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DEPARTMENT OF MINES AND TECHNICAL SURVEYS

BULLETIN 122

GLACIAL LAKE McCONNELL, AND THE SURFICIAL GEOLOGY OF PARTS OF SLAVE RIVER AND REDSTONE RIVER MAP-AREAS, DISTRICT OF MACKENZIE

B. G. Craig

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PREFACE

Since 1890 features suggesting the former presence of glacial lakes in southwest District of Mackenzie have been noted by geologists. The author has pieced together various bits of information scattered through the literature and supplemented them with his own observations made during a recent helicopter-supported reconnaissance over much of the region. A vast glacial lake thus outlined has been named Glacial Lake McConnell in honour of the first geologist to suggest the presence of glacial lakes in the region.

The events during the period of glaciation, particularly during the retreat of the ice, are discussed at some length.

J. M. HARRISON,

Director, Geological Survey of Canada

OTTAWA, March 29, 1963

Bulletin 122—Der McConnell-Glazialsee und die Oberflächengeologie von Teilen der Gebiete der Kartenblätter Slave River und Redstone River im Mackenzie-Distrikt. Von B. G. Craig.

Bringt neues Beweismaterial für die Existenz eines großen Glazialsees in der Nähe des Großen Sklavensees.

Бюллетень 122 — Ледниковое озеро МакКоннель и геология поверхности частей листов Невольничье реки и реки Рэд-Стоун, округ Мэкензи. Б. Г. Крэйг.

Работа приводит новые доказательства наличия большого ледникового озера вблизи Большого Невольничьего Озера.

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GLACIAL LAKE McCONNELL, AND THE SURFICIAL GEOLOGY OF PARTS OF SLAVE RIVER AND REDSTONE RIVER MAP-AREAS, DISTRICT OF MACKENZIE

Abstract

The area was completely glaciated by the Wisconsin Laurentide ice-sheet, which extended westward into Mackenzie Mountains. There is no evidence that Cordilleran ice entered the area from the west.

A vast glacial lake, Glacial Lake McConnell, which extended from Great Bear Lake through Great Slave Lake to Lake Athabasca, was formed during deglaciation as a result of differential isostatic depression towards the east. This lake originated as three separate lakes in the three basins but became one vast lake as the topographic low between Great Bear Lake and the northwest arm of Great Slave Lake, and the Slave River Lowland became ice-free. Elevations of lacustrine features that formed during the maximum stand of the lake are about 925 feet above sea-level along its eastern boundary and decrease westward. Subsequent isostatic readjustment lowered water levels until the large glacial lake separated into smaller lakes, one of which was ancestral to Great Slave Lake. The minimum amount of readjustment indicated in this basin is slightly over 2 feet per mile.

During the earliest phases of ice-retreat, flow was diverted to the north and south by the mountain barrier along Mackenzie and Liard Rivers. Subsequent marginal thinning and eastward retreat produced a radial pattern of flow features in the western part of the area. Stagnation on Horn Plateau while ice was flowing actively on either side of it formed two lobes in the east-central part of the map-area. During the last phases of deglaciation flow was to the southwest and the ice-margin was almost parallel with the edge of the Precambrian Shield.

Résumé

La région a été complètement recouverte par la calotte Wisconsin-Laurentide qui s'étendait vers l'Ouest jusqu'aux monts Mackenzie. Il n'y a pas d'indices que des nappes glaciaires en provenance de la Cordillère soient entrées dans la région par l'Ouest.

Une grande étendue d'eau, le lac glaciaire McConnell, qui réunissait le Grand lac de l'Ours, le Grand lac des Esclaves et le lac Athabasca, s'est constitué pendant la déglaciation à la suite d'un dénivellement isostatique vers l'Est. Il a trouvé son origine dans trois lacs séparés situés dans trois bassins

qui ont formé un seul vaste lac quand la dépression topographique réunissant le Grand lac de l'Ours, le bras Nord-Ouest du Grand lac des Esclaves et les basses terres de la rivière des Esclaves s'est libérée de la glace. Les formes lacustres, constituées lorsque le lac a atteint sa grandeur maximum, se trouvent à une hauteur d'environ 925 pieds au-dessus du niveau de la mer le long de sa limite orientale, mais décroissent en allant vers l'Ouest. La compensation isostatique ultérieure a abaissé le niveau de l'eau jusqu'au moment où le grand lac glaciaire s'est divisé en lacs plus petits, dont l'un est l'ancêtre du Grand lac des Esclaves. Ce bassin a subi une compensation isostatique minimum d'un peu plus de deux pieds par mille.

Pendant les premières phases du retrait des glaciers, la montagne, le long du fleuve Mackenzie et de la rivière Liard, a détourné la glace vers le Nord et vers le Sud. L'amincissement ultérieur des rebords de la calotte et sa retraite vers l'Est a produit un réseau radial d'écoulement glaciaire dans la partie occidentale de la région. La stagnation de la glace sur le plateau Horne, alors qu'elle s'écoulait librement de chaque côté, a amené la formation de deux lobes dans la partie Est du centre de la région à l'étude. Pendant la dernière phase de la déglaciation les glaciers coulaient vers le sud-ouest et le front de la calotte était presque parallèle au rebord du Bouclier précambrien.

INTRODUCTION

Location of Area and Accessibility

The map-area lies in southwest District of Mackenzie except for a small part in the extreme southwest corner, which is in Yukon Territory. It is bounded on the east by the Precambrian Shield, on the west by longitude 124 degrees, on the south by latitude 60 degrees, and on the north by latitude 64 degrees.

The area can be reached by road along the Mackenzie Highway as far as Hay River settlement. A road that was under construction during 1957 from about mile 31 south of Hay River northwestward to Mackenzie River just east of Fort Providence has since been completed from that point northeastward to Frank Channel, south of Fort Rae, and thence to Yellowknife. Winter tractor roads connect most of the settlements. Commercial airlines have scheduled flights to Fort Smith, Hay River, and Fort Simpson and occasional flights to Fort Providence and Wrigley. Charter aircraft may be obtained in Hay River and Yellowknife. Slave River, Great Slave Lake, Mackenzie, and Liard Rivers provide routes for large-scale water transport, as well as a canoe route. The lower parts of streams tributary to this system are navigable during early spring but in general contain many rapids and falls.

Major settlements are Fort Smith, Hay River, and Fort Simpson. Trading posts, generally with a Hudson Bay Company store, an RCMP detachment, and a mission, are at Fort Resolution, Fort Rae, Fort Providence, Fort Liard, and Wrigley. Indian villages are numerous along the major water routes.

Previous Work

Most geological reports of work done in the map-area contain data on the abundant glacial and postglacial features. The earliest report that draws any conclusions concerning the glacial history is by McConnell (1890). Field observations have been reported by Bell (1900), Hume (1921), Camsell and Malcolm (1921), Williams (1922), Whittaker (1922, 1923), and Cameron (1922a). Cameron (1922b) first suggested a pattern of retreat for the Laurentide ice-sheet in this map-area and the region to the south, and related the history of the glacial lakes to the retreating ice. Raup (1946, 1947) has summarized information from the foregoing reports and extended Cameron's interpretations on the basis of his own field observations. Hage (1945) discussed certain features of the glacial deposits near Liard and Petitot Rivers. Preliminary accounts of the bedrock geology of the area are given by Douglas (1959a), Douglas and Norris, D.K. (1959), Douglas and Norris, A.W. (1960), and Douglas and Norris, D.K. (1960, 1961, 1963).

Present Work

This report embodies part of the results of the helicopter-supported Operation Mackenzie to which the writer was assigned to collect data on the surficial deposits. About two thirds of the four months of the 1957 field season was spent studying the plains part of the area on which this report is based. The organization and operational procedure of the party have been described by Douglas (1959b).

Before the 1957 field season the writer prepared an aerial photograph interpretation of as much of the Pleistocene geology as possible. Field work was designed to supplement and to check this interpretation, and data were collected in various ways. Most were obtained on helicopter traverses from each camp (*see* Douglas, 1959b, Fig. 4), both on special traverses designed primarily for studying the glacial geology and on bedrock traverses when the logistics of the helicopter allowed for two passengers. From the first camp, situated on the Mackenzie Highway, truck traverses were made from the south boundary of the map-area to Hay River, and west from the highway towards Fort Providence as far as Kakisa River. A canoe traverse was made along Mackenzie River from Trout River to Fort Simpson, and local canoe traverses were made from each camp. Boat traverses were made from Fort Liard to Fort Simpson along Liard River, and from there to the north boundary of the map-area and beyond as far as Norman Wells. Many hours were spent in the fixed-wing aircraft on exploratory flights designed for examining features of glacial geology, on gasoline-caching flights, and on flights to the various subcamps. Although these provided few opportunities for on-the-ground observations they allowed for an excellent check of much of the air photograph compilation. Some data were collected by other members of the party during the course of bedrock mapping.

Vertical control was provided almost entirely from the 1 inch to 4 miles contoured maps. A barometric altimeter was used along roads, especially along the Mackenzie Highway where there are many bench marks. Advance and unpublished information on elevations of ground features was supplied by the Geodetic Survey, the Topographical Survey, and by the Army Survey Establishment.

Acknowledgments

The writer is indebted to J. E. Savage and G. H. Little, Engineering and Construction (formerly Trans-Canada Highway) Division, Department of Public Works, for air photo mosaics and engineering data on road locations from the Mackenzie Highway to Fort Providence and from thence to Frank Channel.

The writer was ably assisted in the field by J. B. Read.

Physical Features

The map-area lies almost entirely within the northern part of the Interior Plains. On the east it is bordered by the Precambrian Shield and on the west extends for a short distance into the Mackenzie Mountain area (*see* Bostock, 1948). This section contains part of Mackenzie Plain, parts of McConnell, Camsell, and Nahanni Ranges of Franklin Mountains, and a small part of the eastern side of Liard Plateau, including part of Liard Range.

Interior Plains

The Interior Plains, which are flat to gently rolling, are underlain mostly by a lower Palaeozoic succession that consists mainly of flat-lying to gently dipping limestone, dolomite, and shale with minor sandstone.[1] Local relief is generally due to glacial landforms. In places low sharp bedrock escarpments occur exposing Palaeozoic rocks, and low plateaux bounded by steep escarpments interrupt the monotonous landscape. These are underlain by flat-lying Cretaceous shales and minor sandstone.

Outcrops are scarce and are generally confined to the low scarps, walls of stream valleys, shores of lakes, and to sink-holes. Precambrian rocks that mark the eastern boundary of the Interior Plains, and of the map-area, are well exposed.

Elevations, except on the plateaux, range from about 600 feet along the edge of the Precambrian Shield to 2,000 feet along the mountain front.

Cameron Hills

This plateau has a steep scarp along the east side and the eastern part of the north side which rises about 1,500 feet above the surrounding plain. It has a flat top, highest along the north side where it reaches an elevation of about 2,900 feet, and slopes gently to the south and southwest to an elevation of about 2,400 feet along the south boundary of the map-area. Along the north side it flattens gradually to the west and no sharp boundary can be drawn for its western edge.

Horn Plateau

The most prominent plateau in the map-area is Horn Plateau, formerly called Horn Mountains. It is bounded by a steep scarp on the south side, by a gentle scarp on the north and northeast sides, and by a gentle slope on the west side. These scarps rise 1,500 to 1,600 feet above the surrounding plain. The highest part of the plateau (about 2,600 feet) is in the south-central section; the central part is irregularly bowl-shaped. Willow Lake, at an elevation of about 2,150 feet,

[1] For a more detailed description of the bedrock geology of the map-area *see* Douglas (1959a), Douglas and Norris, D. K. (1959), Douglas and Norris, A. W. (1960), Douglas and Norris, D. K. (1960, 1961, and 1963), and Stott (1960).

occupies the centre of the bowl and the rim rises 350 to 400 feet around it. At the east end, east of longitude 118°30′, a flat bench occurs at an elevation of 2,300 feet and another east of longitude 118°15′ at 1,800 to 1,700 feet.

Cartridge Mountain

This plateau lies south of Lac Grandin in the northeast part of the map-area. It is bounded on the south and east sides and part of the north side by a scarp but slopes gently downward to the northwest and west. The scarp rises 500 to 700 feet above the plain to the south and east. The plateau surface is gently dome-shaped, reaching a maximum elevation of 2,500 feet.

Ebbutt Hills

This plateau lies west of Horn Plateau, northwest of Fort Simpson. It consists of a low dome with a steep scarp on the east side, rising about 1,100 feet above the surrounding plain to a maximum elevation of 2,100 feet. The dome slopes gently to the west, northwest, and southwest.

Martin Hills

This plateau lies south of the Ebbutt Hills, west of Fort Simpson. It is marked by a gentle scarp on the east end about 1,500 feet high and slopes off gently to the west. Its highest point is 2,317 feet above sea-level.

Smaller unnamed plateaux, generally dome-shaped, occur within the map-area, especially in the southwest corner. These are up to 2,500 feet in elevation and rise gently about 1,000 feet above the plains surrounding them.

Mackenzie Mountain Area

This area consists of mountain ranges and plateaux separated by a system of intermontane valleys. Within the area are rocks of age and lithological type similar to those of the Interior Plains, although most of them have been folded and faulted.

Mackenzie Plain

This plain comprises the intermontane areas between the various mountain ranges. It is continuous with the Interior Plains between Camsell Bend and Willowlake River and "appears to be a strip of the Interior Plains left almost undisturbed within the Mackenzie Mountain area when the front structures emerged from the plains far out in front of the main area of deformation" (Bostock, 1948, p. 17). Elevations range from slightly less than 1,000 to 2,000 feet except along Mackenzie and Liard Rivers where elevations are only 300 to 700 feet.

Mountain Ranges

The topography of these is due largely to bedrock control and is so indicated on the map. They are generally well-defined topographic features, bounded in most places by steep scarps. Although some peaks attain elevations of as much as 5,000 feet, summit elevation generally range from 3,000 to 4,000 feet.

PLEISTOCENE GEOLOGY

Surficial Deposits

The map-area is almost entirely covered with a continuous and generally thick mantle of glacial and postglacial deposits. Subsurface data from a few wells drilled indicate drift thicknesses up to 380 feet (*see* Fig. 5). Sink-holes southeast of Buffalo Lake show drift thicknesses of 30 feet; sections along the rivers tributary to Great Slave Lake and the upper part of Mackenzie River give little indication of drift thickness. On Cameron River in Cameron Hills, at longitude 117°41′, drift 90 feet thick is exposed on the river bank but bedrock is not revealed. Near the north boundary sections as much as 150 feet high that do not reach bedrock are found along Mackenzie River.

Sub-till Stratified Deposits

Stratified material underlying deposits from the last glaciation was observed at three places. Beside Mackenzie Highway, about 23 miles south of Hay River settlement, the following section was revealed in a gravel pit (*see* Pl. I):

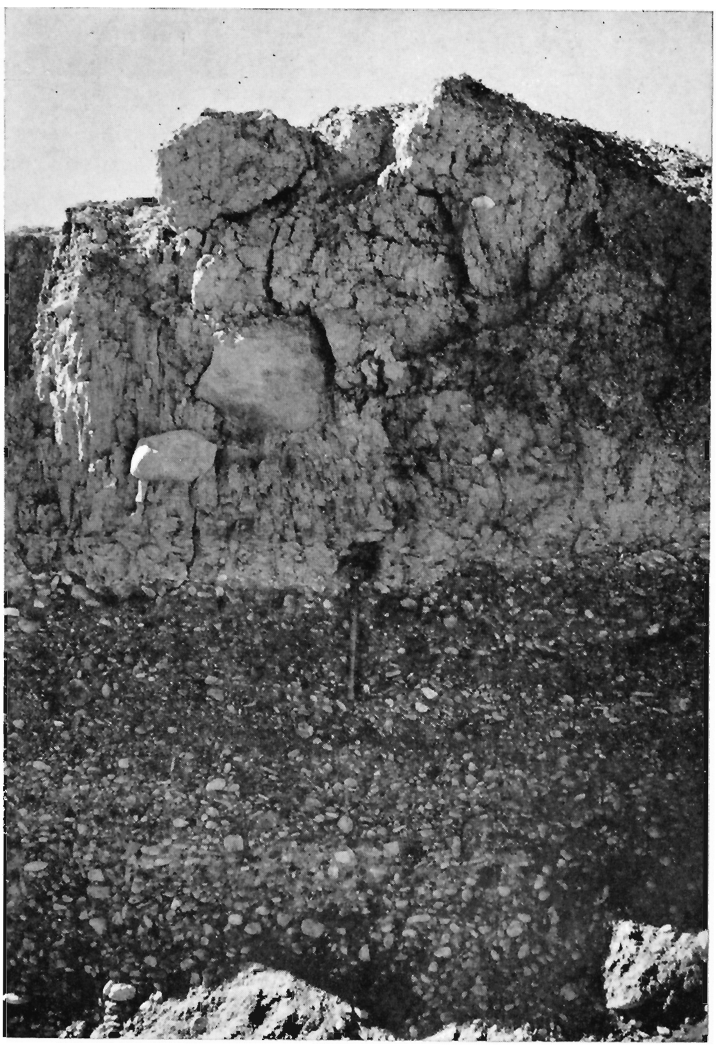
Depth (feet)	
0-5	Medium- to fine-grained alluvial sand
5-15	Light grey-brown till
15-67	Medium-grained gravel
67+	bedrock

A cutbank of Cameron River in Cameron Hills at latitude 60°15′, longitude 117°41′ reveals the following section:

Depth (feet)	
0-17	Dark grey till
17-65	Well-sorted medium-grained sand interbedded with fine gravel
65+	covered

The gravel underlying the till in both these sections contains pebbles and cobbles of granitic rocks and sandstone like the Proterozoic sandstones. It is probable that these fragments were brought from the Precambrian Shield by a glacial advance predating the last one and deposited as outwash or as alluvium by an interglacial stream. Fluvial transport from their source areas is unlikely.

Studies of late Tertiary gravels in southern Alberta and Saskatchewan (Craig, 1956), and in the Lesser Slave Lake area of Alberta (Allan, 1919, p. 12) indicate that at this time drainage across the Plains was eastward. It is probable that the ancestral Hay River had its source southwest of the map-area and did not cross areas of Precambrian rocks; furthermore the gravel in the Cameron Hills is on a plateau at an elevation (2,200 feet) far above most of the Precambrian Shield.



BGC, 2-3-57

PLATE I

Glacial till overlying horizontally bedded gravel, 23 miles south of Hay River.

Hage (1945, p. 25) noted a similar occurrence in the southwest corner of the map-area. He stated:

> Rusty river gravels containing granite pebbles were found along Petitot River 1 mile above the canyon and about 200 feet above the river. The deposit is about 50 feet thick and is overlain by till. Similar gravels were seen along Muskeg River and form a deposit in the main valley. They are probably of pre-glacial or inter-glacial origin.

The granite pebbles could only have been brought to the area by glaciation from the east so that a preglacial origin is not possible but this gravel could have had an interglacial origin similar to that of the two occurrences discussed above.

At several places along Mackenzie River, sections were observed that showed glacial till overlying flat-lying beds of sand and gravel. These sections are not continuous laterally and the stratified sediments occur within a few feet of the present level of the river. It is believed that the till was emplaced over the sand and gravel by landslides, which were observed at several places along the river (*see* Pl. II), and that the sand and gravel is relatively recent alluvium overlain by colluvial till.

BGC, 14-5-57

PLATE II. Recent landslide in bank of Mackenzie River. At this locality, which is a few miles west of the map-area, glacial till has slid over modern river alluvium.

Glacial Deposits

A mantle of glacial till is present throughout the map-area, and, even where the surface material is of some other origin, till is found at the base of many sections or overlying the bedrock. Sieve analyses of a series of 25 samples of till show an inconsistent variation; the mechanical composition seems to be more dependent on the landform from which the sample was taken than on variations in the local bedrock. In general, the till is silty to clayey in texture, stony, and grey-brown to yellow-brown.

Glacio-fluvial Deposits

Deposits of glacio-fluvial origin are uncommon. Sand and gravel, generally very bouldery, form the eskers and outwash deposits. Some bedded silt and gravel is found in end moraines, particularly in the southern part of the map-area.

Lake Deposits

Evidence of lacustrine action is widespread in much of the eastern part of the map-area. Lake deposits consist mostly of beach ridges, generally sand and gravel. Where scarps exist, possibly due in part to the action of lake water, beaches consist of limestone shingle. Bottom deposits of sand, silt and clay are widespread but no thick deposits were observed.

Alluvial Deposits

In a wide area along Slave River and a large part of Liard River, as well as in smaller areas along other major rivers, deposits of sand and silt are found well above the present flood plains of the rivers and represent alluvial deposits that predate the present regimens of the streams. Soils developed on these materials along Slave River have been studied by Day and Leahey (1957).

Aeolian Deposits

North and northeast of Buffalo Lake and in a broad area near Fort Simpson, sand has been reworked by wind action into various forms. Mechanical analyses of four samples of this sand, one from near Buffalo Lake and the rest from the Fort Simpson area, show that about 60 per cent of the material from the first area is in the fine sand fraction and about 15 per cent in the medium sand fraction; about 80 per cent of the material of the other three samples is in the fine sand fraction, which is the coarsest material present. None of the samples contains any silt-size material.

Glacial Features

Bedrock Surface

As has been pointed out earlier, the bedrock surface is almost entirely concealed except in the mountain ranges. The few surface exposures in the Plains areas are generally weathered and frost-shattered. Striae can be observed along rivers where the drift has been removed recently and along Hay River many striae observations were made by digging away the drift from the bedrock surface. In a gross way the plateau areas have a streamlined form with steep scarps facing the direction of ice movement—a shape imposed on them by glacial action.

Ground Moraine

Much of the area that lies above the level of the former glacial lakes has the typical undulating topography of ground moraine. Relief is generally less than 10 feet except where the ground moraine surface is interrupted by other glacial features. Poor drainage has resulted in large areas of swamp and muskeg. On the Horn Plateau, a mat of caribou moss covers vast areas of ground moraine.

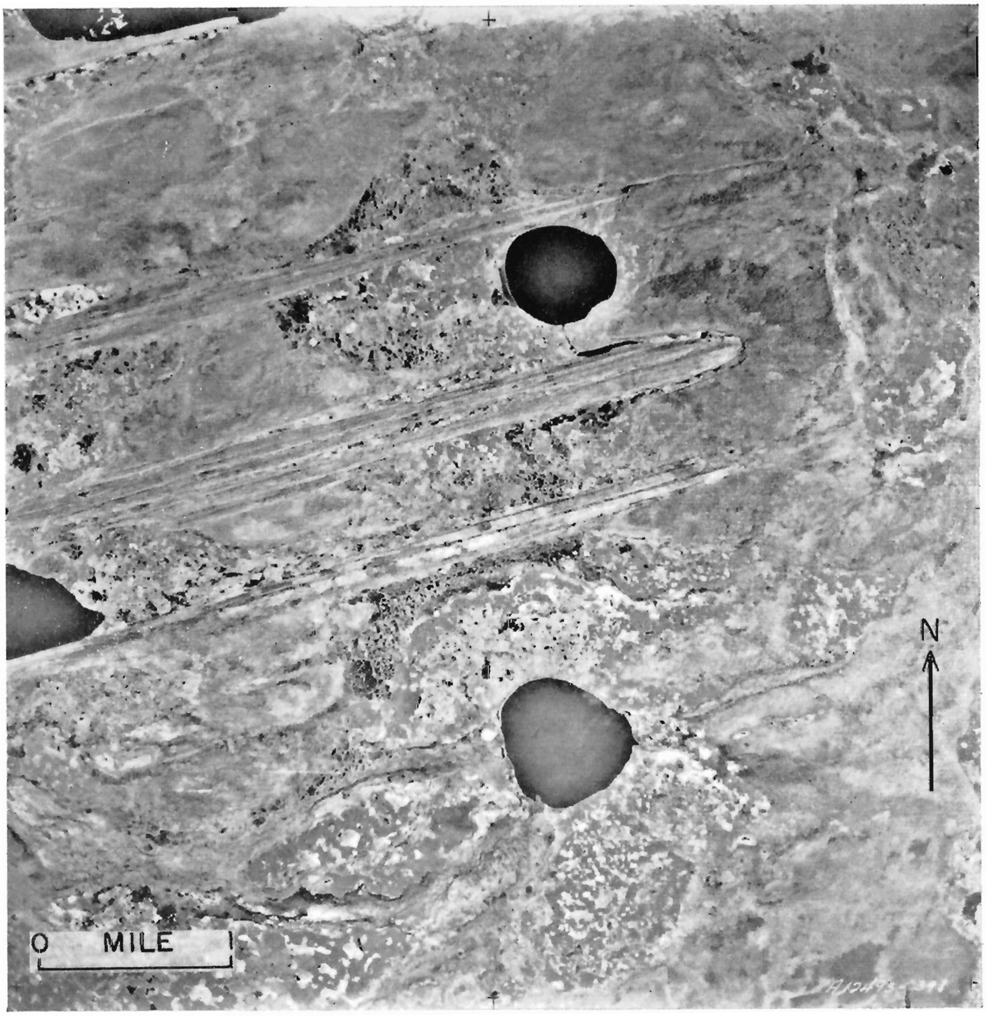
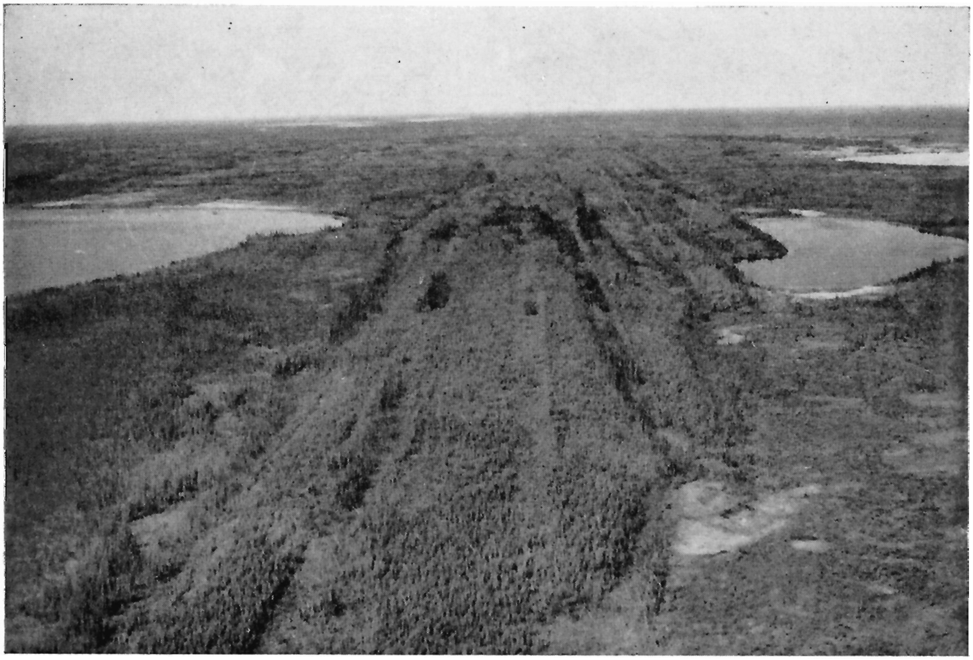


PLATE III. Elongate streamlined hill furrowed by closely spaced ridges and grooves, about 24 miles northwest of west end of Tathlina Lake. (RCAF A12493-398)

Drumlinoid Forms

Drumlinoid forms, comprising drumlins and associated streamlined drift ridges, are locally very abundant, although there are large areas where none is found. Size and type vary greatly. South of Great Slave Lake, on the Cameron Hills, in the southwest corner of the map-area near Petitot River, and in the northwest part between Lac la Martre and the mountain front, individual ridges are long, straight, and uniform in height and width. Northwest of Tathlina Lake and immediately northwest of Bulmer Lake elongate streamlined hills as much as 100 feet high, a mile wide, and several miles long are furrowed by closely spaced ridges and grooves (*see* Pls. III and IV) with local relief from 10 to 15 feet. Elsewhere drumlinoid forms are individual hills with typical drumlin form, although there is great variation in their dimensions. Probably none is more than 100 feet high and only a few hundred feet long.

Most of the drumlinoid forms are composed of till but some are composed of gravel and sand, and at one place silt was noted.



BGC, 6-7-57

PLATE IV. Oblique, low-level, aerial view to the west of furrowed streamlined hill. This feature is 3 miles northwest of uppermost circular pond shown in Plate III.

Transverse Ridges

These features include all drift ridges at right angles to the direction of ice movement, end moraines of considerable size, minor moraines, and the area of hummocky moraine west of the Cameron Hills.

End Moraines

Lac la Martre

A series of discontinuous ridges a few miles east of and subparallel with the east side of Lac la Martre consists of segments up to 10 miles long with gaps of about the same length and has a total length of about 45 miles. In most places the feature exists as a single ridge 20 to 30 feet high but near latitude 63°30′, longitude 117°30′, the ridges are lower, closely spaced, and subparallel.

The ridges are composed of very coarse bouldery till. Boulders, which are numerous on the surface, are very angular, and up to 10 feet in diameter. In some places the ridges are associated with eskers that lead in from the northeast. Some of these eskers terminate at their 'downstream' end in fan-shaped areas of pitted outwash on the distal side of the moraine ridge.

West of Cameron Hills

An irregular ridge resembling an end moraine extends westward from the west end of Cameron Hills. This ridge is about 10 miles long, from a few feet to 60 feet high, and from a few hundred feet to nearly a mile wide. Where it was examined on the ground it is composed of laminated grey silt with rare boulders on the surface. Several south-trending abandoned meltwater channels head at the ridge and an abandoned side-hill channel is continuous with its east end. Although this ridge resembles a similar feature mapped by the writer in southern Saskatchewan as an ice-contact deposit (Craig, 1959, map-unit 3a), because of its superficial resemblance to an end moraine and its relationship to nearby ice-flow and ice-front features, it has been included in this report as an end moraine.

At the west end of this ridge and continuous with it is an irregular elongate zone of hummocky moraine 24 miles long and from 4 to 8 miles wide, with relief of 25 to 40 feet. It was not examined on the ground but appears to be composed of silt similar to that of the ridge to the east. Surface boulders and some sharp kame-like sandy hills were seen. Included with the hummocky topography are ridged dead-ice plateaux as described by Stalker (1960). A small area with no preferred orientation exhibiting similar topography was found east of Blackwater Lake.

Trout Lake

A discontinuous ridge extends eastward for 22 miles from the south end of Trout Lake. Two short segments of a similar ridge are present 6 and 12 miles west of Trout Lake. All these segments as well as the ridge and zone of hummocky moraine west of Cameron Hills are roughly aligned and suggest a moraine system about 125 miles long. The ridge was examined on the ground at a point 8 miles east of Trout Lake. There it is a single ridge 25 feet high composed of coarse grey-brown clay till.

East of Nahanni Range

East of the central part of Nahạnni Range are two segmented irregular ridges that appear to be end moraines. These are sharp-crested, steeper on the east side, sinuous in plan and in places consist of isolated hillocks. They vary in height from 20 to 40 feet and are composed of gravelly till.

Minor Ridges

East of Buffalo Lake

At the east end of Buffalo Lake is a series of subparallel segmented ridges that are probably ice-front features, although their orientation is not quite normal to the direction of ice-flow recorded nearby. They are 10 to 15 feet high, slightly sinuous in plan, and composed of a gritty, stony, clay till with few boulders.

Glacio-fluvial Features

Eskers

Eskers are not common in the map-area. Although small esker ridges are found in many places, large eskers and esker systems, like those so prominent farther east on the Precambrian Shield, are found only around Lac la Martre and in the northwest near Keller Lake, Blackwater Lake, and Fish Lake. Their absence is due possibly to the nature of the bedrock; the Palaeozoic limestones and shales, and especially the poorly indurated Cretaceous shales, provide very little sand-size material. Furthermore, in the area submerged by the water of glacial Great Slave Lake, lacustrine action may have obliterated or obscured any eskers present.

EGC, 5-1-57

PLATE V. Sharp-crested, subparallel esker ridges east of Lac la Martre.

Lac la Martre

Near this lake eskers are generally sharp-crested ridges 40 to 50 feet high. Locally a single esker ridge branches into several subparallel ridges (*see* Pl. V). Most of the eskers are continuous for most of their length, but west of the lake some are discontinuous although the former course of the esker stream is apparent. Many east of the lake are flanked by zones of pitted outwash and some lead into areas of pitted outwash along a line continuous with the end moraine ridge. Where examined the eskers are composed of very stony gravel; most of these are aligned parallel with nearby ice-flow features.

Keller Lake, Blackwater Lake, Fish Lake

Many eskers in the northwest part of the area resemble those described above in size (40 to 50 feet high), and in the composing material (stony gravel) but differ in other respects. There they are shorter and more sinuous, and nearly everywhere comprise multiple ridges. Rarely is the esker aligned with ice-directional features, and the direction of flow of the streams that formed these eskers was probably determined mostly by local topographic conditions. The meltwater forming them was probably derived from large areas of stagnant ice and may have flowed in open channels.

Glacial Lake McConnell and the Evolution of Great Slave Lake

At one stage the Wisconsin Laurentide ice-sheet was bordered on the west by a lake that extended from Great Bear Lake through Great Slave Lake to the region of Lake Athabasca. That lake is here named Glacial Lake McConnell after R. G. McConnell who first realized some of the geological implications suggested by the evidence of former higher water levels in the basin of Great Slave Lake (*see* Fig. 1). This large glacial lake eventually separated into smaller lakes, one of which was ancestral to present Great Slave Lake. Two small glacial lakes existed but were never linked with Glacial Lake McConnell, one in the south half of Trout Lake basin and the other east of Cameron Hills in Hay River valley.

The various glacial lakes were formed during the retreat of the ice either by damming of natural drainage lines by glacial ice or as a result of differential isostatic depression of the land which caused a reversal of the natural drainage. These lakes were wholly or partly drained by the removal of the ice barrier in the first case or by subsequent isostatic readjustment that aided in re-establishing the natural drainage in the second.

The most widespread evidence of the former presence of the glacial lakes is provided by strand lines. Few deltas were observed and bottom deposits give no clear indication of the former extent or history of the glacial lakes.

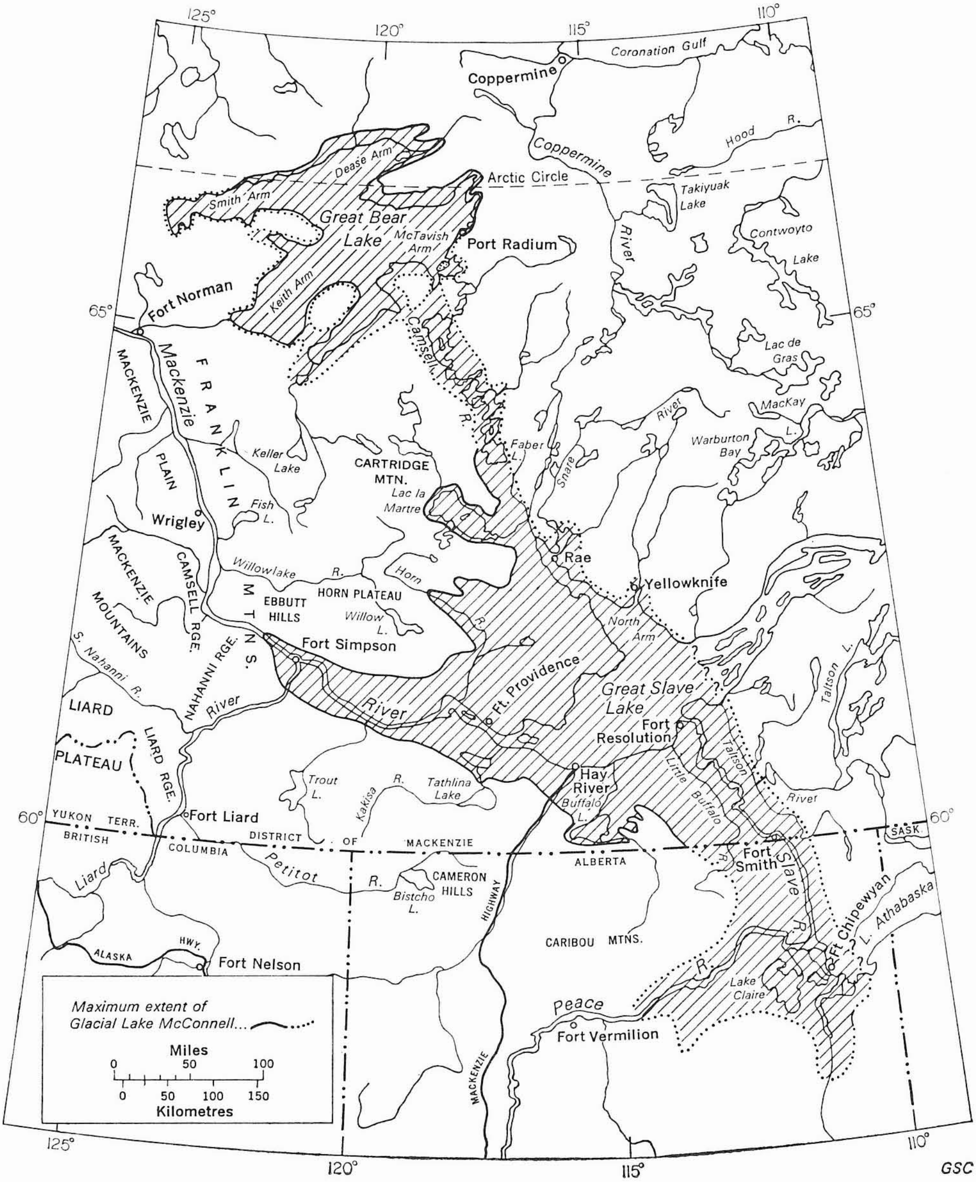


FIGURE 1. Glacial Lake McConnell.

Data in the Region of Great Slave Lake

During and for some time after the retreat of the Laurentide ice-sheet from the map-area, water was impounded against the ice-margin along the upper part of the valley of Mackenzie River above the junction of Liard River and in the basin of Great Slave Lake. The most widespread indications of the higher levels and former extent of this lake are beaches, which are most plentiful at elevations well below the maximum stand of the lake, and occur as concentric rings around isolated hills and as remarkable flights of terraces along more regularly sloping ground. At elevations approaching those of the maximum stand of the lake, however, beaches are fewer, less well developed, and less continuous. None was found around the southeastern flank of Horn Plateau much above an elevation of 800 feet, although the lake level was probably higher, especially at the east end of the plateau. The formation of beaches may have been impeded in areas where the bedrock is shale. Furthermore, in these areas solifluction processes have been more active, both because of the clayey nature of the rocks and the steepness of the slopes and these may have destroyed any beach ridges that had formed.

Two features of possibly deltaic origin were examined. About 33 miles from Hay River on the Mackenzie Highway, slightly above the highest recognizable beach, there is a flat sandy area of about 2 square miles, with an elevation of 900 feet. A road-cut reveals 2 feet of horizontal fine sand overlying finely bedded fine sand resembling foreset delta beds.

The large area of sand dunes near Fort Simpson may have originated primarily as a delta that was subsequently reworked by the wind, although no direct evidence to suggest a deltaic origin was observed. However, this area appears to have been the locus of the western extremity of glacial Great Slave Lake as shown by the distribution of the beaches. Except for the relief of the dunes, the area is nearly flat. Between Liard and Mackenzie Rivers there is a gentle northerly slope from about 640 feet to 600 feet; west of Liard River there is a similar northeasterly slope from an elevation of about 700 feet to just under 600 feet. The small area of dunes 25 to 30 miles northwest of Fort Simpson is slightly above 500 feet. This general area would have received the waters of Liard River and possibly some from part of Mackenzie River, depending on the effect of differential isostatic depression. If an arm of the lake existed in the area, conditions would have been favourable for the formation of a large delta and, as will be suggested later, at an elevation about 600 feet.

Figure 2 shows the western limits of lacustrine submergence within the map-area. It has been compiled by plotting the position of the uppermost distinct strand lines, by extrapolating these for short distances along contours shown on maps, and in places along the south side from the position of a high, north-facing scarp that rises above the level determined for the glacial lake.

The highest beaches in the map-area are in a broad zone extending north-westerly from around Buffalo Lake to Faber Lake. No precise measurements of the elevations of beaches were made except along the Mackenzie Highway, but reasonable approximations appear to be possible by plotting the highest beaches on the contoured maps. Near Buffalo Lake they lie between 900 and 1,000 feet, probably closer to the lower figure; between Lac la Martre and Faber Lake, they also appear to lie slightly above 900 feet. Along the Mackenzie Highway the highest distinct beach has a measured altitude of 868 feet. However, away from the highway and the river, beaches are slightly higher and, as mentioned previously, a small deltaic feature occurs at 900 feet in the same vicinity. Near Kakisa Lake these features are slightly less than 900 feet above sea-level; Tathlina Lake at 911 feet does not appear to have been part of the glacial lake. Between Trout and Bouvier Rivers the top of the escarpment is at an elevation slightly above 800 feet and although beaches are plentiful below this elevation none was found above it. West of Trout River elevations of the highest beaches decrease from about 800 feet to about 750 feet near Jean-Marie Creek, which is the westernmost limit of distinct beaches on the south side of the basin.

The uppermost limit of distinct strand lines and their elevation is difficult to determine on the northwest side of the basin. Unlike those along much of the south side these are not continuous for more than a few miles but are mostly

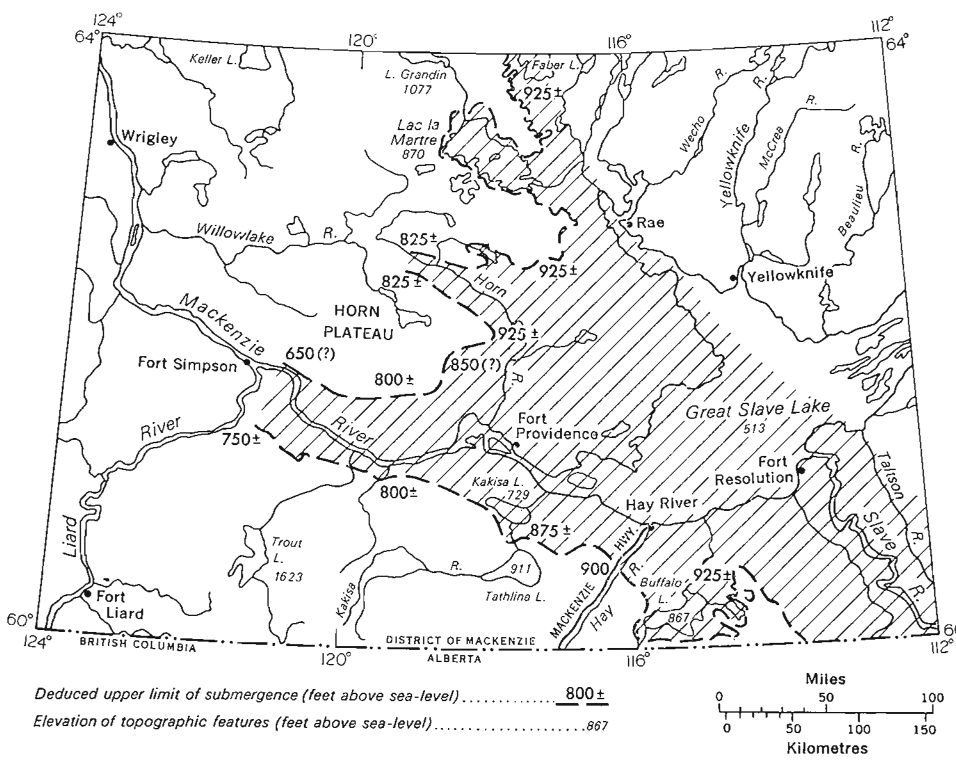


FIGURE 2. Maximum western extent of glacial Great Slave Lake.

short, irregular segments or series of concentric rings around isolated hills. West from near Marion Lake to about Lac Levis the highest beaches continue at slightly above 900 feet elevation. West of longitude 118 degrees, especially on the south side of the Horn River valley, they are much less abundant, and none occurs west of longitude 119 degrees. In this region the highest beaches are at an elevation of about 825 feet. At the east end of Horn Plateau the limit of lacustrine submergence appears to be slightly over 900 feet. South of Horn Plateau the highest beaches occur at about 750 feet at longitude 118°30′, an elevation probably 100 feet below the upper limit of submergence in the area, and at almost 800 feet between longitude 119°00′ and longitude 119°30′. No well-defined series of beach ridges was found west of this longitude and the limit of the glacial lake as shown for this region is largely conjectural. Faint drift trends are apparent on air photographs of the area a few miles north of Mackenzie River. These consist of indistinct parallel lines that are roughly parallel with the river and follow the strike of the ground surface. They extend up to an elevation of about 650 feet and may be strand line features.

There is only scattered evidence that an arm of the glacial lake extended into the Lac la Martre basin. Strand line features were noted on the two peninsulas near latitude 63°15′, longitude 118°10′ and on the flanks of the esker on Big Island. The present elevation of Lac la Martre is 870 feet, which is lower than the maximum elevation of the highest beaches in the general area. The divide east of Lac la Martre lies well above 900 feet northwest of latitude 63°20′, longitude 117°10′, but southeast of this point for about 25 miles the height of land is breached by several saddles whose elevations lie between 875 and 900 feet, one being the course of La Martre River. Numerous islands probably existed in the mouth of the embayment.

Evidence that the lake extended into the embayment that now contains Buffalo Lake is likewise very scattered. On the east, west, and south sides of the lake, beaches are rare and occur only at low elevations, although on the north side they are found above 900 feet. The present level of Buffalo Lake is 867 feet above sea-level, and although nearly all the land around the lake is between 900 and 1,000 feet in elevation, there are numerous channels and low areas below 900 feet that would have allowed the glacial lake at its highest stage to extend into this basin. Although none is shown in Figure 2, many islands must have existed during this stage in the mouth of the embayment.

Origin and Evolution of Ancestral Great Slave Lake

Generalizations arrived at during the course of this study indicate that as (1) the direction of retreat of the Laurentide ice-margin was generally eastward and upstream along the Mackenzie system as far as Great Slave Lake (*see* "Pattern of Deglaciation" below) and as (2) there was no possibility of blocking the normal westward drainage of the basin after ancestral Great Slave Lake began to form, differential isostatic depression towards the east side of the basin was responsible for the formation of this lake.

The first interpretation of the history of Great Slave Lake was made by McConnell (1890, p. 25) who observed abandoned strand lines at the western end of the lake that were lower than those reported earlier by Back at the eastern end. He suggested that the former higher lake levels were controlled probably by "changes in elevation" but possibly by glacial damming. Bell (1900, pp. 109-110) also noted the eastward increase in elevation of old shorelines "indicating a tilting of the lake towards the west or southwest accompanied by a greater lowering of the water at the northeastern extremity." Cameron (1922a, p. 30; 1922b, pp. 351-353) and Raup (1946, pp. 28-30) attributed postglacial changes in elevation of Great Slave Lake to differential changes in the elevation of the land due to isostatic readjustment.

Some conclusions can be drawn as to the amount of isostatic rebound. If it is assumed that the highest strand line features at the east side of the map-area are the same age as those at the west side, then the rate of rebound recorded between the deltas near Fort Simpson at an elevation of 500 feet and the beaches near Faber Lake at an elevation of about 925 feet is slightly over 2 feet per mile. In the Great Bear Lake area Craig (1960, pp. 3-4) has suggested that there is a difference in elevation of lacustrine features over a distance of 145 miles from west to east of 380 feet, or slightly over 2½ feet per mile. These figures can be considered only as components of the total uplift, as the maximum uplift would take place parallel with the direction of retreat. In both areas cited this direction is not parallel with lines joining the observed maximum and minimum elevations of lacustrine features. Furthermore, because uplift took place progressively towards the east as the ice-margin shrunk back, the highest beaches on the east side of the basin are not contemporaneous with those on the west side but are younger and were formed after some readjustment had already occurred in the western part. Hence the range in elevations of these features records only the minimum amount of differential uplift during the lifetime of the lake and does not, of course, indicate the total amount of isostatic depression at the climax of the Wisconsin Laurentide glaciation.

Glacial Lake McConnell

It has been known for some time, as is shown on the Glacial Map of Canada, that glacial lakes were present in the three basins now occupied by Great Bear Lake, Great Slave Lake, and Lake Athabasca. From this study it is apparent that at one stage in the history of deglaciation these basins contained one vast lake, Glacial Lake McConnell, which extended from the north side of Great Bear Lake to the lower parts of the valleys of Peace and Athabasca Rivers and part of the west end of Lake Athabasca basin.

The probable maximum extent of Glacial Lake McConnell is shown in Figure 1. The boundaries that have been determined in part from the writer's field work in the present map-area and in the northern and northeastern part of the Great Bear Lake area (Craig, 1960, pp. 3-4) are shown as approximate. Elsewhere, the probable limits, shown as assumed boundaries, have been determined by various and less reliable criteria. Between Faber Lake and Great Bear Lake on the west side and between Great Slave Lake and Great Bear Lake on the east side the limit follows approximately the 900-foot contour line as shown on the 1 inch to 4 miles topographic maps. Along the south side of Great Bear Lake a similar method was used, allowing for a westward decrease in the elevation of the upper limit of lacustrine submergence to a minimum of slightly less than 600 feet above sea-level. West of longitude 112 degrees, in the southern part, the limit was determined from soil reports of Lindsay, *et al.* (1960, 1961, and 1962), and east from the same longitude from contoured maps where available, again approximately along the line of the 900-foot contour, and from the gross physiography and available spot elevations for those parts for which contoured maps are not available. It has been assumed also that Glacial Lake McConnell reached its maximum extent at about the same time as the ice-margin lay along the edge of the Precambrian Shield.

The northward extension from the Great Slave Lake basin followed a topographic low that connects the northwest arm of Great Slave Lake to Great Bear Lake. The divide between northward and southward drainage in this low is between Mazenod Lake (elevation 712 feet) and Sarah Lake (elevation 702 feet) and is probably at an elevation less than 750 feet above sea-level. Beaches in the vicinity are at about 925 feet elevation.

A similar extension of the glacial lake lay in the Slave River Lowland and occupied at least part of the basin of Lake Athabasca and the lower part of the valley of Athabasca and Peace Rivers. This part of the lake was the last phase of a series of successively lower lakes that were held up by the ice-margin as the valleys of these two rivers became free of ice. However, once the Slave River Lowland became ice-free the water level in the Athabasca basin was determined by the level of glacial Great Slave Lake. The highest lacustrine features in the southeast corner of the map-area are 925 feet above sea-level, indicating a depression of about 400 feet. Lacustrine features in the Athabasca basin are not likely to be found at elevations exceeding about 1,000 feet, or 400 feet above present lake level (695 feet). Measurements of such features are few, but both Camsell (1916, p. 45) and Raup (1946, p. 28) indicated that beaches are present 200 feet above the lake at about the mid-point of the north side. Taylor (1960, p. 173) stated that "Many shorelines occur on the Shield rocks north of Lake Athabasca, but even the highest appears to be no more than 1000-1050 feet above sea-level." Taylor also (p. 175) interpreted an area of aeolian sand and alluvial materials mapped by Lindsay, *et al.* (1960, p. 27, map-sheet 84J) as a delta formed at the last stage of Lake Tyrrell[1]. It occurs on either side of Peace River, about 125 miles west of the west end of Lake Athabasca, and is at an elevation of about 900 feet. This delta may mark the western limit along Peace River valley of the composite glacial lake formed along the western edge of the Precambrian Shield.

[1] Taylor (1960, p. 173) has proposed the name "Lake Tyrrell" for the series of successively lower lakes that were held up by the retreating ice-margin as the valleys of Athabasca and Peace Rivers became ice-free. Earlier and higher phases of Lake Tyrrell than that discussed here had outlets elsewhere than the Slave-Mackenzie.

The history of Glacial Lake McConnell as one vast glacial lake came to a close when the waters of the three basins, Great Bear Lake, Great Slave Lake, and Lake Athabasca, became separate. This was brought about by the lowering of the water level as the ice-front retreated northeastward and further isostatic readjustment took place. Great Bear Lake became separate from Great Slave Lake when the water level fell to about 750 feet above sea-level, the elevation of the divide between them. The control between Lake Athabasca and Great Slave Lake is the sill of Precambrian rocks south of Fort Smith over which Slave River flows. This sill is slightly below 700 feet elevation and hence it was at this level that the two lakes became separate bodies of water. Further separation took place as the water level in Great Slave Lake continued to drop, and the lower part of Slave River valley became alluviated to form the Slave River Lowlands (*see* "Alluvial Features").

Glacial Trout Lake

A glacial lake probably existed for a short time in the south part of Trout Lake basin. Ice-flow features near Trout Lake are parallel with its long axis, and indicate retreat of the ice-margin from south to north. The moraine segments on either side of the lake indicate a pause in the retreat and as the natural drainage of the basin is to the north water was impounded until an alternate outlet was established. At the south end of the lake on the peninsula and on the east and west shores there is a featureless zone below an elevation of about 1,800 feet and a drumlinized zone above this elevation; the boundary between these two zones is marked by a low discontinuous scarp that apparently marks the upper limit of lacustrine action. Abandoned channels south of the lake connect small north-flowing streams tributary to Trout Lake and the headwaters of larger south-flowing streams tributary to Muskeg River which flows into Liard River. These channels could have been carved only by water draining an enlarged Trout Lake. Three such channels exist at different elevations and indicate a complicated history of marginal retreat and lake-level fluctuation.

Upper Hay River

It is probable that as the valley of Hay River became ice-free a glacial lake was confined between Cameron Hills on the west, the high ground southwest of Buffalo Lake, marking the northern edge of the Caribou Mountains, and the ice-margin itself. No field data were collected to support this hypothesis. Its former presence has been suggested by Cameron (1922b, p. 350, fig. 12). Furthermore, Leahey (1953, pp. 2, 6, and map) discussed a lacustrine plain along the Mackenzie Highway from just south of the mouth of Swede Creek at least to the south boundary of the map-area. This plain ranges from 935 feet at its northern limit along the highway to 971 feet at latitude 60°00′. It is distinct from the area having deposits from glacial Great Slave Lake and is separated from it by an area of unmodified ground moraine.

Alluvial Features

Between the south edge of the map-area and Great Slave Lake, Slave River flows through an alluvial plain 25 to 40 miles wide. It is probable that this area was once an arm of Great Slave Lake. This suggestion was first made by McConnell who, when discussing the part of Slave River below Fort Smith stated (1890, p. 62):

> The deposit of postglacial stratified sands is so continuous, and spreads so far on both sides of the river as to lead to the supposition that it was laid down in an ancient arm of Slave Lake, which extended to the south along the line of junction of the Laurentian and Palaeozoic, and corresponded in a general way to the arm of this lake, which now stretches to the north along the same geological line.

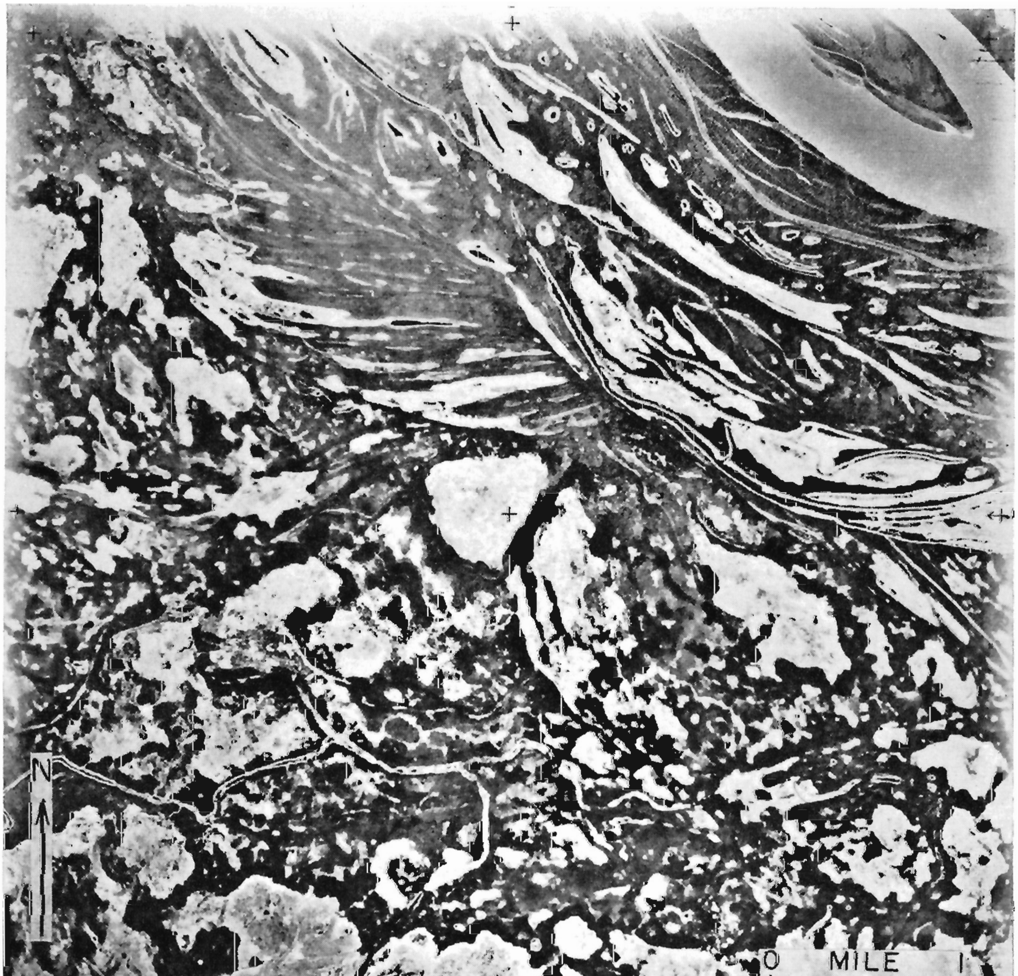


PLATE VI. Alluvium along Slave River showing two stages of deposition as indicated by a well-developed scroll pattern adjacent to the river and an irregular pattern of channel segments away from the river. Centre of photograph about latitude 60°31′, longitude 112°45′. (RCAF A11336-167)

Subsequent workers (Camsell and Malcolm, 1921, p. 78; Cameron, 1922a, p. 10) have agreed with this suggestion. Although lacustrine sediments possibly underlie the alluvial material it is probable that the bulk of the sediment filling the valley is of alluvial origin. Kindle (1918, p. 344) commented on the great amounts of sediment carried by the present Slave River and being laid down in the modern delta.

The surface pattern of the alluvial material in the valley of Slave River indicates two phases of deposition (*see* Pl. VI) that predate present deposition. Adjacent to the river, but not continuous along both sides, is a zone exhibiting the typical scroll pattern of a meandering stream. Although some spring flooding occurs along this zone most of it lies well above the present flood plain of the river except at the mouth where it merges with the modern delta. On either side of this zone is a broader, more continuous zone that shows no regular pattern but in places is marked by abandoned courses of streams and generally consists of short, randomly oriented ridges and flat, swampy areas. This zone is slightly higher than the one adjacent to the river.

A second large area of alluvium is found along Liard River. It extends at least from the south boundary of the map-area to a point about 40 miles below the mouth of South Nahanni River, but is widest at the mouth of the river. Its

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PLATE VII. View to southeast along crest of elongate dune ridge, 22 miles northeast of northeast end of Buffalo Lake.

surface pattern resembles the zone of alluvium adjacent to Slave River—a network of sloughs, abandoned channels, oxbow lakes, and meander scars. This zone lies slightly above the present flood plain of Liard River.

Elsewhere throughout the map-area adjacent to modern streams small areas exhibiting this typical meander pattern lie above the modern flood-plain level.

Aeolian Features

Buffalo Lake Area

North and northeast of Buffalo Lake, sand dunes occur as series of crescentic ridges, concave to the south. The outer arms of many of these series extend to the southeast as elongate ridges (*see* Pl. VII) that vary in length from a few hundred feet where they are merely arms of the crescents to a maximum of 20 miles. They vary in height from 25 to 40 feet although most are even-crested. The easternmost ridge is steeper on the northeast side.

Fort Simpson Area

The sand dunes in the Fort Simpson area comprise four types (a) short, slightly curved ridges, concave towards the north, generally with a southeast orientation (*see* Pl. VIII); (b) long, definite ridges, resembling eskers in plan and oriented slightly west of north; (c) long, poorly defined ridges consisting of series of short, *en échelon* cross ridges; and (d) irregular, randomly oriented hummocks. All forms have a relief ranging from 20 to 40 feet, and as pointed out, have about the same grain size distribution.

The dunes in the Fort Simpson area are believed to have developed on a delta formed in glacial Great Slave Lake.

Sink-holes

Sink-holes were observed in the eastern part of the area, where they occur mostly within an indefinite zone several miles wide extending southeasterly from the mouth of Buffalo River, but a few were noted north of Great Slave Lake, between Lonely Bay and Raccoon Lake. One 2 miles east of Needle Lake is about 150 feet in diameter and 40 feet deep. The following section is exposed:

Depth (feet)	
1	Gravelly rubble
11	medium-grained, lacustrine sand
31	till
41	bedrock

The till surface is capped by a layer of boulders. Another, 7 miles north of Lonely Bay, is dumb-bell shaped in plan. The larger part is 100 feet in diameter and 28 feet deep. It exposes 5 feet of till overlying bedrock. All sink-holes are in areas underlain by gypsiferous beds of Middle Devonian age.

PLATE VIII. Short southeasterly oriented dune ridges in the Fort Simpson area. (RCAF A11038-24)

Lineaments

Air photographs and mosaics of much of the country lying north of Great Slave Lake and Mackenzie River and east of Horn River display a striking pattern of lineaments (*see* Pl. IX). They are widespread throughout most of the area south of a line running southeast from Mink Lake through Caen and Falaise Lakes but occur locally as far north as the latitude of Birch Lake. They are most common in the part of the area devoid of drumlins.

Lineaments appear on air photographs as faint light-coloured markings or as lines of vegetation. Relief is slight and is masked by the vegetation, which grows selectively about them. Small creeks, however, follow along the lineaments for short distances, and in places have accentuated the relief. They vary in length from a quarter of a mile to as much as 6 miles, the shorter ones generally occurring within the drumlin fields. Most of the lineaments are straight, some are slightly curved. Nearly all are oriented a few tens of degrees west of north, mostly within ten degrees either side of N30°W; none is oriented east of north. They intersect commonly, at sharp angles. In the drumlin field northeast of Caen Lake they occur as series of low swales transverse to and in the lower areas between the drumlins. These features were examined on the ground at latitude 61°49′, longitude 116°45′, where relief is 1 foot to 2 feet. The surface material is till and appears to be coarser and stonier in the hollows than it does on the ridges. Mechanical analyses of samples from a ridge and a hollow show 85 per cent and 55 per cent silt, respectively.

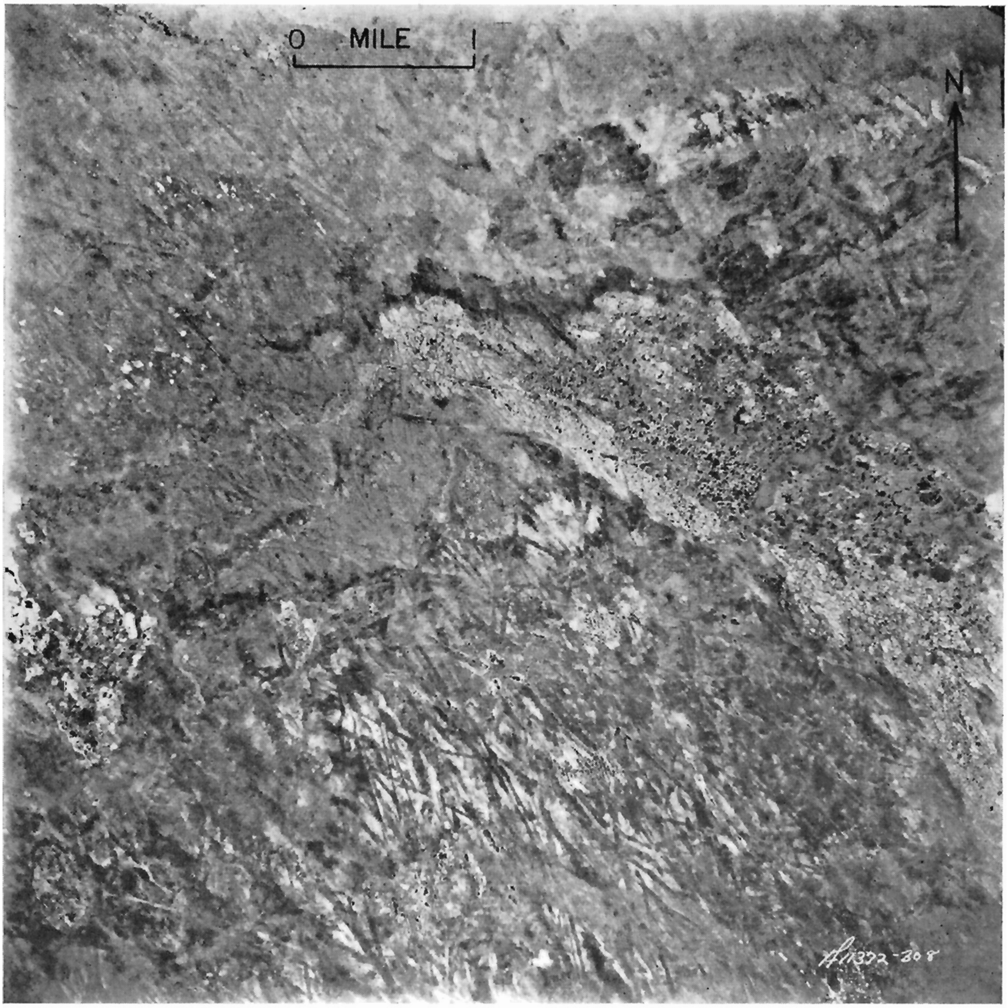

PLATE IX. Typical lineament pattern in lacustrine sediments north of Great Slave Lake. Centre of photograph about 10 miles northwest of head of Deep Bay. (RCAF A11372-308)

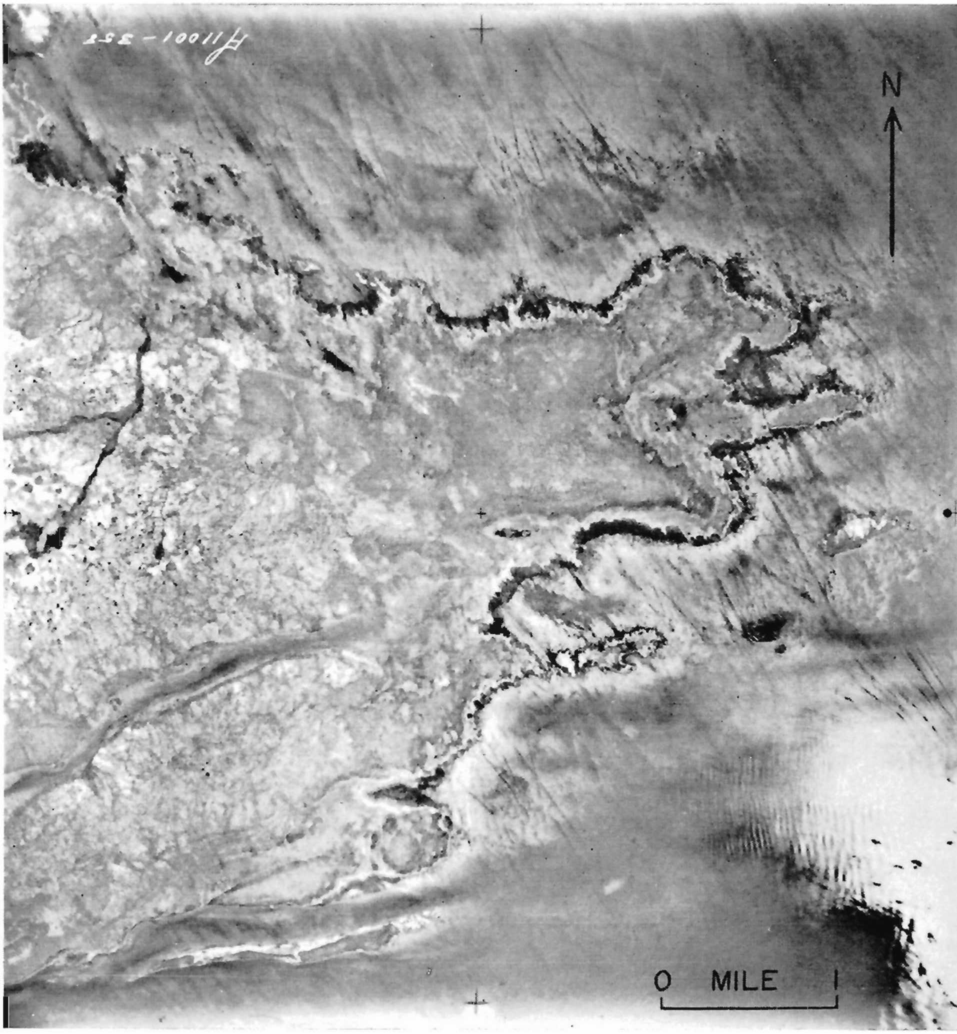

PLATE X. Lineament pattern at east end of Big Island. If this photograph is observed at a low angle it can be seen that some of the lineaments are continuous on either side of the island and cross it at an angle to the shoreline. (RCAF A11001-358)

The origin of these features is uncertain. Weber (1958) studied them near North Channel of Mackenzie River, Deep Bay, and Falaise Lake. He believed that they were formed and are still being formed within and adjacent to the shores of present lakes by the gouging action on bottom sediments of large wind-driven ice-floes during spring break-up. This mechanism may account for some of those near the present shoreline and undoubtedly does account for the smaller ones he observed with boulders at their termini. However, many of the characteristics are not explainable by such a mechanism. (1) The area characterized by the presence of lineaments extends many tens of miles inland from the present shoreline, and it is inconceivable that ice-floes could travel this distance. In that part of the area north of Mackenzie River there are no other large lakes that could supply ice-floes. Even if it is assumed that the grooves are not of recent origin but may have been formed when the lake stood at higher levels during the glacial lake phase, the mechanism of ice-floe gouging can be discounted for reasons outlined below. (2) For an ice-floe to gouge the bottom sediments a critical depth of water would be required so that the floe did not float freely but was buoyed up enough to be moved by the wind. The maximum thickness of ice formed in Great Slave Lake is about 4 feet and in Mackenzie River at Fort Providence 6 feet (Dept. of Transport, 1959), the floes formed from this ice could therefore be no thicker. A difference in elevation of the bottom of only 2 or 3 feet would probably be enough to 'ground' an ice-floe and although the area is flat, differences in elevation of this magnitude are common everywhere; indeed differences of tens of feet are found in the drumlin fields. (3) At many places where lineaments pass from a low area to a high area, they do so at an angle to the topographic feature with no change in the orientation of the lineament. It is unlikely that, even if the obstacle were not too high to stop its movement, the ice-floe would continue to move in a straight line (*see* Pl. X).

It has been suggested by several workers (*see* Mollard, 1958) that in many areas where 'linears' are apparent on air photographs they are a reflection through the drift of bedrock structures, especially joints. Mollard includes lineaments in this part of the map-area (p. 112, and fig. 3) as evidence in support of this hypothesis. During the course of field work the bedrock joint pattern was studied (D. K. Norris, pers. com.). No measurements were made within the area where the lineaments are displayed, but data were collected from four localities just outside this area; near Kakisa Lake, on Horn River above Fawn Lake, on Great Slave Lake between Jones Point and Caribou Point, and near Whitebeach Point. Stereograms prepared by Norris are similar for all four localities and suggest that the joint patterns of the rocks underlying the lineaments may also be the same. Two prominent sets of joints are indicated, one varying from N19°W to N40°W and a second almost at right angles. The northwesterly set aligns well with the lineaments, but no lineaments seem to correspond with the northeasterly set.

In summary, no conclusive evidence suggesting the mode of formation of the lineaments was observed. They align with one of the sets of bedrock joints but this alignment may be coincidence. They are also aligned normal to the direction of ice movement and may therefore be related directly or indirectly to glacial activity. Those northeast of Caen Lake in some respects superficially resemble minor moraines.

HISTORICAL GEOLOGY

The main elements in the physiography of the map-area were probably well developed before Pleistocene time, and the overall effect of glaciation seems to have been to lessen the apparent relief. Scattered information from wells drilled during petroleum exploration reveal great drift thicknesses in places along Mackenzie River and Liard River valleys and indicate that in some places at least, the valleys were deeper before glaciation than they are now. It has been pointed out moreover that the alluvial deposits along Slave River probably represent an infilling of an arm of ancestral Great Slave Lake.

Glacial History

Multiple Glaciation

There is some stratigraphic evidence within the map-area of at least two glaciations. Sub-till stratified deposits as described previously underlie till deposited during the last glaciation. The stratified material appears to be composed at least partly of material brought from the area of the Precambrian Shield by glacial action and subsequently redeposited by fluvial action.

Glacial striae observed at ten localities along Hay River indicate two directions of glacial movement, at approximately S50°W and N50°W. At no locality were the two sets superimposed but the southwesterly oriented striae are more numerous and better preserved suggesting that they were formed later than the northwesterly striking set. Whittaker observed striae on Trout River about 20 miles from its mouth (1922, p. 55) and on Redknife River about 10 miles from its mouth (1923, p. 99). At both places there were two sets, oriented approximately northwest and southwest, and Whittaker concluded that the southwesterly set was younger. There is insufficient evidence to determine whether these two sets of striae in the map-area are due to two distinct glaciations or whether they merely indicate changes in the direction of flow near the margin of the last ice-sheet.

Pattern of Deglaciation

The ice flowed to the northwest in the northwestern and most of the northern part of the area, to the west in the central part, and to the southwest in the southern and eastern parts (*see* Fig. 3). There is no evidence to suggest that Cordilleran ice entered the area, and all the glacial features and deposits are the result of the Laurentide ice-sheet, which crossed the western boundary of the map-area and penetrated into the mountains.

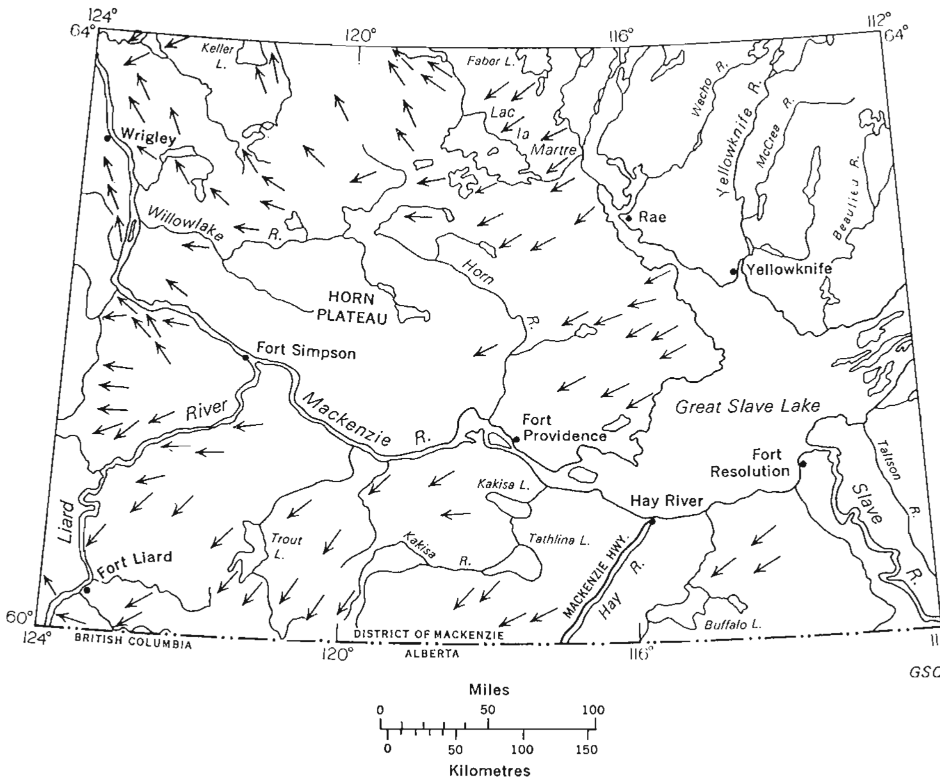

FIGURE 3. Generalized direction of glacial flow features.

Craig and Fyles (1960, p. 5) interpreted the pattern of ice-flow features to "record successive positions of the margin of the ice-sheet and successive ice-movements near the margin during deglaciation". They suggested that the Wisconsin Laurentide ice-sheet comprised a peripheral zone that was the locus of marginal fluctuations at the climax of glaciation and during the early phases of shrinkage, and a central zone across which the ice-sheet retreated more rapidly and regularly. The map-area lies in the central zone except perhaps along the west side where topography had more influence on the flow pattern than did the regimen of the ice-sheet. At the climax of glaciation the ice-sheet probably covered the eastern ranges of Mackenzie Mountains. An ice surface at an altitude of 4,000 to 5,000 feet would leave only a few peaks exposed, and cover the Interior Plains immediately to the east with from 2,000 to possibly as much as 4,000 feet of ice.

Figure 4 shows in a gross way various positions of the ice-margin during its eastward retreat across the area. The positions as indicated are largely hypothetical but are based on (1) the orientation and location of end morainal and other ice-front features, (2) the direction of near-marginal flow features throughout the area, which are assumed to lie at right angles to the ice-front and to represent the last phase of ice movement, and (3) the apparent influence of the gross physiography of the area on the ice-sheet.

During the early phases of deglaciation of the map-area the mountains along the west side first became ice-free, impeding and eventually stopping flow to the west and diverting the ice to the north and south along the mountain front (Fig. 4 I). The effect of passes and low areas in this barrier is shown by diversions in the pattern of flow features near Cli Lake and west of Fort Liard. An anomalous diversion in this pattern is noted on either side of Blackwater Lake. The ice-margin remained static along the central part of the barrier as it shrunk back to the northwest and southwest (Fig. 4 Ia) As overall thinning of the marginal zone of the ice-sheet continued, the locus of the margin along the mountain front became independent of the topographic barrier and was determined by the regimen of the ice-sheet. The pattern of flow features produced at this stage is

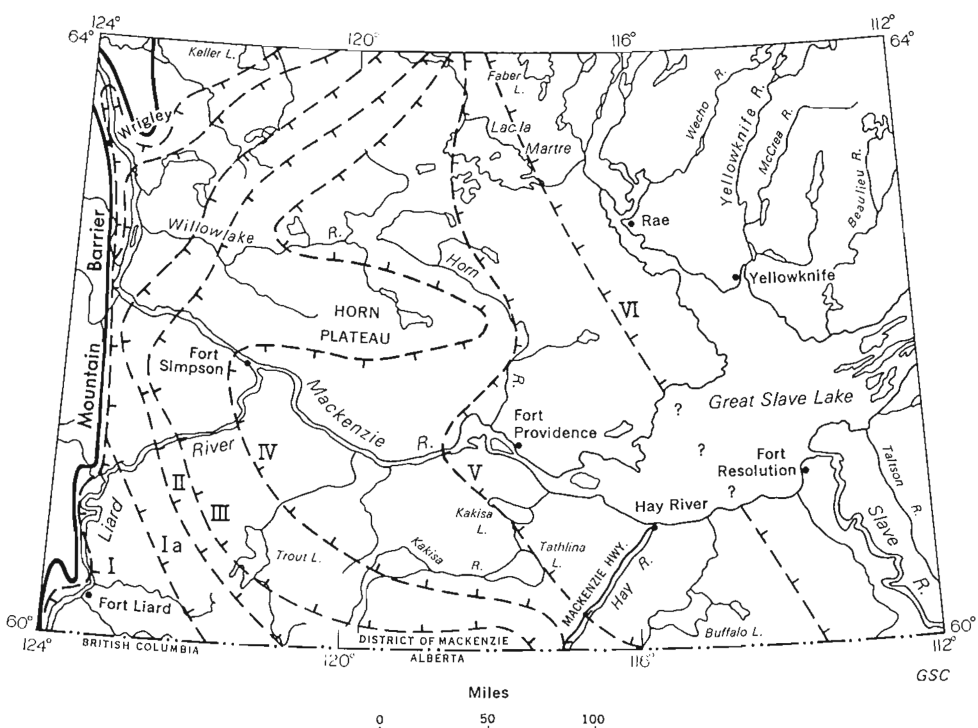

FIGURE 4. Hypothetical ice-marginal positions during deglaciation.

symmetrically fan-shaped towards the west. This pattern of ice-flow persisted as the ice-margin withdrew eastward (Fig. 4, II and III). At one time the margin in the southern part of the map-area lay along the line marked by the end moraine segments between Trout Lake and the west end of Cameron Hills, damming the glacial lake in the southern part of Trout Lake basin.

No ice-flow features were noted on top of Horn Plateau, although there are small drumlinoid features on the northeast side. However, till is present on the plateau surface and locally it is probably tens of feet thick. Furthermore, ice had to cover the plateau in order to reach the observed height of over 5,000 feet in the mountains to the west. It does seem likely that, because of the height of the plateau above the surrounding plain and its considerable lateral extent, stagnation took place on the plateau very early in the retreat of the ice-margin while the ice was flowing actively on either side of it thus forming two lobes in the ice-front (Fig. 4 IV).

Ice-flow features at the east side of the map-area indicate a regular pattern of movement to the southwest. During the final stages of retreat the whole of the ice-margin within the map-area marked the eastern limit of glacial Great Slave Lake. Although the depression containing the western arm of Great Slave Lake might be expected to have had some funneling effect on the direction of flow, the orientation of ice-flow features gives no indication of this. As the glacial lake expanded, calving along the ice-front probably became a dominant factor in determining its position, and it appears that during the final phases of recession from the map-area the ice-front was almost parallel with its eastern boundary.

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