the lake to drain. When the ice-margin had retreated eastward across the Lockhart-Thelon divide proglacial lakes formed in the valleys of the eastward-flowing streams (*see* Fig. 6). Such lakes may have been isolated water bodies in each of the valleys or may have been continuous along the ice-front. A lake in the southern part of the map-area at about latitude 61°30′, longitude 105°00′ probably originated about that time; no elevation data are available. As the land north of the discontinuity became ice-free, small short-lived proglacial lakes formed in the valleys of Back River and its tributaries to produce the beaches found around Beechey and Tourgis Lakes. The sea probably entered the northern part of the map-area along Western River at that time.

A pause in the retreat of the ice-margin north of the discontinuity seems to be marked by the outwash north of Pelly and Upper Garry Lakes and north of Hanbury and Clarke Rivers. No similar frontal position is apparent for most of the area south of the discontinuity and considerable marginal retreat probably took place there during this time. Glacial Lake Thelon occupied much of the northerly oriented part of the valley, and as the ice withdrew this lake extended southeastward

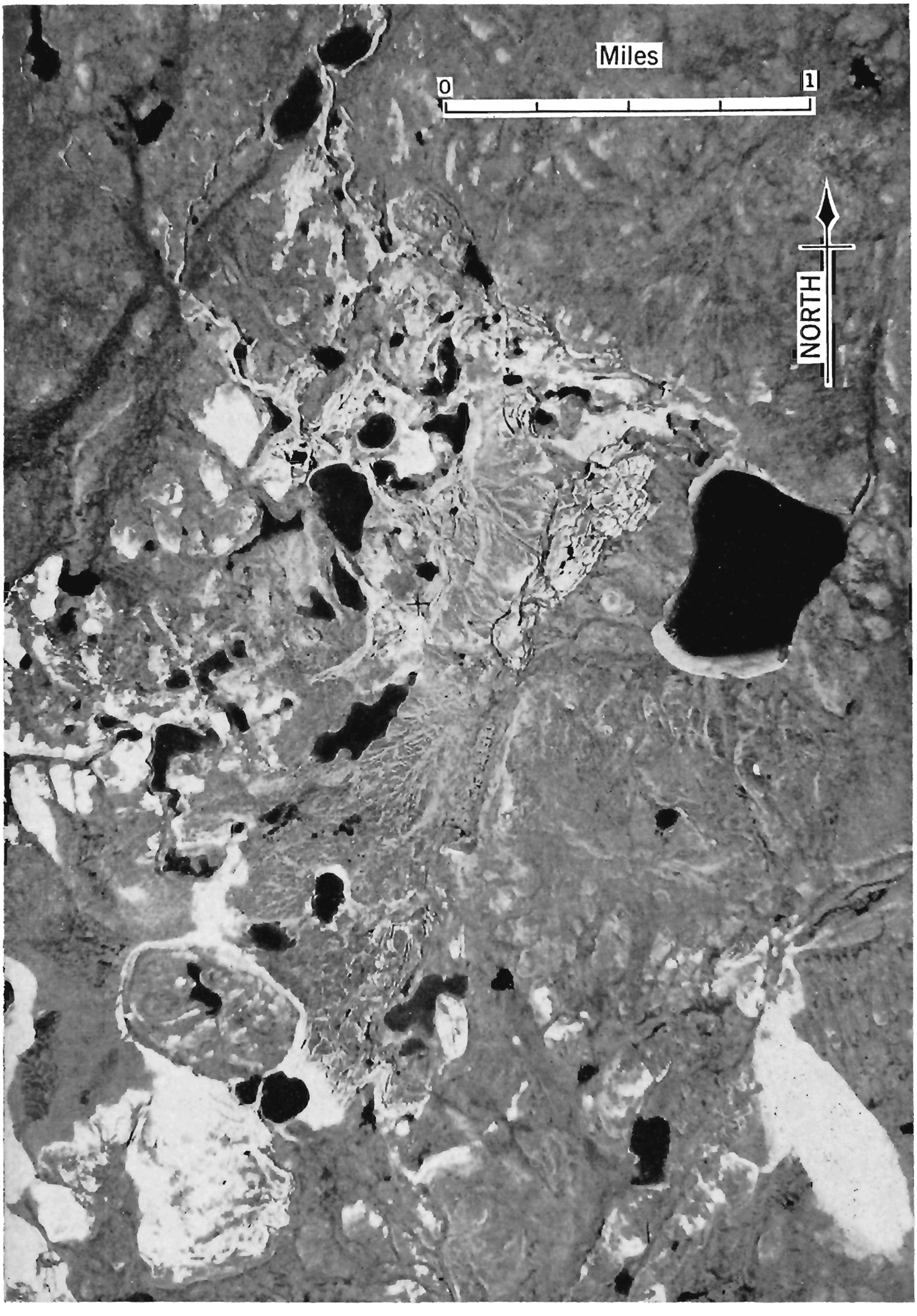


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PLATE XIII. Braided and pitted outwash, 8 miles northwest of Sandy Lake. Slumped ice-contact faces run diagonally to the south-southwest and to the northwest from the lake at east-central side of photograph.

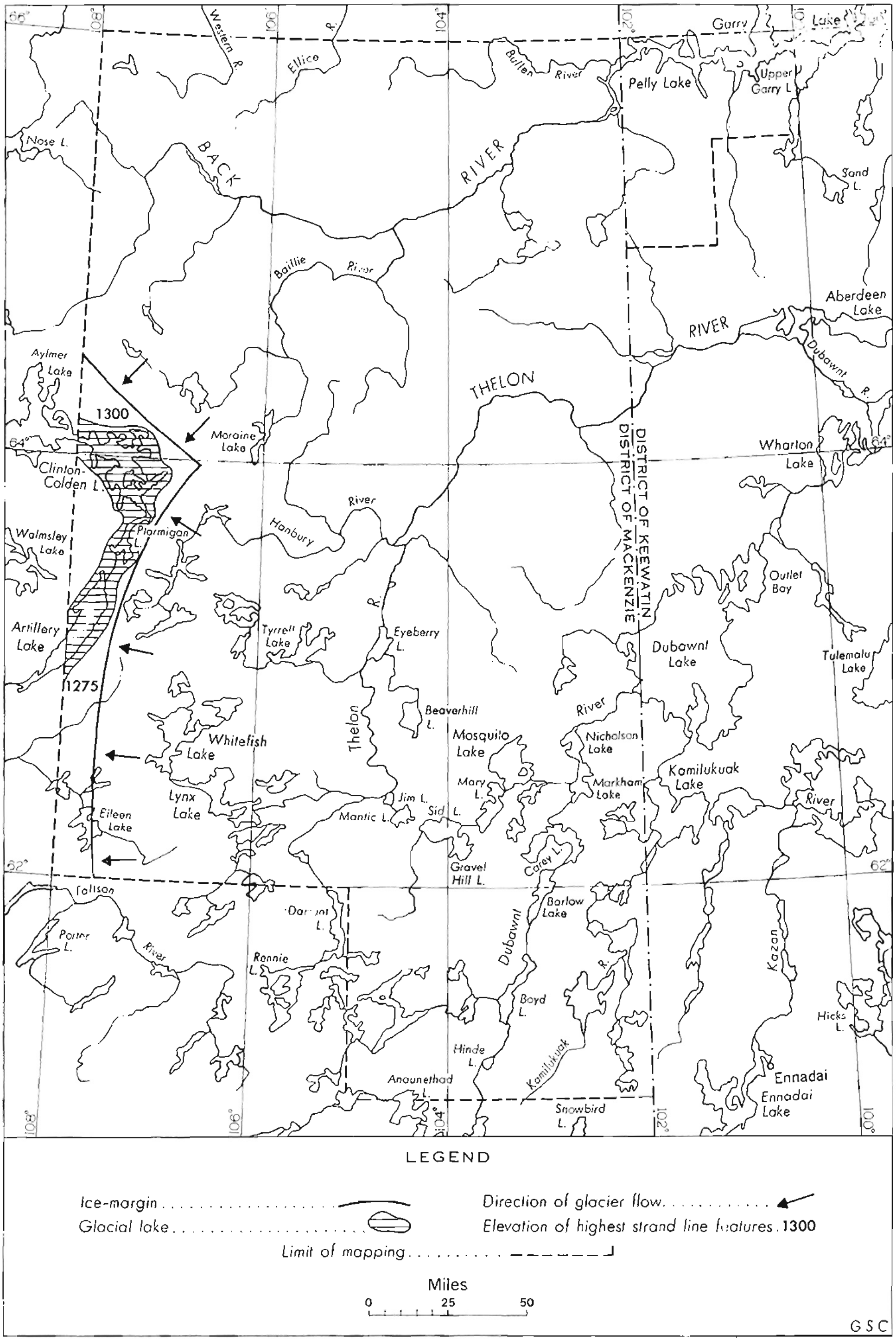


**FIGURE 5. Deglaciation of east-central District of Mackenzie (number 1).**

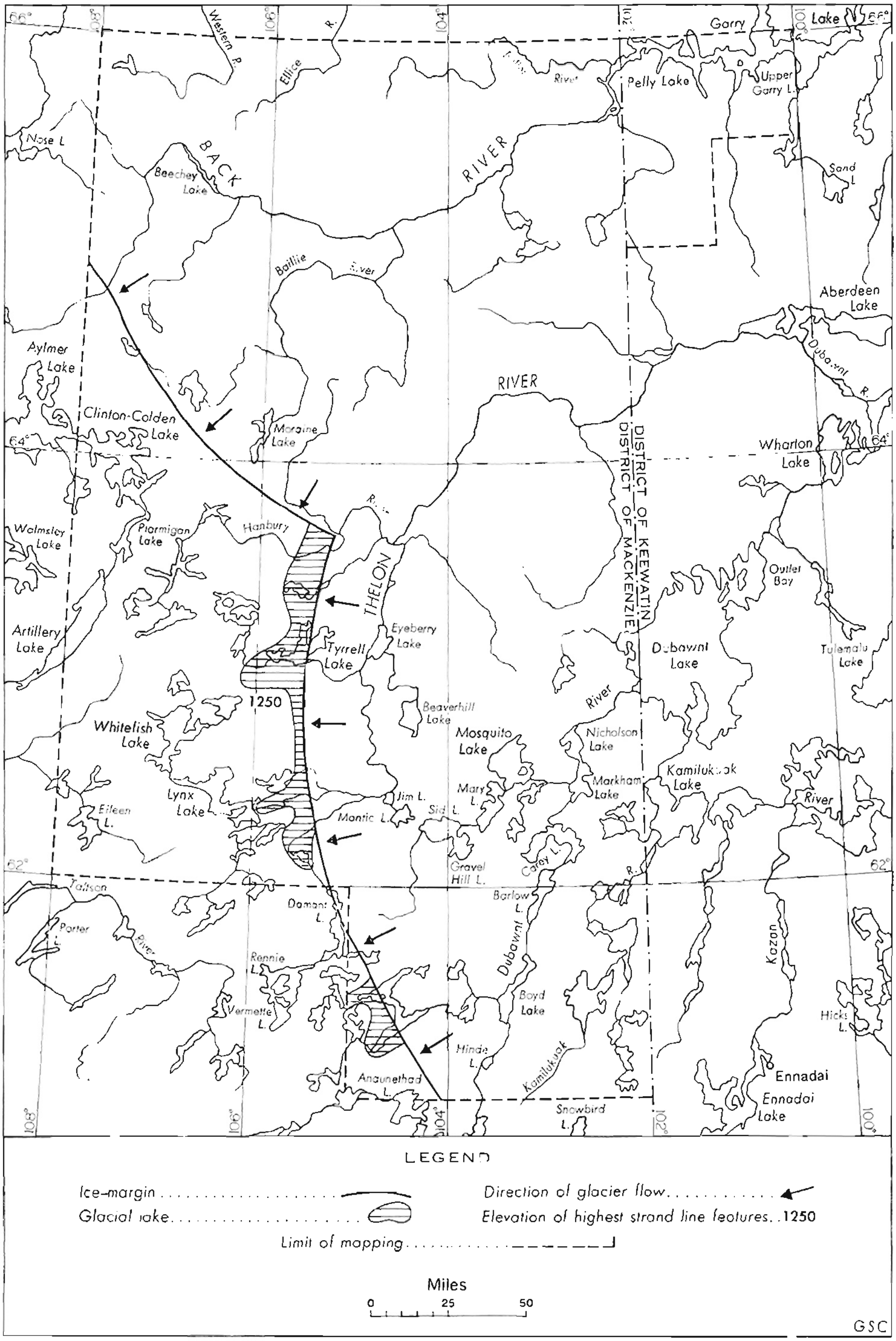


FIGURE 6. Deglaciation (number 2).

into the area now occupied by Sid and Gravel Hill Lakes (*see* Fig. 7). Although evidence of this lake could not be distinguished from that of the next stage it probably stood slightly higher than 1,150 feet above sea-level. In the southern part of the Dubawnt basin south and west of the lower part of Boyd Lake beaches indicate the presence of a former lake at about 1,350 to 1,400 feet above sea-level.

Another pause in the retreat of the ice-margin north of the discontinuity (at about the position shown in Figure 8) is indicated by the abandoned channels in the central part of the map-area. The intricate network of these channels suggests that the history of marginal retreat was more complicated than is shown in the figure. At this stage the level of the northern lake is represented by beaches at about 1,150 feet above sea-level that are widespread from this region southward and eastward as far as Mary Lake. A lake standing about 1,250 feet above sea-level occupied the upper part of the Dubawnt valley and the western part of the Carey Lake basin when the ice-margin passed through Carey Lake. When the ice had retreated to the eastern end of Carey Lake the southern and northern lakes apparently became interconnected and stood at an elevation of about 1,100 feet. Somewhat later, probably as a result of uncovering of a lower outlet, the lake level dropped to an elevation of 1,050 feet, as recorded by beaches around Mosquito Lake.

Figure 9 shows the position of the ice-margin during the last stages of recession from the map-area. At this time Hyper-Dubawnt Lake, which lay largely east of the map-area, stood at an elevation of 900 feet. More than one phase of the lake levels along the valley of Thelon River may be represented in Figure 9. Three possible outlets northward to Back River are indicated. It is improbable that they were all in use at the same time; more probably they were abandoned successively as the ice-margin retreated eastward. Lower stages of glacial Lake Thelon were present in the map-area until the valley became ice-free in the area of the Keewatin ice-divide. At that time marine water probably extended 30 to 40 miles up the valley from the east side of the map-area. As isostatic readjustment continued this embayment was drained and the modern drainage became operative.

## Time of Deglaciation

Only one radiocarbon date that bears on the glacial history has been recorded within the map-area. This date (L-428, 5,500 ± 250 years) was obtained on organic material from a pingo on the floor of the Thelon Valley at latitude 64°19′, longitude 102°41′ and has been discussed elsewhere (Terasmae and Craig, 1958; Craig, 1959). This material is interbedded with silt and appears to have accumulated in a shallow pond in the flood plain of Thelon River. The site is 35 feet above the present flood plain of the river. The organic material and enclosing sediments probably were deposited during an early stage of the river and indicate that the site was ice-free and that glacial Lake Thelon had drained more than 5,500 years ago. The marine embayment may have extended up to or slightly west of this vicinity but it, too, would have lowered sufficiently to allow the river to flow

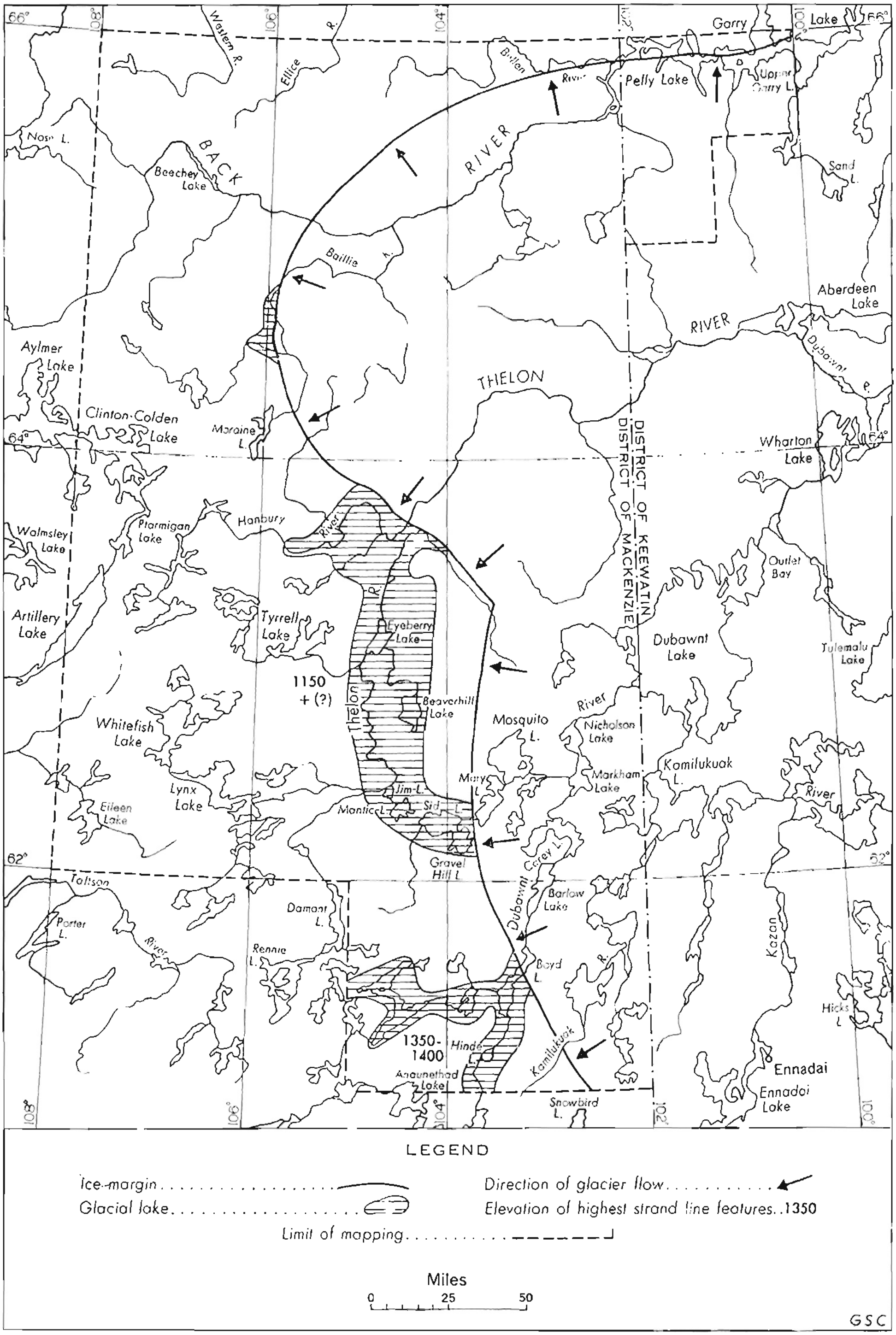


FIGURE 7. Deglaciation (number 3).

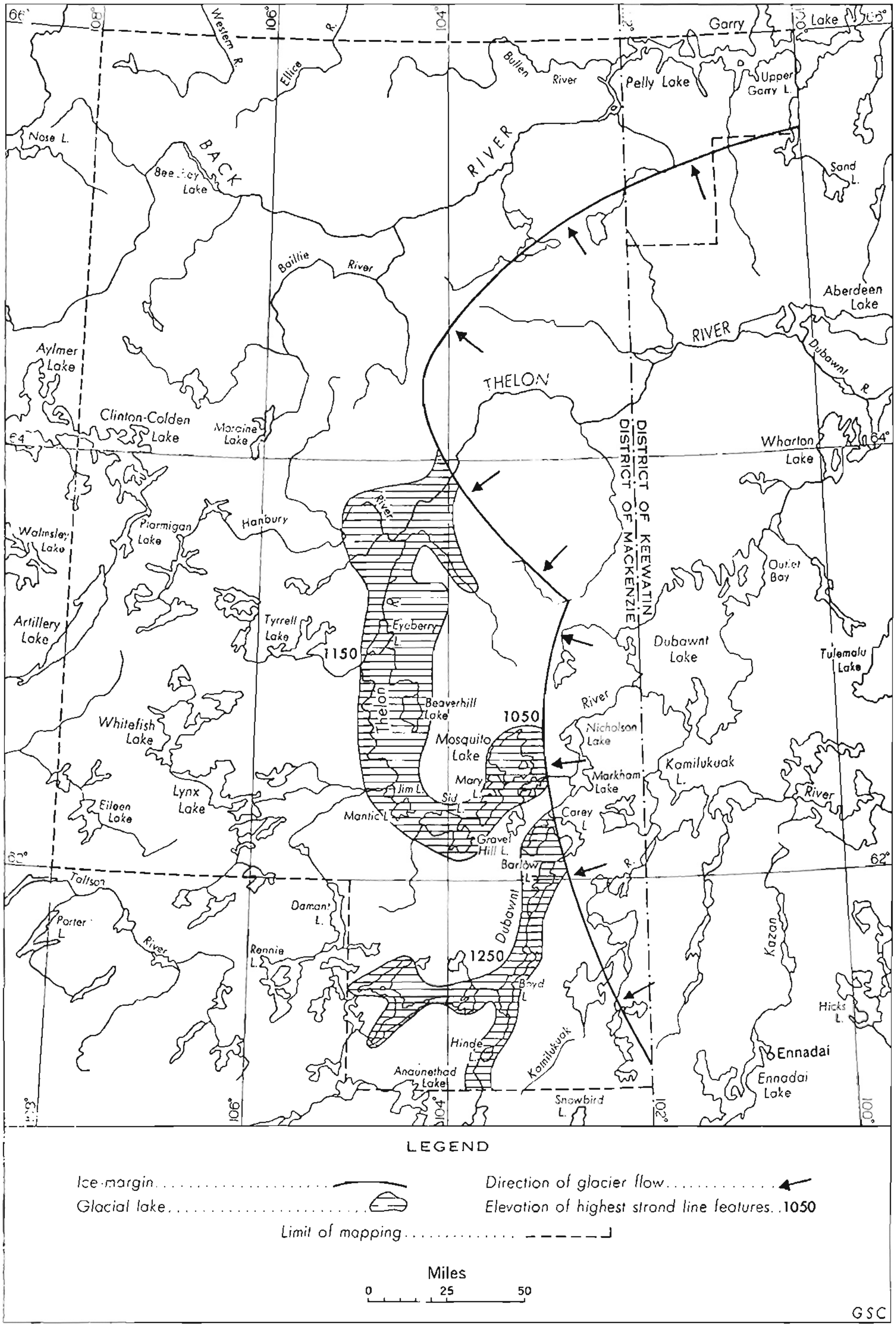


**FIGURE 8. Deglaciation (number 4).**

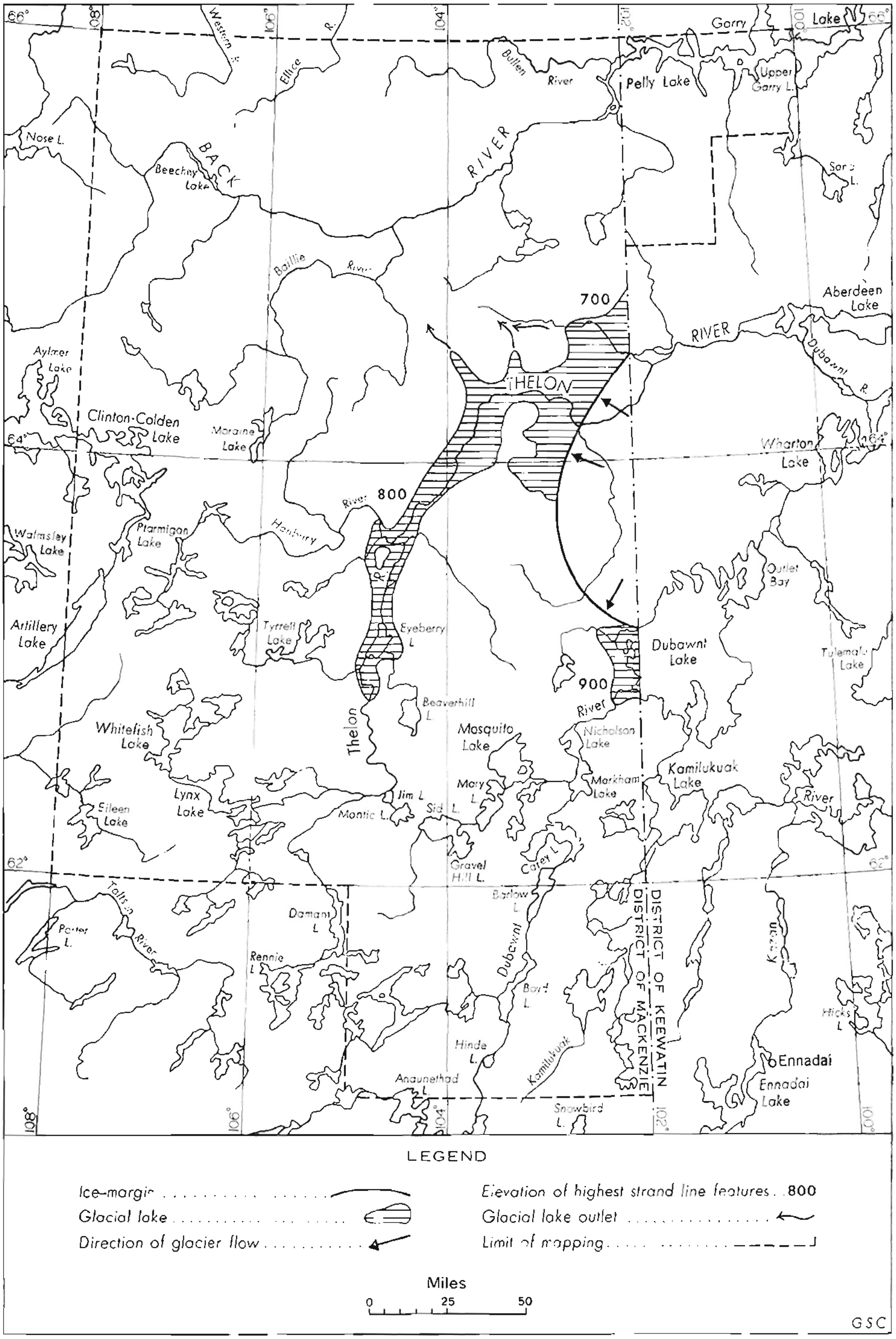


FIGURE 9. Deglaciation (number 5).

normally before the deposition of the material composing the pingo took place. Radiocarbon dates on samples outside the map-area indicate that final disappearance of the ice at the Keewatin ice-divide was as much as 7,000 years ago (Craig and Fyles, 1960, pp. 10-11).

On the basis of the stratigraphic relationships of sediments at two localities east of the map-area and the radiocarbon ages of organic material contained in them, Flint (1956, pp. 280-281) has suggested that a resurgence of glacial flow took place about 4,000 years ago. The writer (1959, p. 510) has concluded, however, that such a resurgence is most unlikely, because any glacial movement that post-dated the deposition of the sediments in the pingo and advanced over the sites discussed by Flint "would almost certainly have dammed the Thelon Valley, flooding the pingo site and probably overriding the area. There is no evidence of such glacial action or lake expansion."

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