



CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

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GEOLOGICAL SURVEY OF CANADA  
BULLETIN 51

**SURFICIAL GEOLOGY OF SOUTHERN  
DISTRICT OF KEEWATIN AND THE  
KEEWATIN ICE DIVIDE,  
NORTHWEST TERRITORIES**

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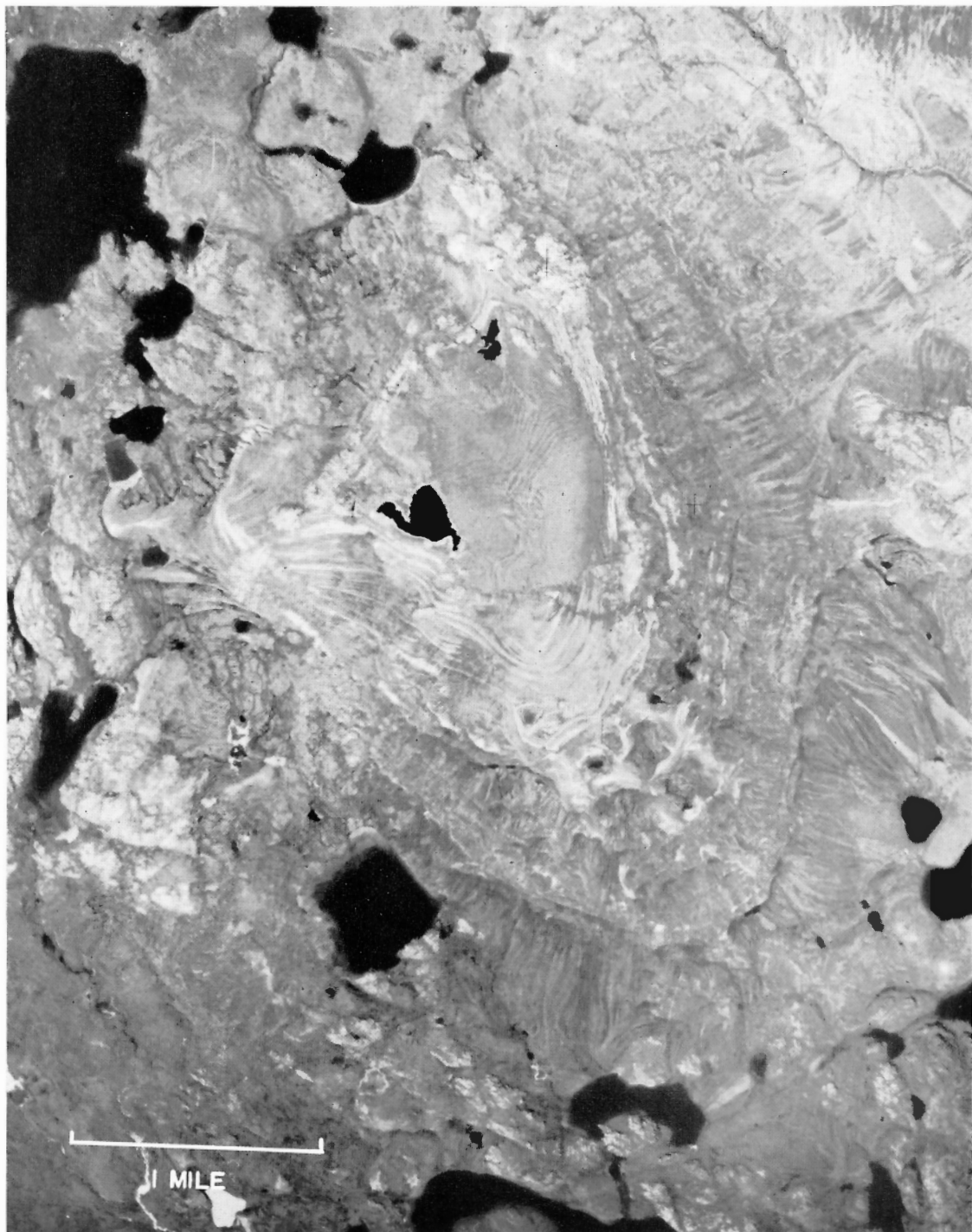
By  
Hulbert A. Lee

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THE QUEEN'S PRINTER AND CONTROLLER OF STATIONERY  
OTTAWA, 1959

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Plate 1. Raised marine beaches around a former island 4 miles north of Carr Lake, southern District of Keewatin, Northwest Territories. (Note the solifluction lobe overlapping the beaches.) Top is north.



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## PREFACE

During preparations for the first helicopter operation (Operation Keewatin) of the Geological Survey of Canada some 22,000 air photographs were examined. This examination led to the accumulation of an immense amount of information on the surficial geology. In order to check and amplify this information by field observations the author was attached to the field party and was made responsible for studying the surficial geology.

Information on the glacial history, the movement of the ice-sheets, the marine submergence, and other events was obtained for a wide area in this remote region. Probably the most interesting is the recognition and delineation of the Keewatin Ice Divide.

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

OTTAWA, May 30, 1958



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# Surficial Geology of Southern District of Keewatin and the Keewatin Ice Divide, Northwest Territories

## INTRODUCTION AND ACKNOWLEDGMENTS

In 1952 a geological exploration, known as 'Operation Keewatin', was made of an area west of Hudson Bay and north of the province of Manitoba. This operation combined three separate projects involving bedrock geology, surficial geology, and topography. Its main purpose was to gather data about this hinterland that would enable the preparation of geological maps amplified by reports. Preliminary accounts of the surficial geology are given by Lee (*in* Lord, 1953a, p. 2 and Figure 1)<sup>1</sup>, and of the bedrock geology by Lord (1953a, 1953b). Other geological work in parts of the area that has a bearing on surficial geology includes that of Tyrrell (1898), Weeks (1933), and Neil and Putnam (1955). In preparation for the reconnaissance about 22,000 aerial photographs, covering about 100,000 square miles in and adjoining the area mapped, were examined by various staff geologists of the Geological Survey of Canada. Data on glacial and shoreline features, together with bedrock structures, probable areas of outcrop, and probable rock types were obtained from the air photographs and plotted on maps to a scale of 1 inch to 8 miles.

This broad region has no roads. The nearest rail and air terminal is Churchill, Manitoba. Charter planes out of Churchill provide access to the area, and the numerous lakes afford landing surfaces. The natural harbours at Eskimo Point and Chesterfield Inlet are visited on occasion by ships during the season when Hudson Bay is free of ice. Some of the rivers are navigable by canoe and provide a means of access into parts of the region.

Throughout the season the party operated as a single unit occupying successive base camps spaced about 90 miles apart. Two helicopters, each carrying one geologist, were used for transportation and a fixed winged aircraft was used for support. The bedrock geology was considered of prime importance, and was the controlling factor in the use of aircraft and in the location and duration of stay at base camps.

This report covers the results of the study of surficial geology of 'Operation Keewatin'; the map (Figure 7) is a controlled interpretation of air photographs. Numerous ground checks were made by C. S. Lord (party chief), G. M. Wright, H. A. Quinn, and K. E. Eade while carrying out systematic geological mapping of the bedrock from helicopters. The remaining

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<sup>1</sup>Names and dates in parentheses are those of references cited at the end of this report.

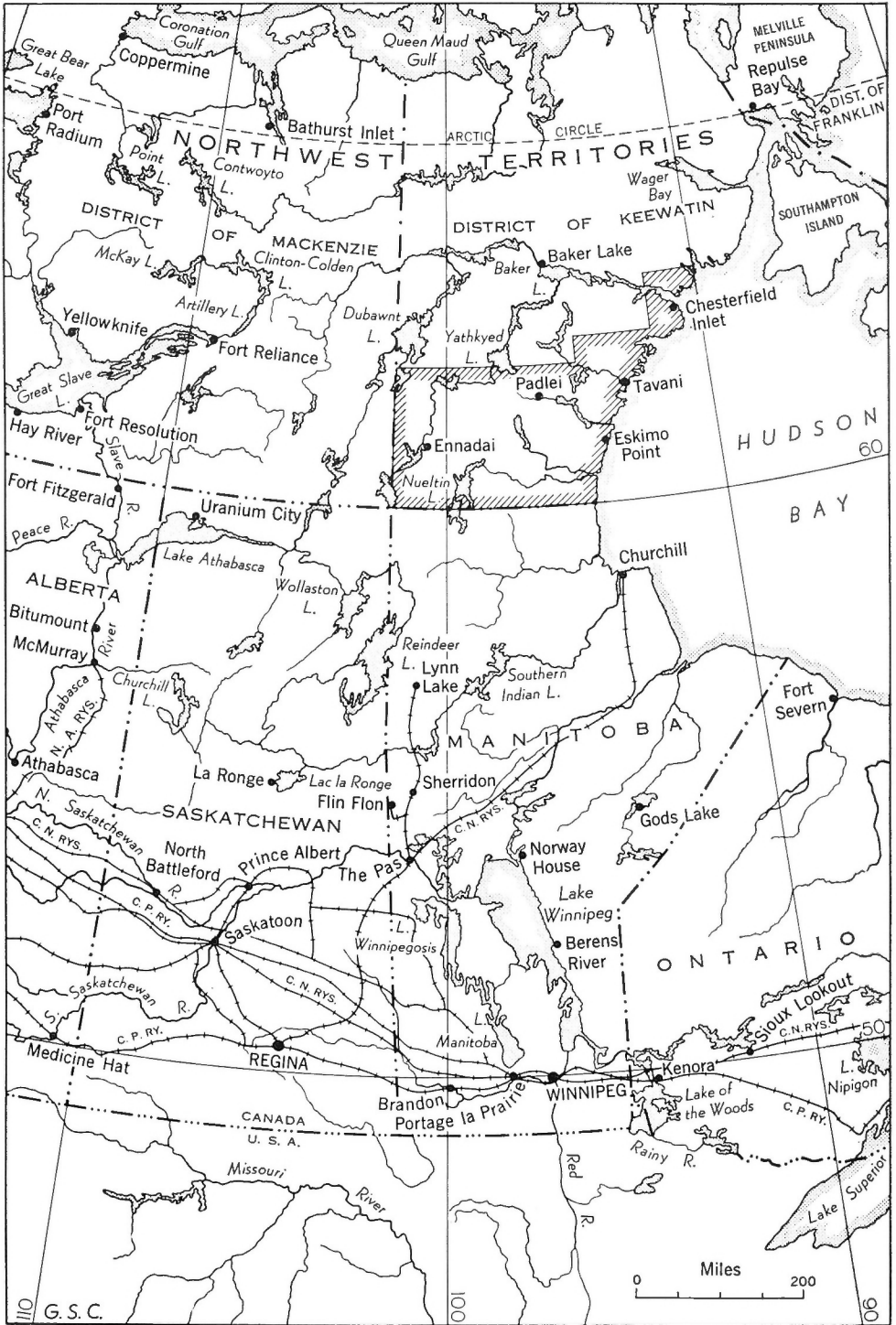


Figure 1. Index map showing location of area covered.

## Introduction and Acknowledgments

ground information was collected by the writer during extensive ground traverses and occasional special traverses by helicopter to study the surficial geology. A Wallace and Tiernem altimeter was carried in each helicopter and was used to obtain elevations on raised shorelines, hills and lakes. Base altimeters were read in camp by T. J. Rusk, who also made the calculations necessary to correct elevations taken at field stations.

The bedrocks of southern Keewatin have been divided into a stratigraphic succession, all of Precambrian age, comprising Archæan, Early Proterozoic, and Late Proterozoic rocks (Lord, 1953a, 1953b). The Archæan rocks include granite, lavas, minor amounts of sedimentary rocks, and their metamorphic equivalents. Included in the Early Proterozoic are quartzite, slate, phyllite, dolomite, etc. These rocks are folded and contorted. The Late Proterozoic rocks, mainly flat lying, include dacitic (?) lavas, pyroclastic rocks, conglomerates, and arkose.

## PHYSIOGRAPHY

Several physiographic names have been used to describe the large area of which this area is a part. It is a typical shield area and, as it is underlain by rocks mainly of Precambrian age, has on occasion been called the Precambrian Shield. It forms a natural physiographic unit and Putnam (1952, p. 6, Figure 3) used the name Canadian Shield for it. Atwood (1940, p. 149), on the other hand, applied the name Laurentian Upland to the same area. The term Canadian Shield is preferred, and the part covered by this survey includes a coastal plain, an interior plateau, and a hill and mountain region (*see* Figure 2).

### Coastal Plain

The coastal plain is composed of two parts, a coastal strip and a zone of terraced drift, each of which has been affected by marine action but to a different degree. The coastal strip borders the west coast of Hudson Bay and is approximately 85 miles wide between lat. 60° and Rankin Inlet. North of Rankin Inlet it narrows to a belt about 8 miles wide and vanishes at Chesterfield Inlet. The coastal strip has few oriented glacial landforms and, because of this, few lakes are oriented parallel to the direction of the last glaciation. Abundant are fine parallel strand lines which, in some places, meet the terraced zone in escarpments, giant bars and spits. A feature of much of the area is the low, flat appearance of the landscape, with wide tidal flats that give the impression of a marine plain underlain by considerable thicknesses of silt and clay. The only section observed in this plain was along a small stream about 9 miles north of Baker Foreland, where there is about 30 feet of fossiliferous clay and silt.

The zone of terraced drift adjoins the coastal strip to the west but wedges out to the north where the interior plain is in direct contact with the coastal strip. The zone of terraced drift is distinguished from the coastal strip by its glacial landforms, notably drumlins and eskers which dominate the landscape and control the shape of the lakes. As the sea-level dropped, the drumlins and eskers formed local prominences. These were terraced by wave action, and giant spits were formed in some places; bay-mouth bars are common. The eskers in this zone have been so greatly eroded and terraced that in many places they are almost unrecognizable. They are marked by a beaded pattern in the area of minor moraines. Low, straight, minor moraines are spaced 400 to 1,100 feet apart and they project into lakes and rise over the drumlinoid forms. They are superimposed over the other drift features.

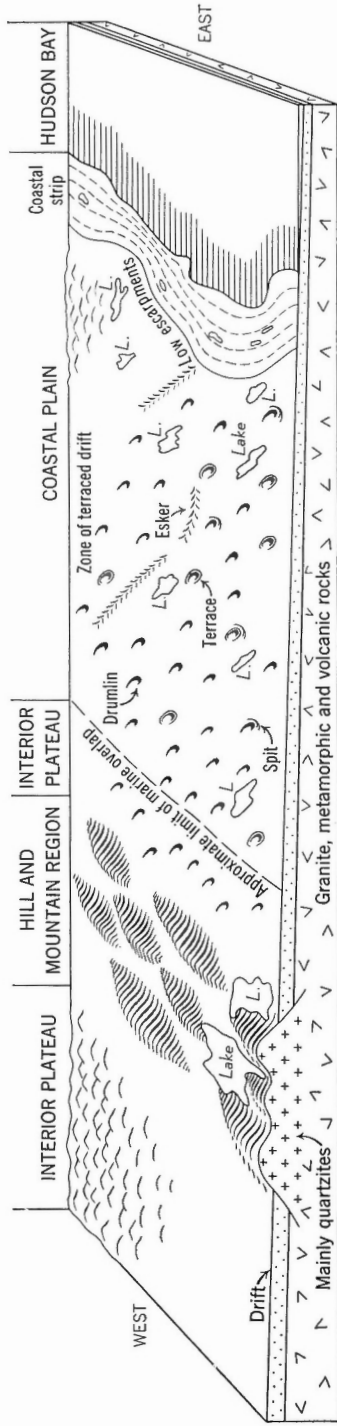


Figure 2. Characteristic features of the physiographic divisions of southern District of Keewatin, Northwest Territories. (The sketch is diagrammatic and does not represent the exact geographic location of each feature shown.)



## **Surficial Geology Keewatin and Keewatin Ice Divide**

The upper foot or 2 feet of drift in this terraced zone have been reworked by wave action and at a later date by frost. It is common to find marine shells in till-like material lying on a frost boil. Actual beds of marine clay and silt, however, were seen only in river-cuts between adjoining lakes.

### **Interior Plateau**

The interior plateau is situated west and north of the coastal plain. In part the area has a thin drift cover with numerous bosses and outcrops, in other places glacial landforms such as drumlins, eskers and minor moraines mask the bedrock surface. The interior plateau differs from the zone of terraced drift by the presence of large areas with bedrock at or near the surface, and by lack of general terracing of the drift hills and a corresponding scarcity of raised beaches, bars, and spits that are present only in the basins of glacial lakes.

### **Hill and Mountain Region**

The hill and mountain region is characterized by a range of hills with a local relief of about 600 feet. The hills trend from between Hurwitz Lake and Mountain Lake northeasterly to Padlei, passing on the way between North Henik and South Henik Lakes. Beyond Padlei, the hills are isolated and few in number. Most of the mountains and hills are formed of quartzite, younger in age than the other rocks and in general more resistant, but some are made of less resistant rocks, such as gabbro. As the quartzites, together with volcanic and granitic rocks, elsewhere form part of the plain, the hill and mountain region cannot be present solely because of the superior hardness of the underlying rock. More probably these hills and mountains are remnants of dividing ranges or of mountain knots developed where several watersheds met, and are composed of the more resistant rocks that fixed the position of the divide earlier in the cycle of erosion.

## PLEISTOCENE GEOLOGY

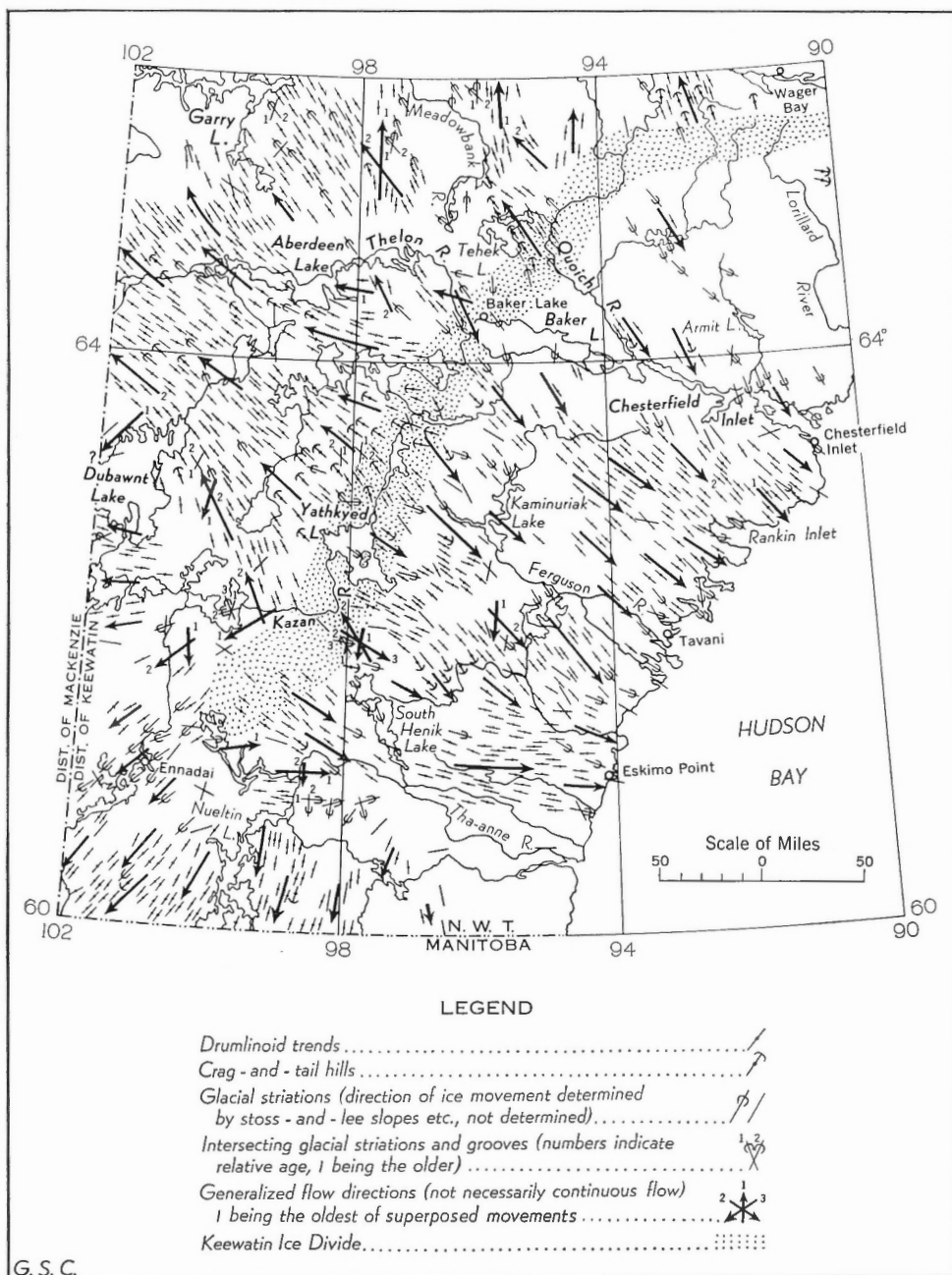
### Glacial Features That Indicate Directions and Relative Ages of Ice Motion

The position of the Keewatin Ice Divide (Lee, Craig, and Fyles, 1957) is shown in Figure 3. The ice divide is a linear zone stretching from Hudson Bay at lat.  $66^{\circ}$  to a point 150 miles inland at lat.  $61^{\circ}$ . The principal directions of glacial flow, shown by directional ice-flow features, were southeastward between the divide and Hudson Bay, northwestward to northward between the divide and the Arctic coast, and southward to westward around the southern end of the divide.

Clear evidence of the southeastward glacier flow between the divide and Hudson Bay was noted at Chesterfield Inlet, Tavani, Maze Lake, Padlei, Nueltin Lake, and other places.

Miniature crag-and-tail forms occur on the surface of many rocks in the northeastern part of the region, near the settlement of Chesterfield Inlet. There granite dykes form hard protuberances about 4 inches wide and a half inch high. These protuberances were more resistant than the surrounding mixed granitic and metamorphic rocks to the wear of the debris in the basal part of the ice-sheet. A protected raised tail of softer rocks has been left by the last glacial flow on the southeast or lee side of the dyke. The miniature crag-and-tail forms in the east-central part of the region near Tavani, are formed of hard epidote zones a foot to 2 feet long and a fraction of an inch high with a raised platform of the protected, softer granite and granite-gneiss left on the southeast, lee side. In the south-central part of the region, near the north end of Nueltin Lake, hard quartz and feldspar grains in a conglomerate form local prominences with protected tails of softer matrix rock stretching eastward. The miniature crag-and-tail forms indicate the direction of basal flow in the ice-sheet. Flow of this kind may be local where the terrain is rugged, but in most of southern Keewatin there is only minor local relief. The forms occur everywhere over this large area and all indicate southeastward glacial motion between the ice divide and Hudson Bay. They, therefore, represent the general movement of the last active ice in that region.

The crag-and-tail hills are composed of a bedrock crag and a tail of unconsolidated materials, and form part of the drumlinoid fields. The crag-and-tail hills shown in Plate VII A are in the east-central part of the region near Padlei. They confirm the southeastward direction of ice-flow on the east side of the ice divide.



**Figure 3.** Position of Keewatin Ice Divide as interpreted from ice-flow markings (crag-and-tail hills, stoss slopes, etc.). From Lee, in Lord 1953a; and Fyles, in Wright 1955.

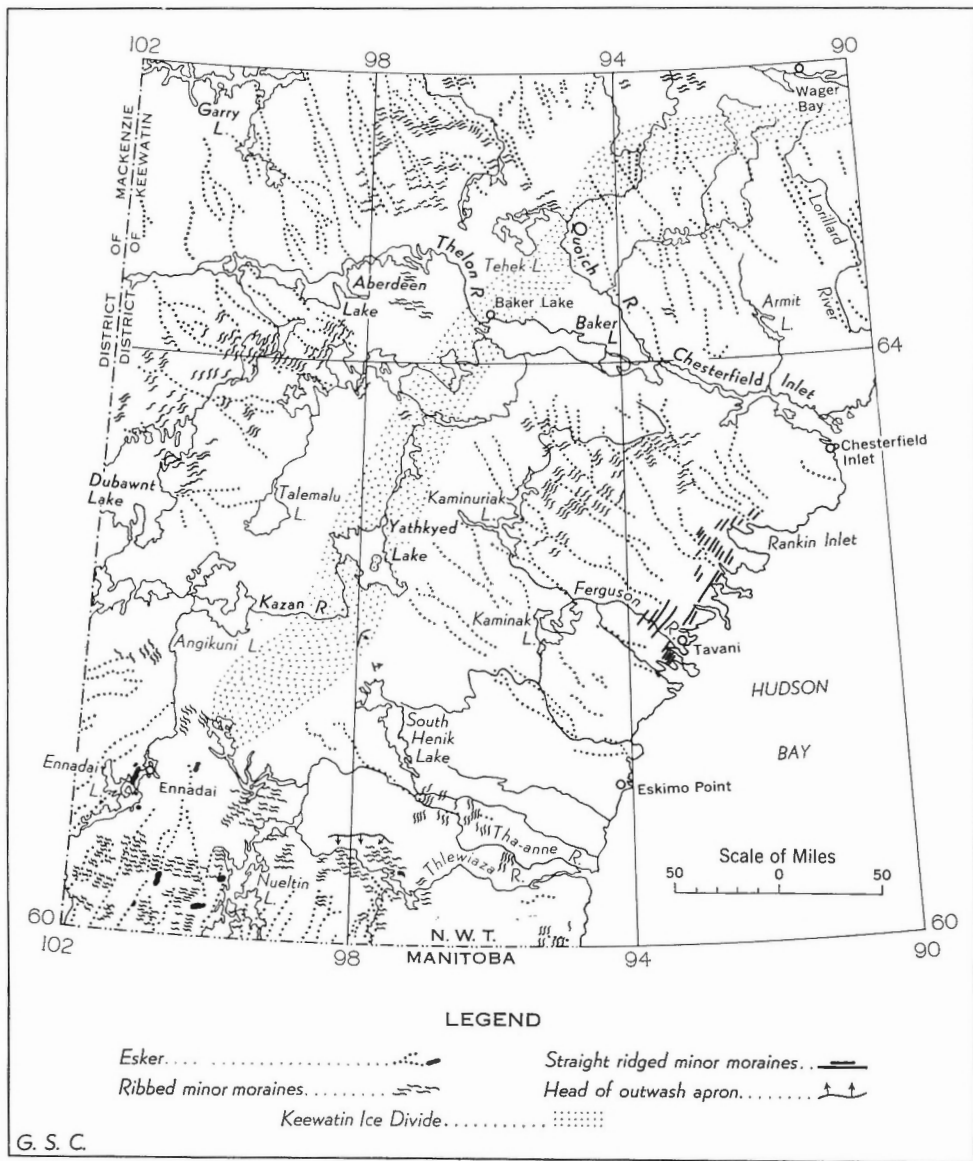


Figure 4. Position of Keewatin Ice Divide as indicated by ice-retreat features. (From J.G. Fyles and H.A. Lee, unpublished maps.)

## Surficial Geology Keewatin and Keewatin Ice Divide

Glacial groovings on the stoss slopes of hills are well displayed east of the divide in the central part of the region between Tavani and Maze Lake. The rolling bedrock surface was dissected prior to the last major glaciation into canyons 5 to 30 feet deep that were transverse to the movement of the last glaciers in the area. The glacier grooved the northwest-facing slopes as it moved southeastward towards Hudson Bay (*see* Plate V A). The grooved stoss slopes can readily be seen from low-flying aircraft and leave no doubt as to the direction of ice motion.

The transport of glacial erratics was southeastward near Padlei where andesite erratics from a source to the northwest rest on granite. The number of erratics decreases rapidly with increased distance southeast from the source.

The southward to westward direction of glacial flow around the southern end of the ice divide has been determined at Ennadai, Nueltin Lake, Angikuni Lake, and other places. Miniature crag-and-tail forms in the southwestern part of the region, near the army post of Ennadai, are composed of feldspar prominences with granite tails. The feldspar grains are worn, rounded, and striated on the northeast side but on the southwest side they are followed by small tails of granite. The distribution of glacial erratics near Ennadai confirms this southwestward motion, as there is an abundance of diabase erratics on the southwest side of a diabase dyke and a rapid decrease in the number farther southwest. Glacial grooves on the northeast side of ice-contact hills south of Ennadai (*see* Plate VI) also show this to be the last direction of glacial flow.

The bedrock surfaces near Nueltin Lake reveal both easterly and southerly sets of striations. Miniature crag-and-tail forms in this general region, as already mentioned, indicate an eastward ice movement and this evidence is supported by the orientation of *roches moutonnées*. Nevertheless, southward glacial flow is clearly indicated by glacial scorings lightly inscribed in the rocks. This southward flow is the latest and is recorded by boulder pavements on the north side of east-trending drumlins, by tails of drift on the south side and around both ends of these drumlins, and by a north-south orientation of the long axes of erratics. The directions of elongation and underside striations of scattered erratics resting on a bare, glaciated rock surface near Nueltin Lake were determined. Each elongated erratic, fifteen in all, was examined from a flat polished surface about 20 feet square. The long axes of all were found to be aligned parallel to the north-south set of bedrock striations. Also the most pronounced set of striations on the soles of the boulders was similarly aligned. These striations, therefore, clearly



represent the latest ice movement in the area. The relationships indicate that the erratics are not of ablation origin, but were transported in the basal ice.

Both southwestward and northwestward glacial movements on the west side of the ice divide are recorded in the rock surfaces in the northwestern part of the region at Angikuni Lake. Some of the rock bosses are faceted on three sides, with each planed surface bearing a differently oriented strong set of striations. The oldest set trends  $S10^{\circ}E$ , a younger set  $S65^{\circ}W$ , and the youngest set  $N30^{\circ}W$ . The direction of movement was determined by stoss-and-lee slopes and the relative ages by superposition of striations, where striations of a younger advance impinged against the far side of the grooves of an older advance.

The earliest glacial flow of  $S10^{\circ}E$ , recorded at Angikuni Lake, has been noted at other places on both sides of the ice divide (*see* Figure 3) and is therefore older than the divide and independent of it. This early southward ice flow is the oldest recorded evidence of glacial flow wherever it has been found, both in rock-inscribed features and from the distribution of erratics. Stones in the till, west of the ice divide, have been transported southward from a source near Dubawnt Lake (Tyrrell, 1898, p. 127F) whereas in approximately the same region younger erratics lying on the surface have been transported southwestward away from the divide.

### Products of Glaciation

#### *Till*

The till cover is sporadically distributed in southern Keewatin. On both sides of Chesterfield Inlet it is mainly absent; in many places it is scanty and in only a few places is it thick. Weeks (1933, p. 66C) reported till 10 to 35 feet thick exposed in cuts along Maguse River, about 12 miles inland from Hudson Bay. Tyrrell (1898, p. 136F) reported "precipitous naked cliffs of red till" along the Kazan River between Angikuni and Yathkyed Lakes. Much of the till observed in the course of the present study appeared to vary with the bedrock from which it was derived. In areas of granite and granite-gneiss the till is gravelly and loosely compacted, with large boulders and shattered rock covering much of the surface; in the area of volcanic and dolomite rocks, on the other hand, the till contains much clay.

Drumlinoid forms are developed on considerable areas of the till plain. Between Hurwitz Lake and Ennadai Lake the height of the drumlinoid ridges is estimated to be 50 to 75 feet and near Ray Lake, where the ridges are best developed, they may be as high as 150 feet. Between Kaminak Lake and the settlement of Chesterfield Inlet a field of drumlinoid ridges shows distinctly on the air photographs. From low-flying aircraft, however, they

## Surficial Geology Keewatin and Keewatin Ice Divide

appear to have a relief of only a few feet, the clear outlines in the air photographs being due to differences in vegetation. Drumlinoid features as interpreted from air photographs, therefore, include whale-back hills ranging in height from a few feet up to 100 or more feet, and in shape from the cigar-shaped or elliptical body a mile to 2 miles in length of the typical drumlin to elongated forms many miles in length.

A ribbed type of landscape, produced by minor moraines, is discernible on air photographs of the region, and constitutes about 10 per cent of the land area. This ribbed pattern forms a 'U' around the ice divide as shown in Figure 4. This type of landscape was examined on the ground at two localities. The first locality is south of Watterson Lake in the central part of the area, lat.  $61^{\circ}01'N$  and long.  $99^{\circ}25'W$ . The ridges trend east, and from the air appear to be fairly regularly 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  $1\frac{1}{2}$  feet. The erratics are mainly of the same composition as the local bedrock, being about 70 per cent granite and granite-gneiss, 20 per cent greenstone, and 10 per cent dolomite and conglomerate. A hole dug to a depth of about 2 feet exposed a till with an estimated composition, excluding boulders, of 70 per cent sand, 10 per cent silt, and 20 per cent clay.

The second locality examined on the ground is in the northwestern part of the region, about 28 miles northeast of the army post of Ennadai (see Plate X A, B). Ridges up to a mile in length trend in a general north-south direction transverse to ice motion as deduced from striations. The west sides of the ridges are composed of blocks lying at the angle of repose. The east sides are less steep and consist of till into which most of the boulders appear to be impressed, some bearing striations on their exposed sides. These striations are parallel with the local direction of ice flow. In between the ridges is a felsenmeer of shattered rock.

The ribbed topography (minor moraines) appears to represent shear moraines, the active ice coming from the direction of the ice divide. Everywhere the drumlinoid ridges are at right angles to the minor moraines, and as the moraines were made during deglaciation, the drumlinoid ridges were also probably made at that time. Both features probably were formed close to the ice-front and represent the final movement of the ice in this region

during the last phase of ice recession. In places the drumlinoid ridges are superimposed on the up-glacier side of the minor moraines or there is other evidence of active ice flow.

A belt of straight-ridged minor moraines that differs from the ribbed type described above lies about 6 miles inland from Hudson Bay near Corbett Inlet. The straight-ridged moraines are more linear and more evenly spaced than the ribbed moraines, and are superimposed on the drumlinoid ridges (*see* Plate XI). Unlike normal beaches, with which they may be confused on air photographs, they rise over the hills rather than encircle them. Similar moraines from Quebec, called washboard moraines, have been described by Mawdsley (1936, Plate 1). The spacing between successive ridges, 400 to 1,100 feet in Keewatin, compares to the spacing of 600 to 1,500 feet for the ridges in Quebec. Moraines of this type have been thought by some geologists to represent annual deposits and, if so, the rate of retreat of the ice-margin west of Hudson Bay in the region of these moraines was about 800 feet a year. However, the annual nature of these ridges has not been proved and any proposed geochronology is not justified.

### ***Glacio-fluvial Sand and Gravel***

Eskers in Keewatin are conspicuous and prominent features of the landscape. They occur as single sinuous ridges, multiple ridges, and as chains of beaded segments. They wind like railway embankments for long distances parallel to the direction of the ice-flow features. Most of the esker systems head at the edge of the Keewatin Ice Divide, where they begin as dendritic drainage channels free of deposits. This lack of deposition close to the ice divide, which in places extends for several miles from it, indicates a shortage of the englacial debris necessary for the formation of eskers in the ice-sheet there. The depositional part of the esker system is farther away from the ice divide and is within, and downstream from, the region of minor moraines (thrust moraines). It is probable that in this depositional area debris was brought up along thrust planes in the glacier to produce most of the vast quantities of englacial and superglacial materials necessary for esker building. The dendritic, branching pattern of the eskers themselves shows that the slope of the ice top was southeastward, between the ice divide and Hudson Bay, and southward to westward around the southern end of the ice divide.

The most abundant and the longest eskers are those that spread southwestward from the divide area. There most eskers are single ridges, similar in cross-section to a railway embankment and as much as 75 to 200 feet high. In places the eskers occur as multiple ridges separated by elliptical and circular depressions. At intervals along their length are enlargements that

## **Surficial Geology Keewatin and Keewatin Ice Divide**

expand outwards and upwards, and terminate as deeply pitted plateaux. Abandoned drainage ways are shown by areas of scoured drift parallel to the eskers and between disconnected segments of the esker ridge.

In the region of ribbed minor moraines, there is a series of open drainage channels and occasional short eskers that meet the main esker at right angles. Both the open channels and the short eskers appear to be related to the minor moraines.

In the area of the straight-ridged minor moraines, the eskers occur as chains of isolated conical hills spaced at more or less regular intervals of 450 to 1,000 feet. Similar beaded eskers elsewhere have been interpreted as indicating successive annual positions of an ice-margin in a large body of water.

The former positions of two ice-margins, one south of the Keewatin Ice Divide and the other east of it, are shown in Figure 4. The position of the former ice-margin south of the divide area is known from a series of isolated gravel hills that form kames about 20 feet high and that lie in a narrow zone stretching easterly. The tops of these hills contain circular pothole depressions and from these depressions dry, drainage channels lead south. The hills and their depressions and outlet channels are clearly the work of meltwater from the ice-cap. They mark the head of an outwash apron that stretches southward away from the former ice-front. Several remarkable boulder streams lead southward from near the eastern end of this part of the ice-margin as mapped. The boulder streams begin abruptly on nearly level ground presumably at the former ice-margin and follow a gentle slope away from this position, each to end in an alluvial fan that forms part of a succession. The position of the ice-margin on the east side of the ice divide has also been determined by the presence of kames with small circular and abandoned channels that demand an ice-marginal origin.

Eskers are accepted by most, if not all, geologists as late features of glaciation. Their radial distribution and dendritic pattern from the Keewatin Ice Divide, fix the divide as a late feature of glaciation. The two former ice-margin positions further show that the glacier margins had retreated northward around the southern end of the ice divide, and northwestward around the east side of the ice divide.

### ***Glacial Lakes***

Around the shores of many of the lakes, and raised above the present lake-levels, are wave-cut cliffs, beach ridges, spits, bars, and similar features, all of which bear evidence that the present lakes were at one time larger. In addition to these once-larger lakes there was also a glacial lake that

included within its basin the areas presently occupied by part of the Kazan River and the present lakes Ennadai, Kasba, and others. This Pleistocene lake, at its maximum extent, is here named glacial Lake Kazan (*see* Figure 5).

The normal northward drainage of glacial Lake Kazan was blocked by glacial ice at a time when the southern ice-margin was some 55 miles north of Ennadai post, near the position now marked by a major spillway. South of the spillway, strand lines of Lake Kazan are present up to 240 feet above the level of Ennadai Lake, or 1,260 feet above sea-level. North of the spillway the high strand lines are absent. Most of the Lake Kazan strand lines are beach ridges, some of which have been continuously traced for several miles. Other strand lines are marked by wave-cut terraces, which are less prominent than the beach ridges but relatively frequent. The bottom deposits of glacial Lake Kazan were not seen; instead, the bottom of the basin is rock or ground moraine.

The position of glacial Lake Kazan and its spillway to the north establishes the areas around the ice divide that first became free of glacial ice, and hence can be related chronologically to the history of the shrinking ice-margins. Inasmuch as the strand lines on the east side of present-day lakes Ennadai and Kasba are near the crests of hills, it is probable that glacial ice formed part of the east shore of glacial Lake Kazan.

### ***Marine Submergence***

The variety of coastal features, the abundance of sea shells, and the contrast between land that was dry and land that was submerged in Pleistocene time are remarkable in southern Keewatin. Gravel bars and spits are formed around many of the local prominences and along the edges of eskers. Hills that were formerly islands are marked by successive rows of long continuous beaches such as those shown in Plate VIII. Other high areas, such as the drumlinoid ridges, are terraced, and the fine materials have been washed from the tops of the ridges and concentrated in the larger depressions.

The shore facies of marine sediments are present from the maximum inland extent of the Pleistocene sea to the present coast. This distribution shows that these features were formed during a falling sea-level and much of the glacial drift must have been reworked by coastal currents at this time. Evidence of only one halt in the emergence of the land from the sea was noted. About 90 miles from the present coast there is a marked change in topography that reflects a change in the character of the underlying marine deposits. West of this line, the dominant marine deposits are sand and gravel of the shore facies, reworked drift forming much of the remaining surface. East of the line, however, the dominant marine deposits are silt and clay



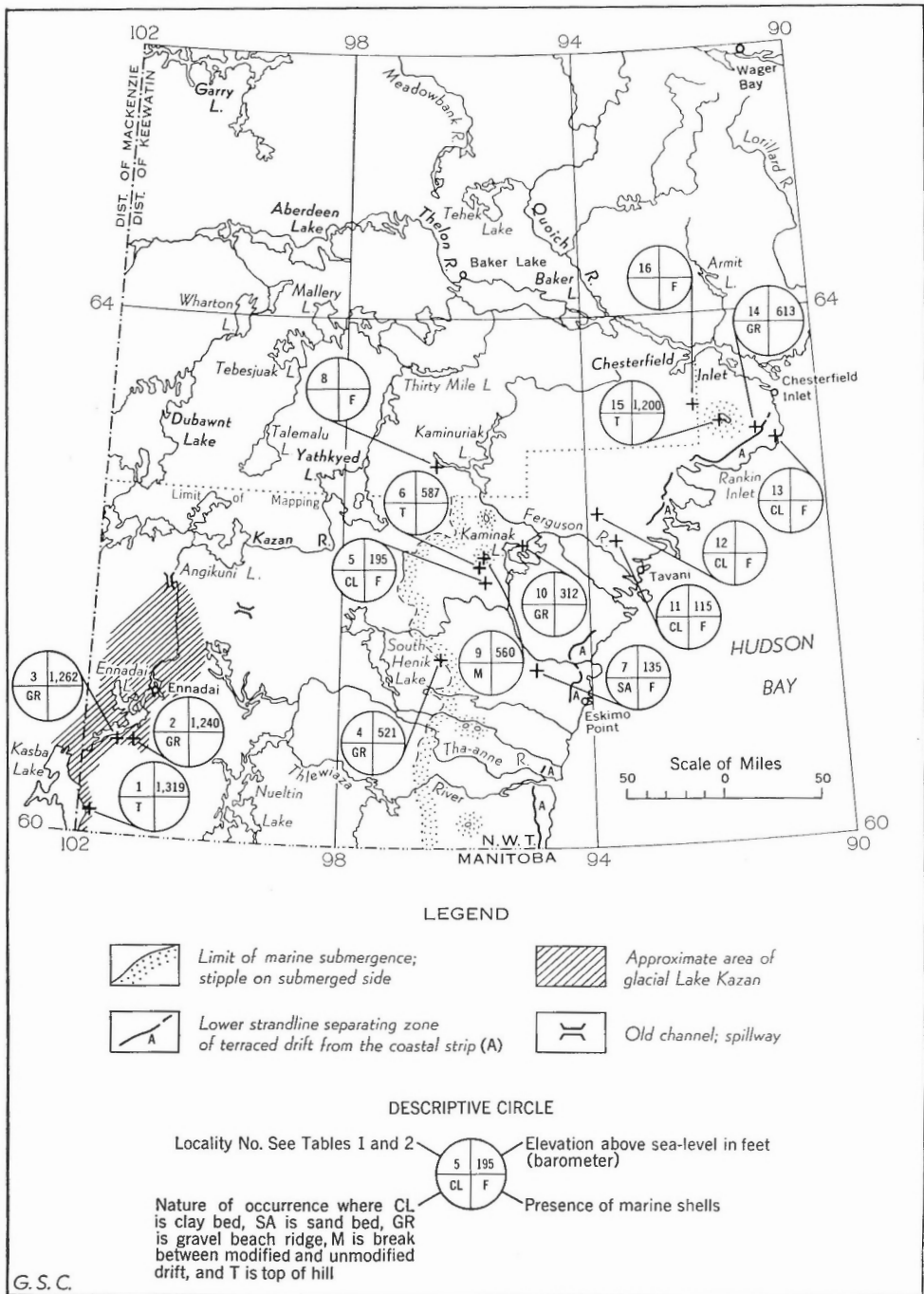


Figure 5. Major Pleistocene submergences in southern District of Keewatin, Northwest Territories.

of the deepwater facies. The composite stratigraphic sequence within the area of marine submergence is glacial drift overlain by silt and clay, overlain in turn by sand and gravel.

The highest former stand of the sea was about 613 feet. This is indicated by cobble beach ridges near the present coast south of the settlement of Chesterfield Inlet. Farther inland near Carr Lake the elevation of the highest strand line is only 560<sup>1</sup> feet. This is indicated by a change from ground moraine along one edge of a wave-pitted, rock-scoured area, to a zone of reworked till, cobble beach ridges, and clay on the other side of the scoured area. Marine shells were found in a frost boil about half a mile from the rock-scoured area. There is little doubt that the 560-foot elevation marks the maximum stand of the sea at that inland position. Assuming both strand lines (613 feet and 560 feet) to have been formed contemporaneously, the upwarping must have been greater at the coast than inland. This would indicate the greater thickness of ice to have been in Hudson Bay at maximum glaciation. In a similar manner the elevations of the maximum inland incursion of the Pleistocene sea increase from north to south (Fyles, *in* Wright, 1955, p. 4) and indicate that the greatest thickness of Pleistocene ice was towards the southern part of Hudson Bay. However, the assumption that both strand lines were formed contemporaneously cannot be proved. An alternate explanation can be given for the different elevations of the highest strand lines. Possibly the oldest strand lines are near the coast and in the southern part of the area, and these were formed while the northern and inland areas were still covered by glacial ice. By the time the latter areas had become ice free and strand lines were formed some uplift had already taken place and had raised the elevation of land under the old strand lines. The problem then remains as to whether the tilt of the raised beaches is towards or away from Hudson Bay.

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<sup>1</sup> Elevation and location are revised from Lee, *in* Lord 1953a, p. 2 and Figure 1.

## Surficial Geology Keewatin and Keewatin Ice Divide

*Table 1*  
*Depths of Submergences*

Locality	Height Above Sea-Level (feet)	Description
<b>A. Lake Submergence</b>		
1 (Quinn)	1,319	Top of hill; below this is a sequence of gravel beach ridges; local base Kasba Lake at 1,093'
2 (Lee)	1,240	Gravel lake beach; another beach about 20' lower; local base Ennadai Lake at 1,021'
3 (Lee)	1,262	Lake terrace; sequence of lower lake terraces and gravel beaches at 1,240', 1,222', 1,217'; local base Ennadai Lake at 1,021'
<b>B. Marine Submergence</b>		
4 (Lee)	521	Gravel bar near maximum inland distance of marine submergence; local base Maguse Lake at 134'
5 (Lee)	519	Flat summit and minor beach ridges on top of esker; sequence of lower wave-cut scarps on side of esker at 514', 512', 477'; clay beds with marine shells near base of esker; local base Carr Lake at 199'
6 (Lee)	587	Top of hill, unsubmerged during post-glacial marine submergence; local base Carr Lake at 199'
9 (Lee)	560	Contact between quartzite bedrock washed and scoured by wave action and solifluction lobe overlapping from unsubmerged hill crest; top of hill at 593' was unsubmerged; highest gravel bar at 561'; sequence of lower boulder terraces at 553', 545', 534', 523', 510', 494', 470'; local base Carr Lake at 199'
10 (Lord)	312	Cobble beach; local base Kaminak Lake at 182'
14 (Lord)	643	Top of hill; cobble beaches estimated to be 30' below top of hill; strand line at about 613'; local base Chesterfield Inlet at sea-level
15 (Quinn)	1,200	Top of hill; elevation estimated from helicopter altimeter; unreliable, but gives order of magnitude of highest hills in region; no information on strand lines

Table II

## List of Shells Collected From the Deposits of the Pleistocene

Marine Submergence in Southern Keewatin<sup>1</sup>

(See Figure 5 for locations)

- 5 (Lee)  
 Pelecypoda  
*Clinocardium ciliatum* (Fabricius)  
*Hiatella arctica* (Linné)  
*Serripes groenlandicus* (Bruguiere)
- Gastropoda  
*Buccinum tenue* Gray  
*Buccinum* sp.  
 3 indet. gastropods
- Crustacea  
*Balanus crenatus* Bruguiere
- 7 (Lee)  
 Pelecypoda  
*Astarte* cf. *A. crenata* Gray  
*Clinocardium ciliatum* (Fabricius)  
*Hiatella arctica* (Linné)  
*Mya truncata* (Linné)
- Crustacea  
*Balanus crenatus* Bruguiere
- 8 (Collected by W. P. McGill, and submitted by Lord and Lee)  
 Pelecypoda  
*Hiatella arctica* (Linné)
- Gastropoda  
*Acmaea patina* Eschacholtz  
*Buccinum* cf. *B. ciliatum* Fabricius  
*Buccinum* spp.  
*Tachyrhynchus* sp.
- Crustacea  
*Balanus crenatus* Bruguiere

<sup>1</sup>Shells identified by Frances Wagner, Geological Survey of Canada.

## Surficial Geology Keewatin and Keewatin Ice Divide

- 11 (Lee)  
Pelecypoda  
*Astarte* cf. *A. arctica* Gray  
*Astarte* spp.  
*Chlamys islandicus* (Müller)  
*Clinocardium ciliatum* (Fabricius)  
*Hiatella arctica* (Linné)  
Brachiopoda  
*Hemithyris psittacea* (Gmelin)
- 12 (Eade)  
Pelecypoda  
*Hiatella arctica* (Linné)
- 13 (Quinn)  
Cliffs up to 30 feet high on north bank of a river. Strata of silt, fine sand, and clay in horizontal beds. A few shells observed, but none collected
- 16 (Quinn)  
Shells present, but none collected

### History

The District of Keewatin is the region first proposed by Tyrrell (1898) to have contained the centre of dispersal for a major ice-sheet—the Keewatin ice-sheet. This sheet, at its maximum extent, was supposed to have reached the southern border of Wisconsin drift in northern United States. The hypothesis that this region was a centre for a separate major ice-sheet has been queried, mainly because of its low elevation and low precipitation. According to Flint, 1943, the North American continental ice-sheet began in the highlands of Quebec and Labrador and the mountains of Baffin Island, and spread westward across this Keewatin region. In later years reports on the directions of glacial flow in this region were conflicting. From a plot of drumlinoid ridges as they appear on aerial photographs numerous writers, such as Downie, Evans, Wilson (1953), Bird (1953), Dean (1953), and, indirectly, Taylor (1956), concluded that glacial flow was northwestward out of Hudson Bay. This appears to support the concept of the westward movement of the Laurentide ice-sheet.

Lee (*in* Lord, 1953a, p. 2, Figure 1) showed that rather than the drumlinoid ridges indicating a northwestward movement out of Hudson Bay, the rock-inscribed features indicate a southeastward flow, between a linear zone (Hicks Lake to Ferguson Lake and probably beyond) and Hudson Bay. Around the southern end of this linear zone the flow of glacial ice was shown by Lee to be southward to westward and on the west side northwestward.

Neil and Putnam (1955) from field observations confirmed the flow on the east and west side of the linear zone. They further correctly extended the linear zone to the north using the data of Lee (*in* Lord, 1953a) and the plot of drumlinoid ridges of Bird (1953).

Fyles (*in* Wright, 1955, p. 3, Figure 1) mapped the extension of the linear zone shown by Lee and called this linear zone an ice divide. He interpreted the ice divide as the zone into which the last glacial ice retreated. He further showed the movement on the west side of the ice divide to have been northwestward to northward.

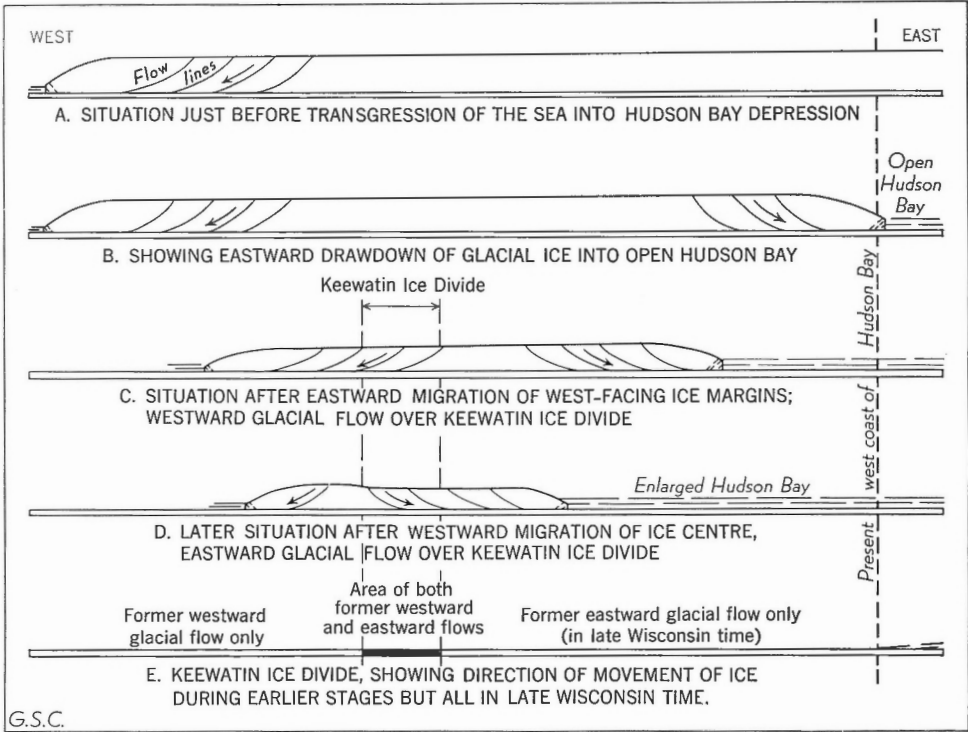
Wilson (1955) concluded from airphoto studies that an ice divide existed in a position similar to that suggested by Lee (*in* Lord, 1953a) and Neil and Putnam (1955), and further showed two long offshoots from near the southern end of the linear zone which he inferred are also ice divides. One of these stretches to the northwest from Yathkyed Lake to Great Bear Lake and the other to the southeast from Yathkyed Lake to Churchill.

Flint (1956, p. 281) suggested that a reconstituted glacier existed in the region of the ice divide. He based this hypothesis on reports from two localities, one from either side of the ice divide, of glacial debris overlying organic material. Radiocarbon dates for the organic material from both localities were about the same.

Lee, Craig, and Fyles (1957, p. 1760) defined the Keewatin Ice Divide as the zone occupied by the last glacial remnants of the Laurentide ice-sheet west of Hudson Bay. The minor moraines, eskers, and most glacial flow features record the trends of successive ice movements near the margin during deglaciation.

The sequence of glacial events deduced from the field observations is as follows. As the Laurentide ice-sheet waned in northwestern Manitoba the glacier margins first retreated northward and northeastward. Glacial ice still remained in the north with its southern margin 55 miles north of Ennadai post at a position where there is now an abandoned major spillway. The normal northward flow of streams was blocked by glacial ice, and proglacial lakes such as Lake Kazan were formed. Later the ice-margin west of the Keewatin Ice Divide retreated towards it, and lake levels dropped (*see* Figure 6A) as escape routes opened. On the east side of the Keewatin Ice Divide, the northward retreat of the ice-margin changed to a northwestward retreat. This change of flow took place in a broad zone between the Thanne and Thlewiaza Rivers where the two directions of ice flow are at sharp angles and superimposed. The change was probably caused by the sea breaking through Hudson Strait into Hudson Bay and drawing the glacial

**Surficial Geology Keewatin and Keewatin Ice Divide**



**Figure 6.** Cross-section of an ice-sheet illustrating ideally the late glacial history leading to the development of the Keewatin Ice Divide.

ice down from the northwest into the then-deep water of Hudson Bay (see Figure 6B). As the westward-facing ice-margin migrated to the east, ice overlying the Keewatin Ice Divide flowed to the west (see Figure 6C). This is indicated by the westerly orientation of the *older* set of striations and other similarly oriented rock-inscribed features. Rapid flow of ice into the newly opened parts of Hudson Bay must have decreased the thickness of the eastern part of the ice-sheet. This would have caused the centre of the ice-sheet to migrate westwards (see Figure 6D) so that the flow of the ice over the Keewatin Ice Divide changed from west to east. This is shown by the direction of the *youngest* striations and rock-inscribed features. The position of the Keewatin Ice Divide is thus established by features left by the ice-sheet. These trend westward only, west of the divide, southeastward only, east of the divide, and in both directions within the area of the divide (see Figure 6E).

Because the Keewatin Ice Divide is the final position of the wasting ice-sheet, it is outlined not only by the features of late glacial flow, but also by those of the late glacial recession. This is clear from the consistent relationships of the trends of drumlinoid features to those of minor moraines and esker systems, and more particularly of the trends of all three to the outline of the ice divide itself. Still another line of evidence helps to establish the late age of the Keewatin Ice Divide. The early movement of the ice was southerly on both sides of the ice divide and was therefore independent of it. This early southward flow of ice is the oldest recorded evidence of glacial flow wherever it has been found, both in rock-inscribed features and from the superposition of strata containing index erratics.

The glacial landforms now visible in southern Keewatin are features formed during the waning stages of glaciation. There is no field evidence to indicate that the Keewatin Ice Divide was active during the initial and maximum stages of Wisconsin glaciation, in fact evidence to the contrary has already been cited. It must be concluded that, as the landforms and rock-inscribed features were formed late in the period of glaciation, they cannot be used as evidence for a Keewatin continental ice-sheet that grew in situ, as was proposed by Tyrrell (1898). There is, indeed, no direct field evidence from which may be inferred the sequence of events in this region during the initial stages of Wisconsin glaciation.

The southeastern offshoot from the Keewatin Ice Divide shown by Wilson (1955, and *in* Flint, 1957, pp.154 and 315) and inferred to be an ice divide can be satisfactorily explained as the region where glacial flow changed from behind northward-retreating ice-margins to behind northwestward-retreating ice-margins, this change being caused by the entrance of water into the Hudson Bay depression and a resultant accelerated flow of glacial ice from the northwest towards the new ice-margin standing in the then-deep water of Hudson Bay. The northwestward-trending offshoot from the Keewatin Ice Divide, which Wilson (1955, and *in* Flint 1957, pp. 154 and 315) also believed to be an ice divide, is in the same position as the southern margin of ice late in the Wisconsin. This is clear from evidence that glacial Lake Kazan was dammed by ice along that line; a condition that Craig (*in* Wright, 1957, p. 5) noted also for other lakes farther west. Indeed it may be questioned whether even the evidence gained from the study of air photographs lends support to the hypothesis that these linears are ice divides. It can clearly be seen that the flow of the ice was, in many places, parallel with the linears instead of away from them in both directions as would have been the case if they had truly been ice divides. There seems no reason, therefore, in the light of what is now known, to regard either of these offshoots as an extension of the ice divide.



## Surficial Geology Keewatin and Keewatin Ice Divide

Late nourishment caused local expansions of the remnant of the ice-cap, these late advances taking place mainly around the southern end of the ice divide. That these advances took place is indicated by features indicative of the latest movement and these are: southern alignment of long axes of erratics superimposed on bedrock that in the main shows east-west flow of the ice; drift tails around the ends of easterly oriented drumlins; and flutings on the north sides of ice-contact deposits. Northwest of the ice divide Taylor (1956, p. 954) cited "pro-glacial" silt overlying organic matter as evidence for the last ice-advance. The age of the peat determined by carbon-14 analysis is  $4,140 \pm 150$  years (Y-261). Flint (1956, p. 281) used this evidence for his hypothesis of a reconstituted glacier over the ice divide. The evidence however hinges on the interpretation of the origin of the silt as proglacial. This interpretation is questioned by Craig (*in press*) who describes a site in the Thelon Valley to the south where organic matter dated at  $5,500 \pm 250$  years B.P. (L-428) is in a pingo formed out of flood plain alluvium and indicates a climate that was warmer than at present and ice free considerably earlier. Craig's interpretation of the geology of the site is incompatible with the interpretation of the proglacial origin of the silt. He suggests that the whole section enclosing the peat at site Y-261 may well have resulted from nonglacial fluctuations of the Back River.

The other evidence, the presence of till overlying peat dated at  $5,220 \pm 340$  years B.P. (Y-231), is more difficult to explain. Obviously the peat was formed on land that was at the time free of both ice and the sea, and yet there is evidence in the beaded eskers that the sea was in contact with the ice-front all during deglaciation. In other words, the sea appears to have followed the ice-front as the latter retreated across the land, and the region near Rankin Inlet from where the peat is reported, must have been, at the late stage of deglaciation, fully 600 feet under the sea. The peat, therefore, could not have started to form until some time after the withdrawal of the sea from the vicinity. Only a marked glacial advance could have overrun the area and left till overlying the peat and the evidence is all against a late advance of the ice of this magnitude. Beach ridges, bars, and spits, all witnesses left behind after the retreat of the sea, show no sign of having been overridden by any such ice-sheet. Two possibilities are left. The peat may be pre-Wisconsin in age and the radiocarbon date wrong. An error of this magnitude is however unlikely and more probably the explanation is that the position of the till over peat was caused by frost action, with either the till rising and spreading over the peat or the peat sinking and being buried as the whole mass slowly flowed. If this is so, there remains

no clear evidence for a reconstituted glacier in this region.<sup>1</sup> All other facts can be explained by the concept that the Keewatin Ice Divide was a late remnant feature of the Laurentide ice-sheet west of Hudson Bay and that it received nourishment nearly to its end. The glacial ice did not stagnate but rather the ice-margins withdrew with minor forward pulsations.

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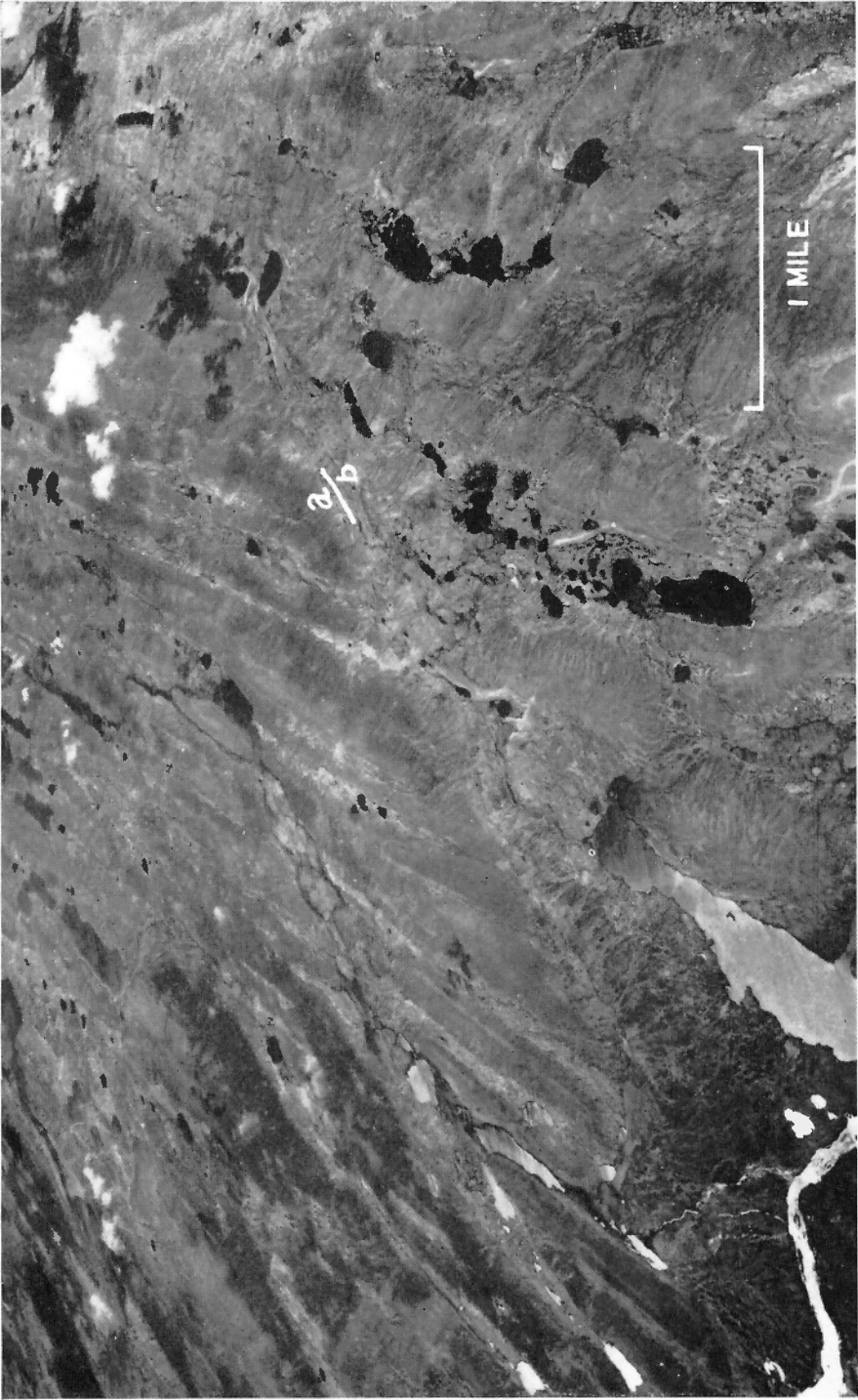
<sup>1</sup> Since going to press, a radiocarbon date of  $6975 \pm 250$  years B.P. (Sample number LC-53 -172, dated by Isotopes Inc.) was obtained on shells from surface marine clays in this same area of marine submergence. Undisturbed till in the area underlies the clay and hence is older than 6975 years B.P. The peat at site Y-231 is younger than both the time of last glacial ice and the time of marine submergence. (Location of dated shell site is in a river-cut a mile south of Carr Lake, lat.  $62^{\circ}01'N$ , long.  $95^{\circ}42'W$ . Barometer elevation of shells is 210' A.S.L. High strand lines nearby are at 560' A.S.L.)

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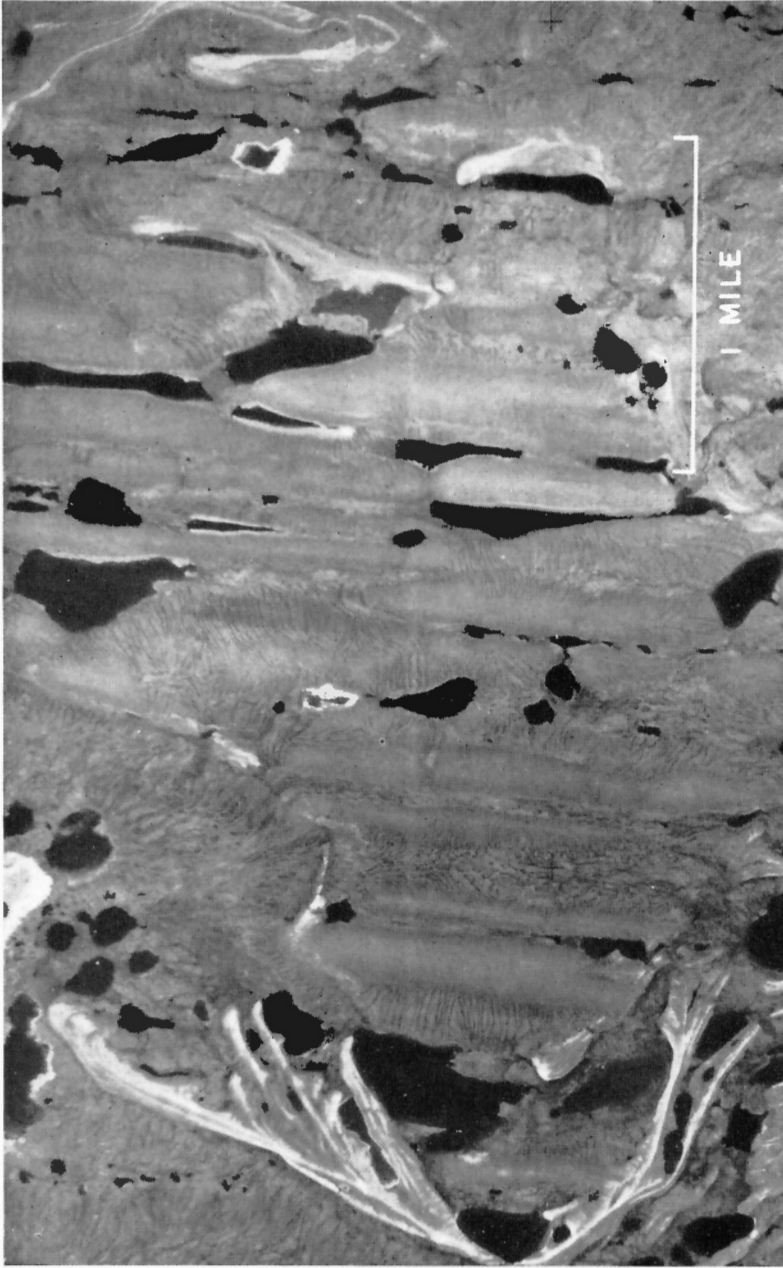
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RCAF T296L-212  
*Plate II.* Textural changes across limit of Pleistocene marine submergence; (a) area above submergence, (b) area formerly submerged. (Looking west.)



RCAF A12846-186

Plate III. Giant spits developed around a former foreland of drumlin hills. (Right is north.)



RCAF T77L-6

Plate IV. Coastal plain showing the break between the coastal strip (a), and the zone of terraced drift (b). Looking west.





H.A.L., 23-5-52

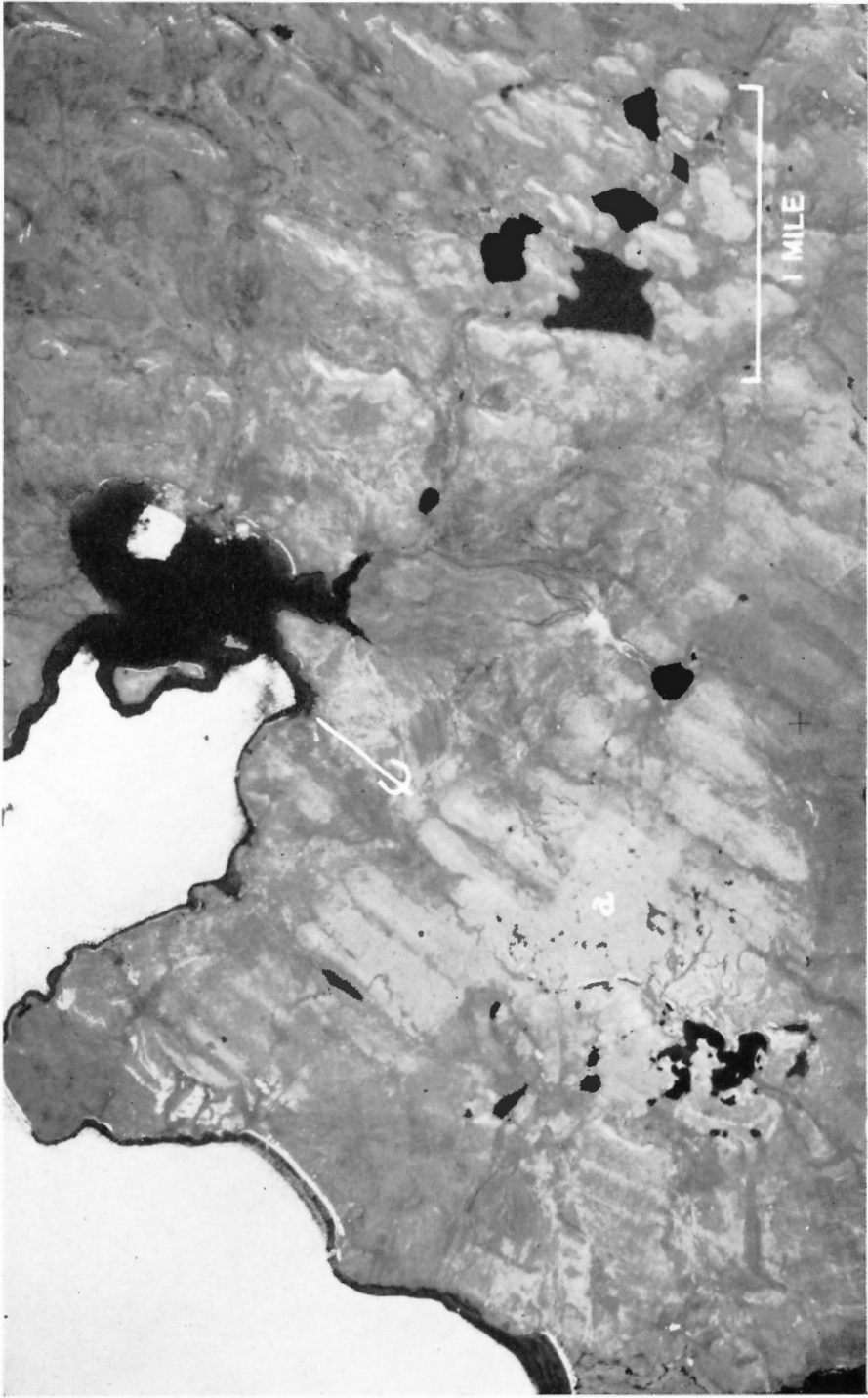
- A. Glacial grooves on the northwest side of a bedrock hill north of Tavani, near Maze Lake. (Ice-movement was from left to right.)

*Plate V*

- B. *Roches moutonnées* south of Ennadai post. (Ice-movement was from left to right.)

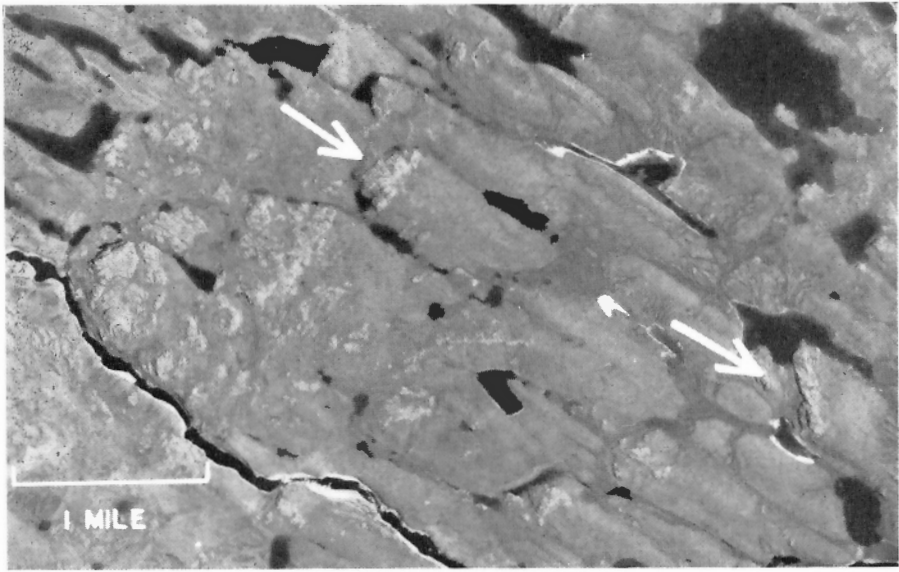


H.A.L., 6-4-52



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Plate VI. Overrun ice-contact deposit (a) south of Emadai post. (Top is north.)



RCAF A14379-32

- A. Crag-and-tail hills near Padlei. (Ice-movement was from top left to bottom right.) Top is north.

*Plate VII*

- B. Beach ridges of glacial Lake Kazan, on the east side of Kasba Lake.



H.A.L., 29-29-52

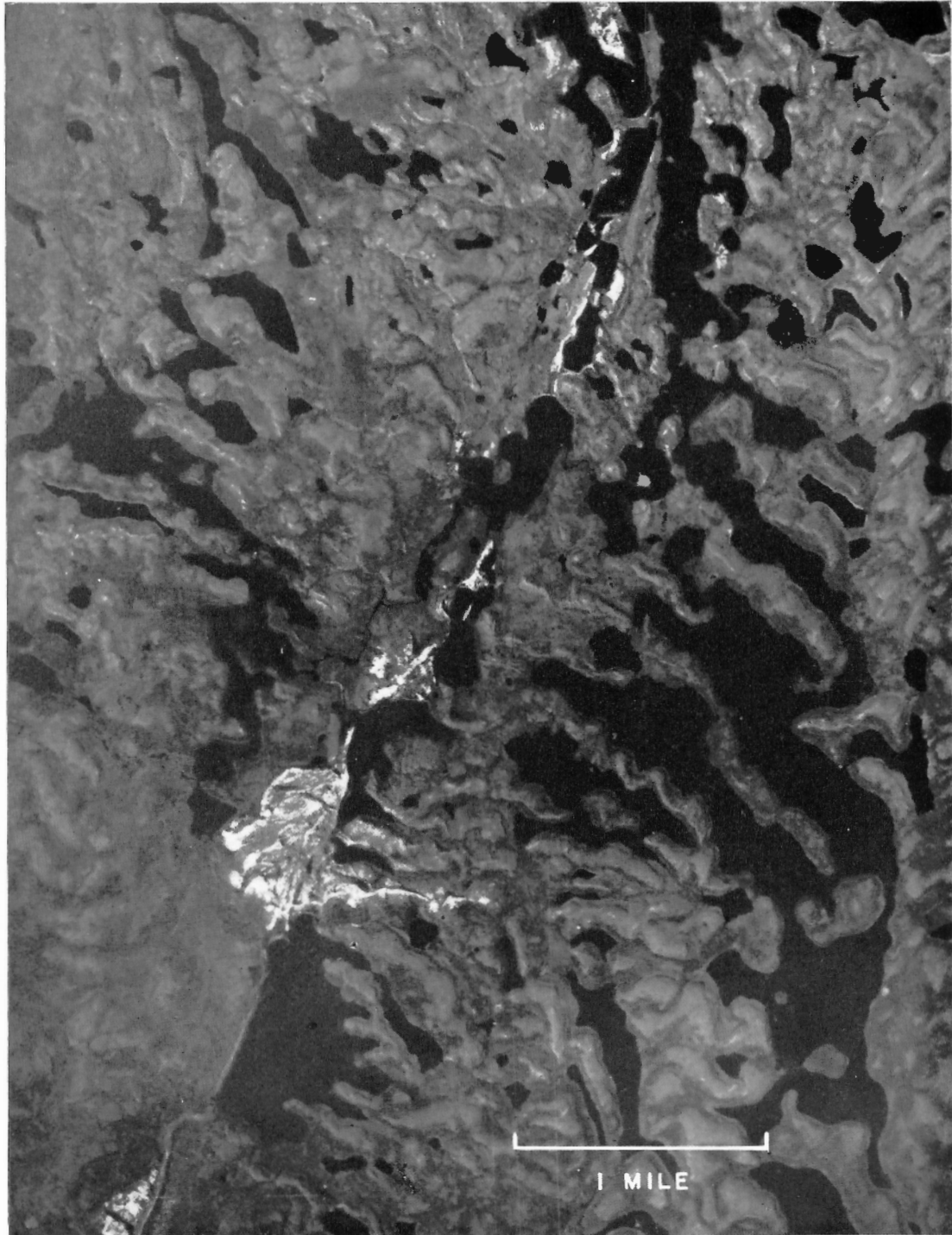


H.A.L., 18-5-52

**Plate VIII.** A and B. Beach ridges and terraces of the late glacial, marine submergence formed around a former island; 4 miles north of Carr Lake. These are ground views of the beaches shown in Plate I.



H.A.L., 21-2-52



*Plate IX.* Ribbed minor moraines and esker system (white), south of Ennadai army post. (Top is north.)

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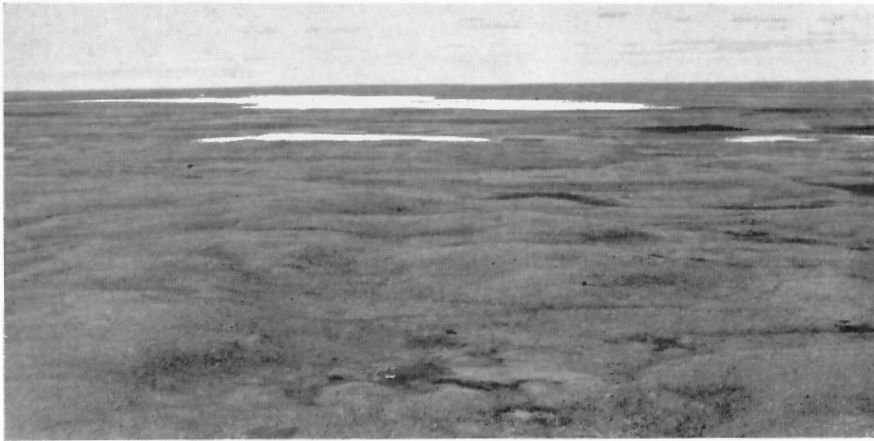


H.A.L., 8-5-52

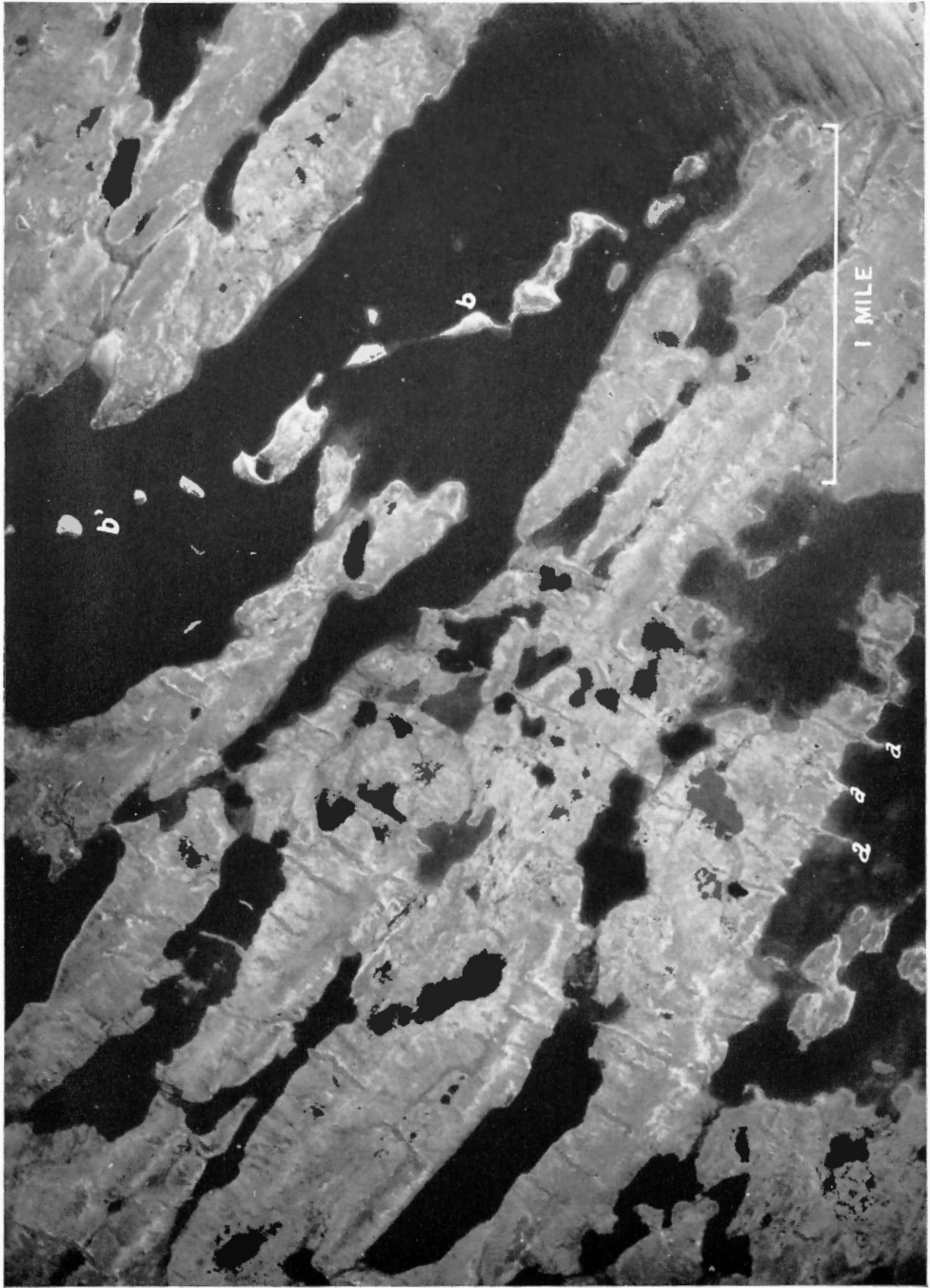
- A. Ribbed minor moraines in background, and felsenmeer field seen from the ground;  
about 28 miles northeast of Ennadai army post.

*Plate X*

- B. The same minor moraines with their boulder cover seen from a helicopter.



H.A.L., 29-2-52



RCAF T160C-40  
**Plate XI.** Straight-ridged minor moraines (a), and beaded esker (b); about 6 miles west of Corbett Inlet. (Top is north.)





A. Shattered quartzite.

H.A.L., 13-5-52

*Plate XII.* Frost-action features.

B. Frost-heaved greenstone.



H.A.L., 20-4-52





A. Ridge about 10 feet high, formed of angular blocks.

H.A.L., 17-6-52

*Plate XIII.* Ice-shoved features around present lakes.

B. Incipient ridge with stone tracks leading to it.



H.A.L., 25-4-52

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