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THE PERIGLACIAL GEOMORPHOLOGY OF THE RANKIN INLET AREA, KEEWATIN, N.W.T., CANADA

Abstract

The glacial landforms and periglacial surface features of a previously little known area bordering Hudson Bay, northern Canada, are described. The area lies 480 km north of the treeline and is entirely within the zone of late glacial and postglacial marine submergence. The present-day climate is typically arctic, and the vegetation, tundra; permafrost lies to a depth of 300 m. The last glacial ice to cover the area flowed southeastward from the direction of the Keewatin Ice Divide. Glacial landforms include till sheets, drumlinoid and morainic ridges, and an abundance of fluvioglacial forms including eskers and crevasse-fillings. Periglacial forms are classified and described, the classification being devised in such a manner as to allow convenient description of the forms. Non-sorted patterned ground forms in which vegetation comprises an important element predominate. Most common are frost-fissure polygons, non-sorted circles, steps, vegetation nets, and hummocks. The most vigorous processes are those associated with marine fine sand and silt and the formation of non-sorted circles, steps, and vegetation nets. Fluvioglacial ridges and raised beaches, associated with frost-fissure polygons, are the most stable surfaces. Relationships between each periglacial feature and landform, vegetation, and depth of active layer are examined. No correlation was found to exist between stage of development of periglacial form and the time elapsed since the postglacial emergence of the land surface from the sea.

INTRODUCTION

Despite a considerable volume of published and unpublished data concerning the periglacial geomorphology of the cold regions of the world, there remain gaps in our knowledge of the details or regional variations of periglacial forms. The following qualitative description of the periglacial geomorphology of the Rankin Inlet area is offered as a contribution toward closing a large gap in the knowledge of forms present in the tundra region to the west of Hudson Bay. The paper is based on fieldwork undertaken in the summer of 1967.

The study area, comprising approximately 2,500 square km, borders the northwest coast of Hudson Bay, and is centred on the settlement of Rankin Inlet (fig. 1). It lies some 480 km north of the treeline and of the southern boundary of continuous permafrost (*Geol. Surv. Canada*, 1967). No detailed

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geomorphological work had been undertaken in this region. Extensive descriptions of the physiography and Pleistocene features of southern and central Keewatin had been published by the Geological Survey of Canada (J. G. Fyles *in* Wright, 1955, p. 3–4; H. A. Lee *in* Lord, 1953, p. 2; H. A. Lee, 1959). Modern geological surveying in southern and central Keewatin has been

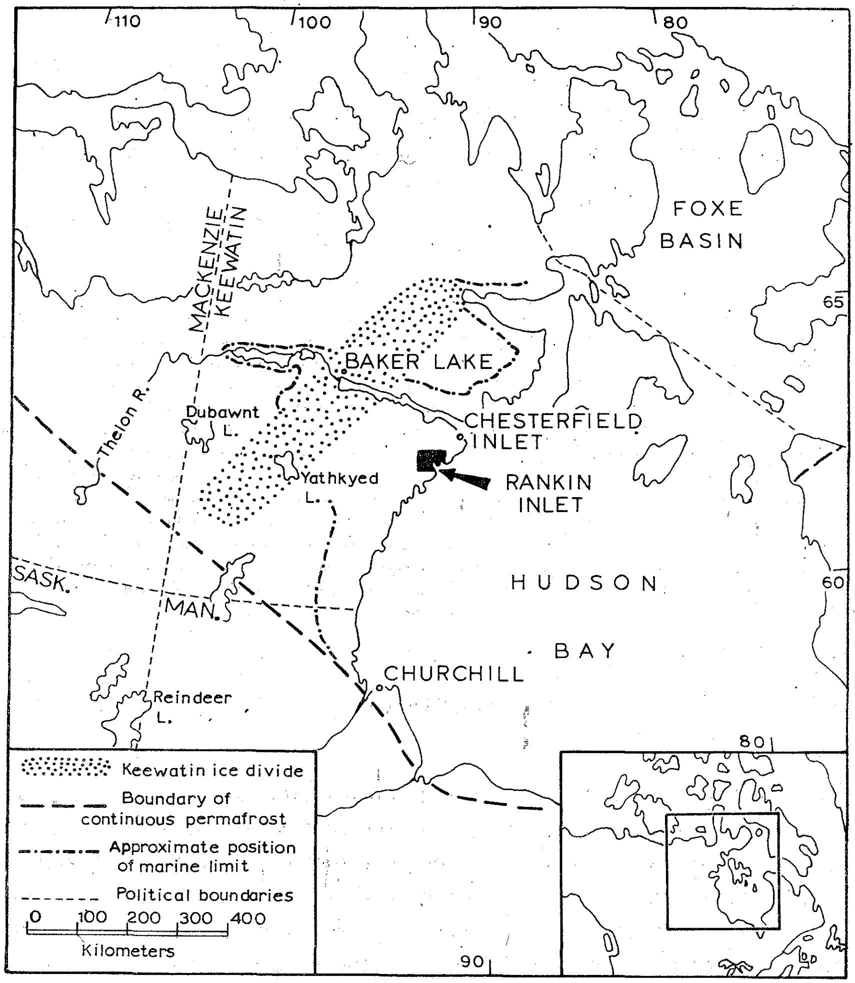
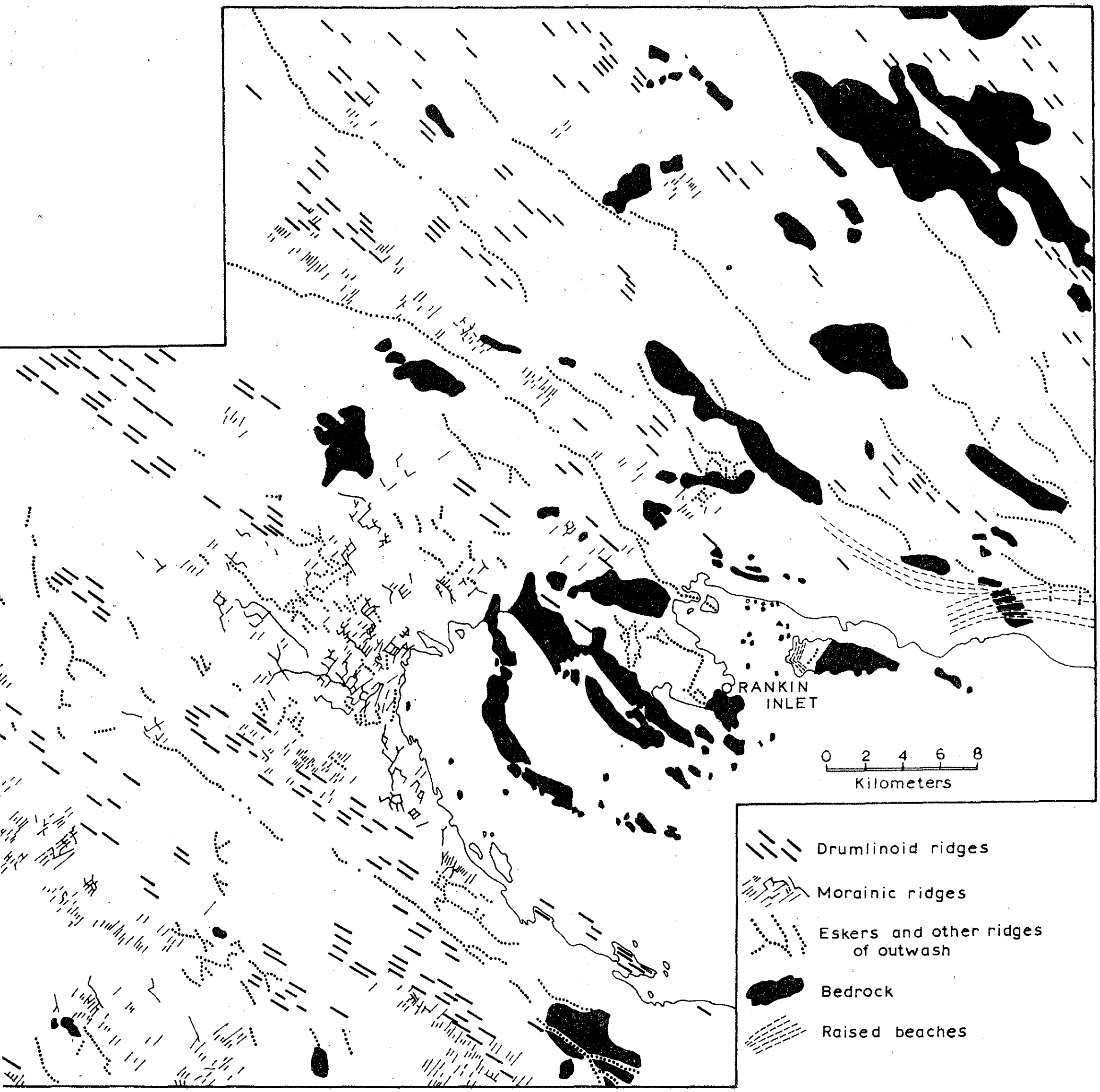


Fig. 1. Location of study area (shaded black)

conducted by the Survey's helicopter reconnaissance surveys "Operation Keewatin" (Lord, 1953a and 1953b) and "Operation Baker" (Wright, 1955). Geological maps at a scale of 1:506,880 (8 miles to the inch) were published with the respective reports. Because of the lack of previous geo-



› 21, J. Jamas, p. 128-129.

Fig. 2. Geomorphology

morphological maps of any detail, and of data concerning other aspects of the physical geography of the Rankin Inlet area, it is necessary to describe briefly the physiography, climate, vegetation, and glacial geomorphology of the area.

The area is typical of the monotonous Shield country to the west of Hudson Bay, although this coastal strip differs in certain details from the interior, for it lies entirely within the zone of postglacial marine submergence (fig. 1). Approximately four-fifths of the study area lies less than 60 m above sea level; the highest land rises in the northeast to about 150 m. Low relief throughout much of the area results in an undulating and montonous landscape. Drainage is deranged and lakes cover an estimated 25% to 30% of the total area. Most of the land-surface comprises glacial and fluvioglacial deposits and marine-sorted sand and silt. Cambrian and Precambrian rocks protrude in places as low, glacially smoothed rock knobs.

The last glacial ice to cover the area moved southeastward from the direction of the Keewatin Ice Divide (fig. 1). It deposited ground moraine and moulded drumlinoid ridges which are fairly well preserved throughout much of the area. Upon the decay of the ice-sheet, ablation moraine and much fluvioglacial material were deposited. Fluvioglacial forms are well preserved (fig. 2).

Within postglacial times, the land bordering the west of Hudson Bay has experienced a net uplift in relation to sea level of approximately 180 m (Lee, 1962). The age of seal bones, excavated by the writer on an island to the east of Rankin Inlet and dated by the University of Saskatchewan Radiocarbon Laboratory, appears to corroborate evidence of the rate of emergence determined by certain other workers (e.g. Lee, 1962). The age of the bones, which were collected from 45 m above present sea level, was determined to be 3915 ±70 years. According to this evidence, over half of the study area has emerged from the sea only within the last 4,000 years.

CLIMATE

The present climate of the whole of Keewatin has been described by F. K. Hare as "one of the windiest and coldest varieties of arctic climate" (Hare, 1963). For a marine location, the climate of the west coast of Hudson Bay is remarkably continental. Between 1921 and 1955, the absolute temperature range recorded at Chesterfield Inlet (see fig. 1) was 63°C (−33°C to +30°C); mean daily temperature for January and February, the coldest months, was −14°C, and for July and August, the warmest months, below 10°C. Total annual precipitation (rain plus water equivalent of snow) at Chesterfield Inlet was approximately 28 cm (Hare, 1963); the measured mean maximum depth of snow is 45 cm (Potter, 1965).

At present, the depth of permafrost at Rankin Inlet is approximately 300 m (*Geol. Surv. Canada*, 1967); the depth of active layer varies from 25 cm in marshy depressions, to over 1.8 m in esker crests.

VEGETATION

The following generalized description of the vegetation of the Rankin Inlet area is based on the writer's observations. The main plant associations recognized are the following:

A. Rock outcrop. Lichens with occasional isolated mosses and vascular plants in crevices.

B. Lichen-moss tundra. A thin cover of lichens and dry moss on the driest sandy sites. With increasingly moist conditions, other vascular species occur, particularly heath plants. This variety passes into the richer growth of C.

C. Lichen-heath tundra.

D. Hummocky tundra. In less well drained habitats. The distribution of species reflects changing moisture conditions between hummocks and depressions: lichens, grasses and heath plants grow on hummock-tops, with sedges and mosses in depressions. With increasing poverty of drainage, sedges and damp mosses dominate. The size of hummocks varies from less than 7 cm to more than 20 cm in height. Downslope this variety passes into E.

E. Marsh tundra. A dense growth of sedges and mosses occurs on flat sites which remain wet throughout the year.

F. Freshwater communities. Aquatic plants passing into the wettest type of E, Marsh tundra, around lake margins.

G. Strand communities. Including halophytic species and confined to rocky and sandy seashore habitats.

H. Snowflushes. A dark heath dominated by the Artic Bellheather, (*Cassiope tetragona*).

Of the above, A to F are the most common. A fact of significance in an appreciation of the periglacial geomorphology of the Rankin Inlet area, and of the contrasts between the forms present here and those of more northerly areas is that the vegetation of central Keewatin, althought thoroughly arctic in character, is appreciably more luxuriant than that of the High Arctic.

Vegetation therefore plays a major role in determining the nature of periglacial forms in the Rankin Inlet area. It partly restrains solifluction and forms an important element of non-sorted partterned ground features.

GLACIAL GEOMORPHOLOGY

The glacial geomorphology of the area may be classified as follows:

Eroded rock surfaces

Till: ground moraine, ablation moraine
- drumlinoid ridges
- morainic ridges: transverse and reticulate

Fluvioglacial:
- eskers: broad, sandy; narrow, boulder-covered; "beaded"
- crevasse-fillings and kame-like plateaux.

Eroded rock surfaces are generally smooth and mammilated. Grooves and striations are well preserved beneath lichen growth on many outcrops. Some classic *roches moutonnées* occur 6.4 km north of Rankin Inlet.

Because of the effects of wave-action and deposition by the postglacial sea, it is not everywhere possible to distinguish between ground moraine and ablation moraine. Glacial erratics abound on till surfaces and occur on many fluvioglacial ridges. Impressive boulder fields lie to the southwest of the Inlet. In part, these may have been thrust to the surface by frost-action, or may represent a lag concentrate from which finer material has been removed by marine wave-action.

Drumlinoid ridges occur in fields (see fig. 2) where the total relief is less than 12 to 15 m, though drainage conditions cause a marked difference between ridge-tops and intervening depressions.

The surface features (vegetation and periglacial forms) of morainic ridges are similar to those of drumlinoid ridges, but the former are generally less than 3 to 5 m above the surrounding terrain. They comprise two apparently distinct groups: those lying transverse to the direction of former ice-flow, and those which form a reticulate pattern (see fig. 2). Some probably had an "ice-pressed" origin near the front or beneath the ice sheet prior to its final disappearance.

Eskers (see fig. 2) comprise the most striking landforms in the area. They assume a variety of forms including the following: high ridges with broad top surfaces of coarse sand and gravel; sharp-crested, boulder-covered ridges; and a combination of broad ridge with bouldery, sharp-crested summit. "Beaded" eskers are common, consisting of separate or connected bouldery mounds. The "broad" form of esker attains the greatest dimensions, with estimated heights of over 9 m, and widths, in places, of over 270 m.

Other fluvioglacial ridges which are genetically related to eskers are crevasse-fillings and kame plateaux. The relief of many isolated plateaux of outwash sand and gravel is similar to that of "broad" eskers; crevasse-fillings, on the other hand, are generally much lower than the eskers. Typically, the latter form a plexus of ridges, with lakes occupying the dead-ice hollows which form the depressions of the "waffle" pattern.

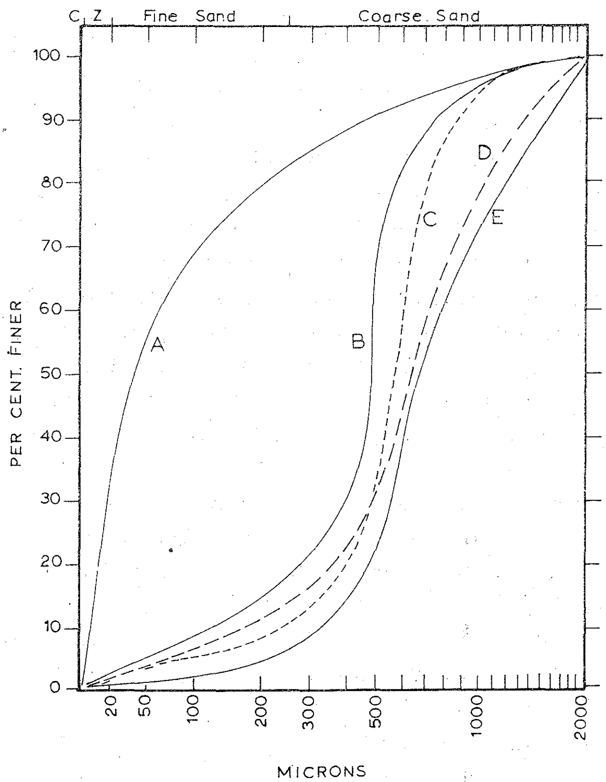


Fig. 3. Grain size distribution curves

Sample A from non-sorted circle; samples B–E from a sandy raised beach

Modifications effected during the postglacial marine transgression include the terracing of some of the glacial landforms, the fromation of raised beaches, and the effects of wave-action and marine deposition. Certain of the drumlinoid ridges have been partly eroded, apparently by marine wave-action. Raised beaches of both sand and gravel, and cobbles have been formed, though in few places did conditions favour the formation of flights of beaches. Such flights consist of low, vegetated swells of sand and gravel with an occasional pebbly beach. Despite marine modification, the orientation and form of glacial landforms continue to reflect strongly their glacial origin.

The deposits which have been subjected to frost action during the most recent phase of landscape evolution are therefore of glacial, fluvioglacial and marine origin. In figure 3 are shown grain-size distribution curves for samples of material of less than 2 mm grain-size diameter. Curve A is typical of sand comprising non-sorted circles. Curves B to E represent samples collected from a sandy raised beach on which is developed an irregular pattern of fissure-polygons ("tundra polygons") with low rims only 15 cm high (see A, below). The marine, silty, fine sand has proved most susceptible to periglacial processes and provides conditions for the most vigorous periglacial activity. Glacial till is a less favourable medium for such activity: it is less susceptible to frost action, and commonly occurs in relatively well drained ridges. Nevertheless, lodgement till contains fine sand which gives rise to an abundance of certain forms, both on level sheets of till and on drumlinoid ridges and moraines. The sand, gravel, and boulders of well drained fluvioglacial ridges, and the gravel and cobbles of raised beaches are more stable than the marine sand and glacial till, but have not escaped the effects of frost processes. Every type of glacial landform, indeed every landform in the area exhibits the result of frost action of one kind or another.

PERIGLACIAL GEOMORPHOLOGY

The periglacial forms of the Rankin Inlet area may be classified as in Table I. This classification, based upon Washburn's classification of patterned ground (Washburn, 1956), is not genetic, although some of the members of the groups are evidently related genetically. It is devised in this manner in order to facilitate convenient description of the whole range of forms. As detailed investigations have yet to be made into the processes occurring in each form, it is possible to comment only on the probable mode of origin. The nomenclature used is believed to be suited to the features described; new terms are suggested where the forms concerned differ from those described by other workers. For purposes of comparison, Washburn's terminology (Washburn, 1956) is included.

Groups A, B, C, and D may be described as "patterned ground", and Group E as "miscellaneous" periglacial forms. In figure 12, which illustrates a "model" of the periglacial landscape of the area, the distribution of the most common periglacial features is shown in relation to the various glacial landforms.

Table I

Classification of the periglacial features of the Rankin Inlet area

	Terminology of Washburn (1956)
A. Polygonal forms:	
A1. Fissure polygons of irregular pattern on relatively well drained sites	Non-sorted polygons
A2. Tetragonal fissure polygons in marshes	Non-sorted polygons
A3. Lichen-border polygons	Non-sorted polygons
A4. Sedge-border polygons	Non-sorted polygons
A5. Miniature (desiccation) polygons	Non-sorted and sorted polygons
B. Forms resulting from injection and heaving:	
B1. Non-sorted circles	Non-sorted circles
B2. Steps	Non-sorted and sorted steps
B3. Vegetation nets	Non-sorted nets
B4. Sorted circles	Sorted circles
B5. Sorted nets	Sorted nets
C. Miscellaneous patterned ground forms:	
C1. Non-sorted stripes	Non-sorted stripes
C2. Hummocks	Non-sorted nets
C3. Hummock garlands	—
D. Solifluction lobes and terraces	Including sorted and non-sorted steps
E. Miscellaneous periglacial forms:	
E1. Lake-shore features	
E2. Frost-shattered rock	

A1. FROST-FISSURE POLYGONS (TUNDRA POLYGONS) OF IRREGULAR PATTERN ON RELATIVELY WELL DRAINED SITES

One of the most common periglacial forms is the frost-fissure polygon, the trenches of which trace thermal contraction fissures in a variety of materials, and under various conditions of drainage and vegetation. This feature is best developed on eskers, crevasse-fillings, and related forms where a lichen-heath association occurs. It is also present on some ridges of till.

Only on gentle slopes ($<4°$) of fairly well sorted and well drained coarse sand and gravel is a polygonal pattern well developed, and then very irregularly, with polygon sides up to 18 m long. On many fluvioglacial ridges a polygonal pattern may have failed to develop because of lack of space: single fissures extend along or across the ridge in an irregular, "open" pattern. In cross-section, the trenches which extend along frost fissures vary considerably: they may be "V"-shaped or "U"-shaped; rims may be absent, developed along both sides of the trench, or on one side only. Rimless trenches were observed where polygons cut relatively well sorted sand and gravel containing few large cobbles and boulders, whereas the highest rims are associated with poorly sorted, bouldery esker deposits (*cf.* observations of rim size on Baffin Island made by King and Buckley, 1969, p. 114). The greatest observed width between rim crests, and height from rim-crest to trench-bottom were 2.4 m and 75 cm respectively.

J. B. Bird expresses doubt as to the existence of ice-wedges beneath the deep active layer associated with coarse deposits in northern Canada (Bird, 1967, p. 193). Nowhere in the Rankin Inlet area did the present writer encounter ice-wedges in the permafrost beneath fissure-trenches, but deeper excavation would be necessary in order to verify the presence or absence of such wedges. As many trenches are waterlogged in spring and remain damp throughout summer, it is not unreasonable to assume that ice-wedges underlie some of the trenches, particularly where permafrost lies within one metre of the surface. The trenches may represent a form of thermokarst where subsidence has followed the gradual melting of ice-wedge tops consequent upon a slight climatic amelioration (Britton, 1966). Occasionally, where the trenches extend to lake-banks they have collapsed to form depressions as deep as 1.5 m: this strongly suggests that ice-wedges of substantial size recently underlay the frost

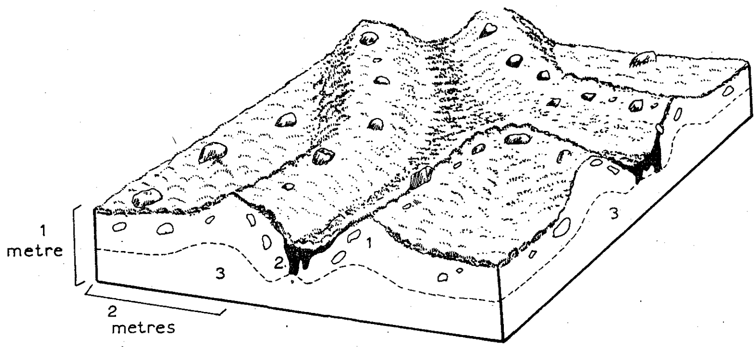


Fig. 4. Frost fissure polygons: the junction of three trenches

1. Steeply dipping boulders in well developed rims; 2. peat descending into sand beneath mossy trench floor; 3. frozen

fissure-trenches and have been thawed consequent upon the lake's erosion of its banks.

Figure 4 shows the typical profile revealed beneath the trenches. The lobes of organic matter are similar to involutions caused by frost-churning, but a more general downward movement is suggested by profiles such as that shown in figure 5, in which a wider column of organic matter may represent a gradual filling of space left by a slowly melting ice wedge, or it may be the top of a wedge of sand.

A2. FISSURE POLYGONS IN MARSHES

The fissure polygons which occupy marshy depressions (pl. 1) throughout the area differ from those of type A1 in shape, size, and in the character of their trenches. They are tetragonal, have sides as long as 90 m, and are much more uniformly spaced than polygons on better drained surfaces. They form on marshy depression floors sloping at less than 2°, where up to 18 cm of peaty organic matter overlies sand and silt. Frozen ground lies within 30 cm of the surface. The trenches, as wide as 1.8 m, and 25 to 50 cm deep, are filled

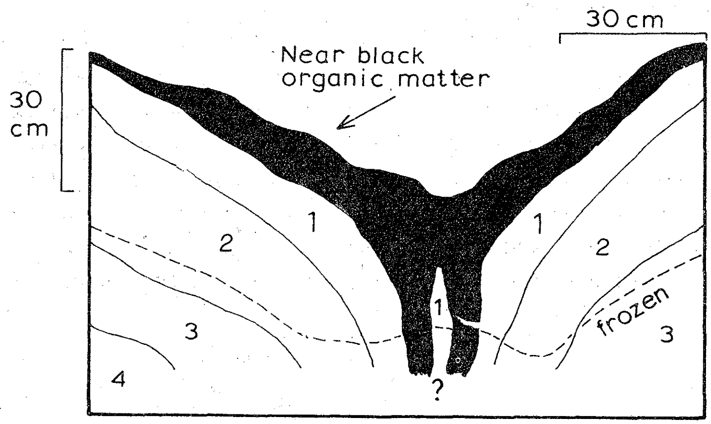


Fig. 5. Cross section of a trench showing horizons of sand dipping with peat below the permafrost table

1. brown coarse sand with high organic matter content; 2. yellow-brown, gravelly, coarse sand with cobbles 3. yellow-brown, coarse sand; 4. grey fine sand

with sedges; many contain standing or running water. A crack usually extends through the sedges along the centre of the trench; where this widens, iron--stained sand and cobbles are exposed. Rims are present beside troughs only where they extend through slightly better drained ground. Excavation of pits in the waterlogged trenches proved impossible.

On air photographs, tetragonal fissure polygons are commonly visible beneath shallow lakes. A number of the dry depressions occupied by polygons are former lake floors.

A3. LICHEN-BORDER POLYGONS

These are not common; they are 3 to 4.5 m in diameter and cover areas of less than 800–900 square metres on windswept, very dry sites occupying fluvioglacial ridges. The most regularly shaped are hexagonal. Their edges consist of shallow, sandy furrows occupied mainly by lichen (*Alectoria* sp.), and enclose slightly domed centres where a layer of stones without vegetation overlies medium-coarse sand. This stone veneer is probably a lag concentrate from which sand has been winnowed by the wind.

Similar polygons have been named *vegetation polygons* by Hamelin and Cook (1967, p. 161); Popov (1962, p. 81) described them more accurately as *lichen-border polygons*. J. R. Mackay (1958, p. 53) has described from the Anderson River area of northern Canada *high centred polygons* which form a pattern resembling that on a tortoise carapace; these are developed on outwash sand and gravel, and are most common on hilltops.

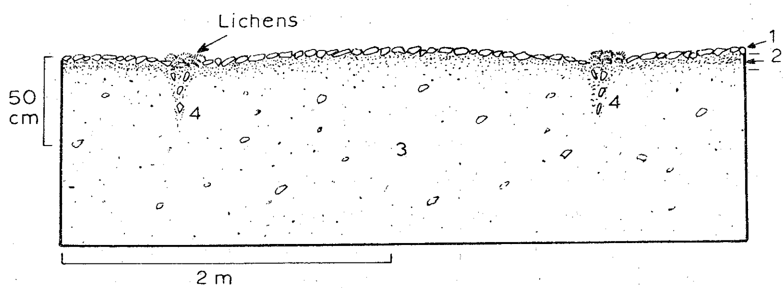


Fig. 6. Section through lichen-border polygons

1. veneer of stones; 2. brownish-yellow medium-coarse sand; 3. clean, gravelly, coarse sand with a few cobbles; 4. wedges of 2

Profiles revealed by excavation across lichen-border polygons suggest their probable origin (fig. 6). In the active layer (1.5 to 1.8 m deep) beneath each furrow lies a wedge of sand containing vertically oriented stones. Presumably, sand and stones have trickled into thermal contraction fissures to leave the slightly depressed polygon-borders.

A4. SEDGE-BORDER POLYGONS (PL. 2)

An uncommon type of polygon was found only on a very few sites where slopes on the edges of marshy depressions do not exceed 0.5°. Permafrost lies within 45 cm of the surface. It is likely that the polygons are inundated in spring, but their surfaces are dry and firm in late summer.

These polygons are irregular in shape; the largest are 24 m across. Their flat centres, which for the most part consist of bare, mucky sand, contain secondary, less well defined polygons. The trenches separating the main polygons are as deep as 15 cm, as wide as 75 cm, and contain moss and hummocks. Associated with the hummocks are sedges (*Carex* sp.) with Arctic bell-heather (*Cassiope tetragona*), Arctic avens (*Dryas integrifolia*), willow (*Salix* sp.) and lichen (*Cetraria* sp.). An open crack extends through the mossy floor of the trenches, which are dry in August. Beneath the trenches, fine sand is mixed with black, peaty organic matter to a depth greater than 30 cm. Grey, silty, fine sand, similar to the material which forms non-sorted circles and which underlies "vegetation nets", occurs beneath the polygon-centres, but no evidence of injection or heaving is visible. A relationship between "sedge-border polygons" and vegetation nets cannot be ruled out. They occur in similar topographic situations, similar materials, and have similar dimensions.

A5. MINIATURE (DESICCATION) POLYGONS

Miniature desiccation polygons are common on surfaces of non-sorted circles. They are 10 to 15 cm long, most are hexagonal, and all form a net. Their borders are small fissures. Non-sorted polygons have stoneless borders, whereas sorted polygons have small stones aligned on edge in the fissures.

Desiccation polygons, although not formed by frost action, may nevertheless be affected by diurnal freezing or frequent freezing and thawing in spring, with subsequent movement of stones to form the sorted variety

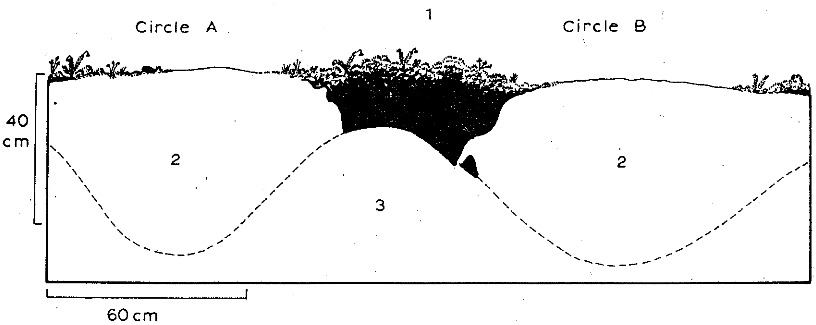


Fig. 7. Section through two non-sorted circles

1. vegetation over peat which extends into the frozen horizon; 2. silty, fine sand; 3. frozen

(Troll, 1944: p. 58 of the S.I.P.R.E. Translation). Wind and rain are also capable of sorting particles into desiccation cracks (Corte, 1965, p. 131).

B1. NON-SORTED CIRCLES

Non-sorted circles and related steps comprise some of the most common periglacial forms in the Rankin Inlet area. More or less circular patches of bare, silty, fine sand, varying in diameter from 0.3 to 1.8 m or more, occur in pockets on fluvioglacial ridges, and cover large areas on till and moraines. The sand was found to have a grain-size distribution similar to that represented by curve A, figure 3. Gentle slopes (0.5° to 2°), underlain by homogeneous deposits of silt or fine sand, are commonly characterized by vegetation nets. Circles do not occur together with tundra polygons either on dry or marshy sites.

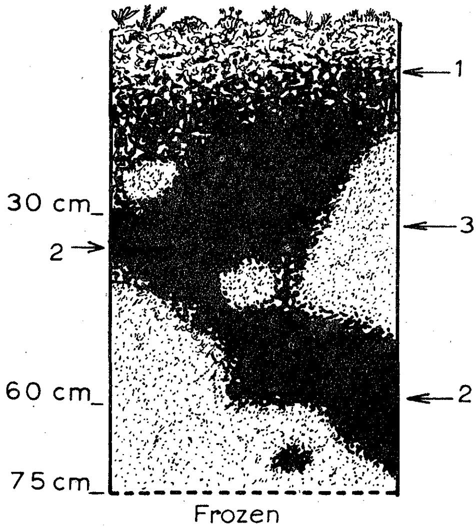


Fig. 8. „Frost-churned" soil

1. brown undecomposed organic matter; 2. peaty organic matter, becoming black with depth, surrounded by grey-stained sand; 3. yellowish-grey, silty, fine sand with patches of organic matter

On dry, elevated sites, such as the side-slopes of fluvioglacial ridges and the crests of drumlinoid ridges, the surfaces of non-sorted circles are slightly domed above the level of surrounding vegetation, and are commonly of the *stony earth circle* type described by Williams (1959a). The stones are angular, most lie flat on the surface, though some stand on edge in the sand. On many drumlinoid and morainic ridges, a distinct feature has been formed in which a group of both old and presently active circles form a circular, flat-topped mound. Peat-filled depressions surround each mound and separate it from others. On damp sites with thick, mossy vegetation, non-sorted circles have flat surfaces lying below the surrounding vegetation. Their shape tends to be more irregular than that of circles on drier sites, and their surfaces are wetter in spring and early summer.

Figure 7 illustrates the profile revealed by excavation in mid-July through two adjacent circles in a fairly dry situation on a solifluction lobe. By this date, the sand had thawed to a depth of 48 cm beneath the circles, but only 18 cm in the peaty, organic matter underlying the borders. The yellowish-grey, slightly gritty, silty, fine sand of the circles showed no significant change of grain size with depth. Beneath the centre, the sand formed a wet sludge; toward the edge it became drier, was firm and vesicular, and broke off in cubic aggregates. The organic matter merged downward from brown, fibrous plant remains to near black, well-decomposed matter which extended into frozen sand. The contact between organic matter and sand was sharp. Figure 8 shows a more complex incorporation of organic matter in fine sand between three circles on a drumlinoid ridge. At this site, the organic matter extended down to 75 cm where the ground was frozen in mid-August.

B2. STEPS

These forms may occur on slopes of 4° or more, and consist of non-sorted circles bounded on the downslope side by vegetation. There is commonly evidence of a slow flow where circles are distorted in a downslope direction until movement halts or is inhibited by vegetation (fig. 9a). Evidence of flow

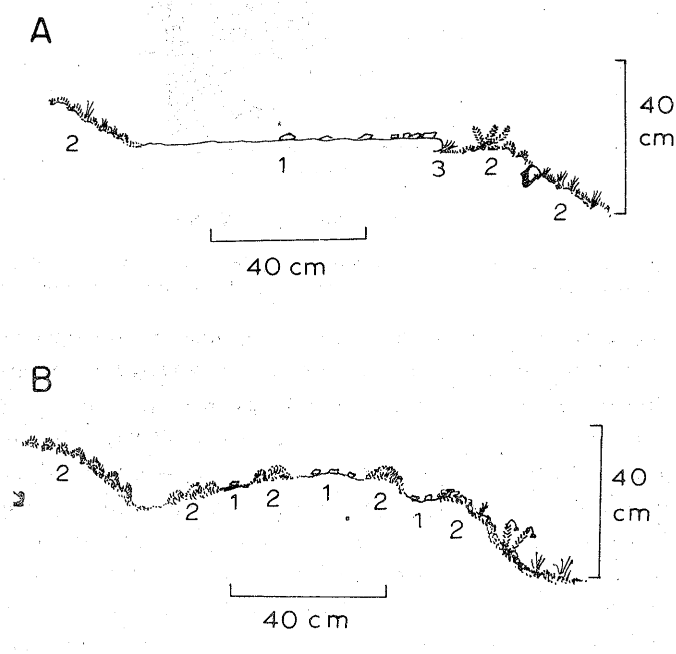


Fig. 9. Section through a step

A. The silty, fine sand shows signs of flow: 1. bare sand, stones concentrated toward lower end of lobe; 2. vegetation; 3. vegetation over-run by sand

B. The stony surface of the fine sand shows no evidence of flow: 1. bare sand of the non-sorted circle; 2. vegetation

of wet, silty, fine sand includes: spilling of sand over the restraining vegetation; wrinkles (occasionally emphasized by a concentration of small stones and therefore slight sorting) around the edge of a flowing lobe; and the movement of sand over organic matter. Such movement constitutes microsolifluction and is probably an important mass-wasting process. It is possible that some steps are not genetically related to the injected circles, but represent a flow of silty, fine sand without heaving.

Signs of flow may be absent in the drier, very stony sand. Typical here are circular steps with slightly raised surfaces bordered downslope by a steep bank of vegetation (fig. 9b).

B3. VEGETATION NETS (PL. 3)

A form of non-sorted net is common on poorly drained, gently sloping surfaces such as occur in dead-ice hollows and other depressions. Rings of vegetation border circles of B1 above, and measure between 60 cm and 3.6 m in diameter. The vegetation of the borders comprises ridges, as high as 25 cm, of mosses and vascular plants forming a tight sod over fibrous, peaty organic matter. The fine sandy circles may be inundated by as much as 15 cm of water during the spring and early summer thaw; by late summer they become dry and firm. Stones may cover much of their surfaces. In large, irregular units, several circular active centres of frost heave may be outlined by platy stones on edge.

It is possible that ice thrust may contribute to the formation of the ridges which comprise vegetation nets. Mackay (1958, p. 81) has described "thrust ponds", 30 to 60 cm deep, occupying ill-drained flats in the Anderson River area of Canada. The ponds have raised rims which, Mackay believes, are probably due to ice thrust.

Nets commonly merge into areas of individual, sunken, fine sandy centres ("cemetry hollows"), similar to, but more irregular than the units of vegetation nets, they lie well below the surrounding vegetation, and are as much as 6 m in length.

B4. SORTED CIRCLES

As mentioned above, rings of stones commonly outline centres of frost-heave in vegetation nets. The stones are angular, commonly platy, and stand on edge in the sand. Apart from these, sorted features are scarce.

B5. SORTED NETS

A small number of sorted nets of the type shown in figure 10 were encountered on what appeared to be seasonally dry pond floors between the beach-

-lines of flights of raised beaches, and in kettle holes on eskers. Similar, submerged, sorted nets have been reported by Derruau from near Knob Lake, Labrádor (Derruau, 1956, p. 15), and by Mackay from Garry Island, on the Mackenzie Delta (Mackay, 1967). The net shown in figure 10 occurs on the flat floor of a depression measuring 27 m long on a broad esker. The flat surfaces of the centres of the net, measuring from 25 cm to over 90 cm, consist of medium to coarse sand mixed with angular gravel. The borders, consisting of rounded stones as long as 13 cm, some of which stand on edge, vary in width from 7.5 cm to 30 cm. Stones of the same dimensions extend beneath the surface to about 15 cm, with some dipping steeply. Beneath the centres, and beneath the bases of the border stones occurs wet sand similar to that on the surface of the centres. In mid-August, the water table was at a depth of 40 cm.

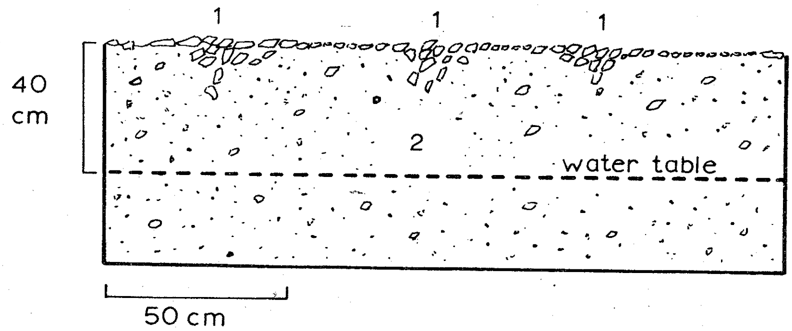


Fig. 10. Section through a sorted net

1. stone borders of circles; 2. coarse gravelly sand

Billings and Mooney (1959) have described a sorted net from the alpine tundra of Wyoming, where they believe that a cyclic relationship exists between hummocks and the polygons of the net. They give evidence of an apparent cycle of degradation and disappearance of peaty hummocks, and consequent frost heaving at the sites of the hummocks, which produces polygon centres. The surface of the polygons was only just above the summer water table, and the site was subject to periodic inundation. The occurrence of sedge hummocks on the nets found in the Rankin Inlet area, and of organic matter in the sand beneath the nets, suggests that the surface was at one time thickly vegetated. Sedges were seen to be encroaching upon other, similar depressions at present occupied by ponds. Possibly, the hypothesis of Billings and Mooney has application beyond the alpine tundra zone of Wyoming.

C. MISCELLANEOUS PATTERNED GROUND FORMS

Included in this category are forms which are difficult to classify, either in a descriptive or genetic sense, with the features so far described. Non-sorted stripes are of confined distribution; hummocks are widespread; "hummock garlands" occur on many ill-drained surfaces of low slope (one degree and less).

C1. NON-SORTED STRIPES

These were found only on the flanks of broad eskers (pl. 4). They are similar in most respects to the stripes described by Washburn (1947, p. 87–88) from Victoria Island, Northwest Territories, Canada, but form a less regular pattern. The stripes comprise alternate bands of pebbles and lichen extending down slopes of 11° to 15°. The stone stripes consist of a veneer of angular and subangular stones, 1.25 to 2.5 cm long, over coarse, gravelly sand. The same material underlies the vegetation stripes. At the top of the slope, the stones form a laterally continuous surface, whereas bands of vegetation which separate the stripes widen gradually downslope and merge to become almost continuous across slope at the base. The vegetation consists of lichen (*Alectoria* sp. and *Cetraria* sp.), crowberry (*Empetrum nigrum*), and lingberry (*Vaccinium vitis idaea*). Crumpling of vegetation at the downslope end of the stone stripes suggests a downslope movement of stones.

Beneath surfaces of both stones and vegetation, the profile reveals 7.5 cm of dry, clean stones, and 10 cm of finer gravel with vegetal remains, overlying coarse, gravelly sand with occasional subangular cobbles up to 15 cm in diameter. This material was frozen at a vertical depth of 1.2 m in July. No evidence of downslope movement was present beneath the surface veneer.

A. L. Washburn (1947) is of the opinion that the stones of non-sorted stripes move by unsaturated creep which could be activated by frost action, growth and decay of vegetation, and removal of supporting particles by slope-wash or wind.

C2. HUMMOCKS

Hummocks are common features of most poorly drained surfaces in the area. They measure from several cm to 45 cm in height. Three types of hummock were recognized: the first comprises a mound of living and dead organic matter and appears to have formed mainly by plant growth. Beneath many, the core of peat extends as a lobe into underlying sand. The second type appears to have formed mainly as a consequence of frost action, where a mound of fine sand has been pushed upward to form a hull of sand covered by organic matter and colonized by plants. Downslope movement is suggested by the asymmetrical profiles of certain hummocks, the steeper side being downslope, and by plants which have become disoriented and incorporated into the base on the downslope side. A third type of hummock, up to 45 cm in height, comprises erosion remnants. They occur downslope from spring snow drift sites where meltwater erodes vegetation, peat, and sand in channels between the hummocks.

C3. HUMMOCK GARLANDS

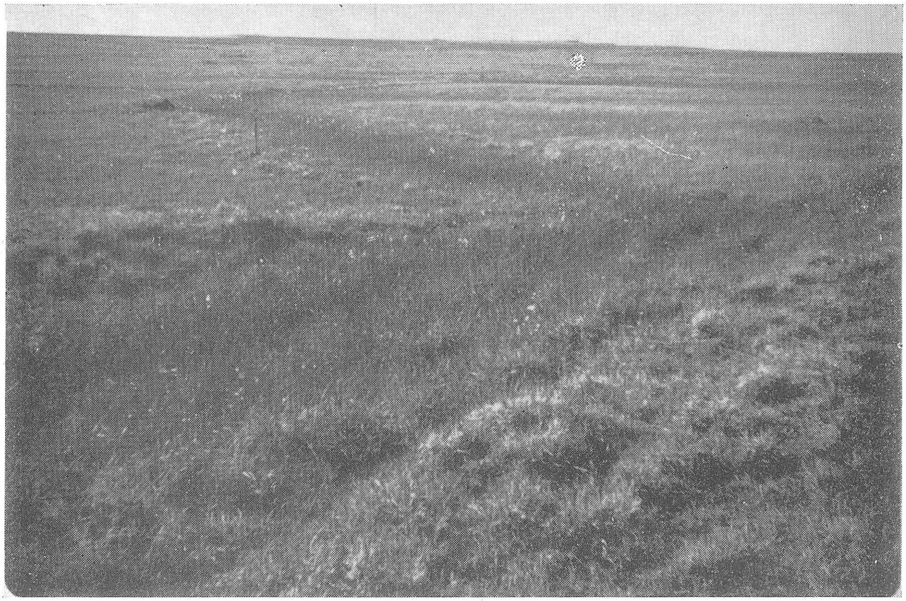
Arcuate hummocky ridges, similar to the *vegetation arcs* described by Mackay (1958) and Williams (1959b), occur transverse to certain low, poorly drained slopes. They are generally about 30 cm wide and 30 cm high; nowhere were they seen to be continuous for more than 18 m. The intervening surface is dark, mucky sand with a discontinuous cover of sedges. The growth of heath plants and the yellow lichen (*Cetraria* sp.) reflects the improved moisture conditions of the "garlands".

A relationship with the rings of vegetation nets (B3 above) is possible, but from the geometry of the "garlands" it appears that they may owe their origin to different processes. No evidence of frost heaving was observed on the surfaces between ridges.

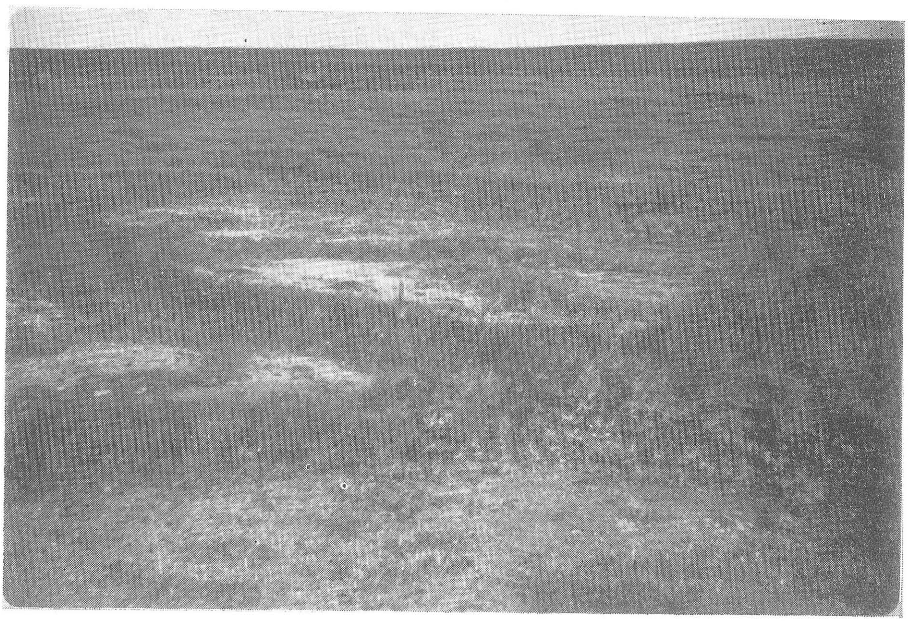
D. SOLIFLUCTION LOBES AND TERRACES

Solifluction lobes and terraces represent a significant mass movement and are common landforms throughout the Rankin Inlet area. Fine and silty sand, which is very unstable and liable to flow when saturated, is abundant in the area. It has been shown by Williams (1957) that solifluction may also occur in coarser material.

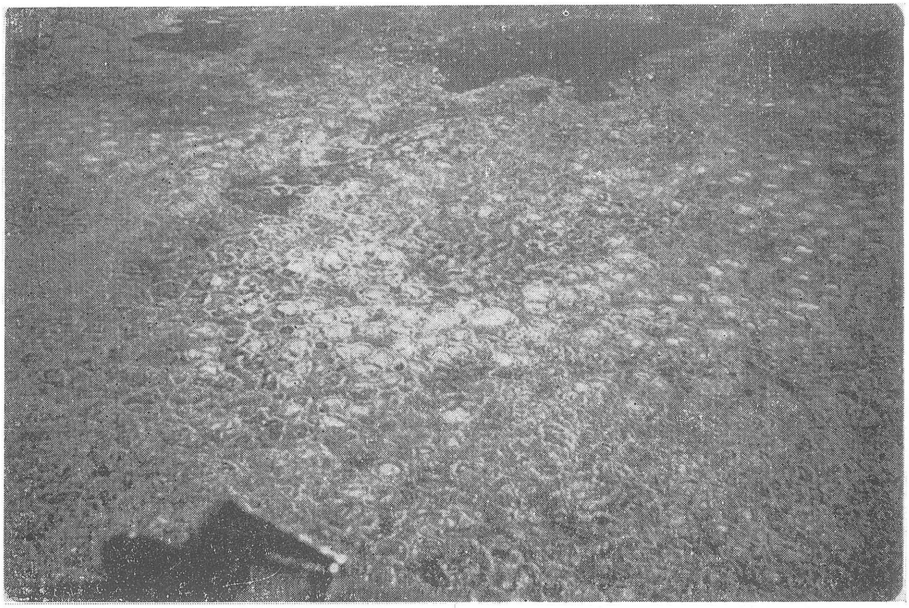
Solifluction lobes are particularly well developed on the flanks of eskers. They may be single, connected laterally, or occur in succession downslope. In a number of cases, an apparent relationship was seen to exist between fissure-trenches and solifluction lobes, where lobes interrupt the continuous path of a trench which extends downslope. The largest lobes have steep frontal scarps as high as 1.2 m, and top surface of 2° to 5° slope and 27 m long. Lobes commonly occur immediately below a break in slope, the slope above the lobe being as steep as 30°.



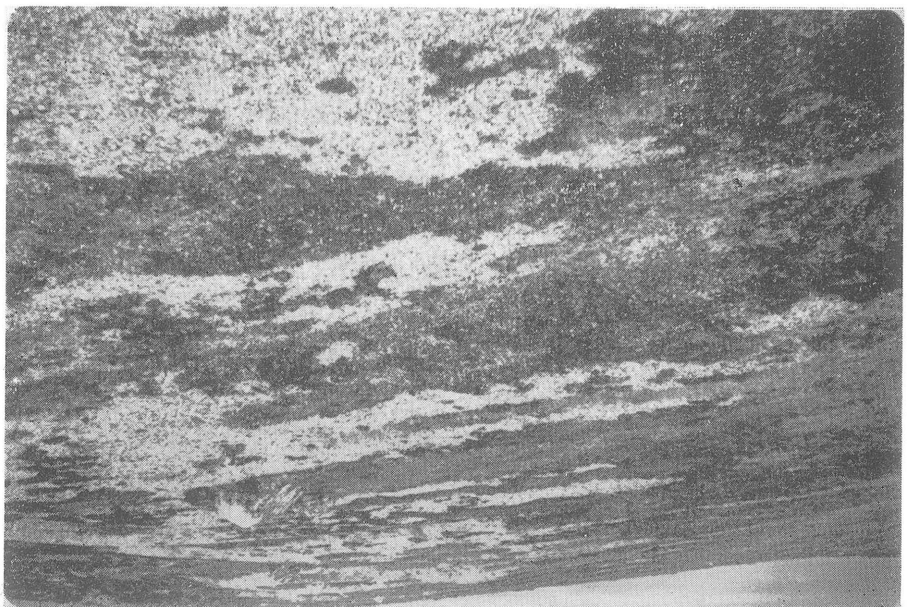
Pl. 1. Fissure polygons in marshes. In the foreground rims have formed beside the fissure trench (Spade for scale)



Pl. 2. Sedge-border polygons. The larger polygons are subdivided by minor fissures (Trowel for scale)



Pl. 3. Vegetation nets as seen from a helicopter



Pl. 4. Non-sorted stripes developed on the flank of a broad esker

Most of the lobes have a dense cover of vegetation. Active movement is evidenced at lobe-fronts where vegetation is ruptured and folded into the base of the advancing bank, and on top-surfaces where wet, mucky sand is usually exposed in patches. A crescentic area of bare mud may occur on the lobe surface below the break of slope at the rear; hummocks and folds of vegetation become increasingly larger toward the front. Non-sorted circles are common on the top surface. Figure 11 is based partly on a number of excavations in the Rankin Inlet area.

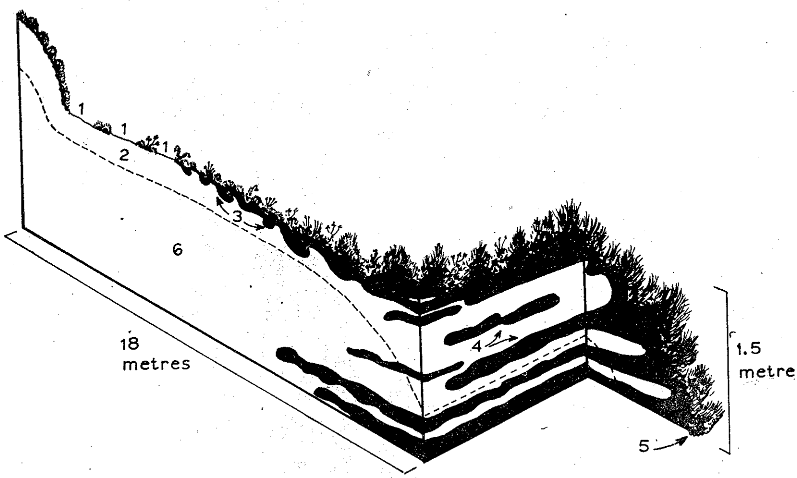


Fig. 11. Sections through a solifluction lobe. Based on excavations in the Rankin Inlet Area and sketches in Sigafoos and Hopkins

1. bare surfaces of wet muck and non-sorted circles; 2. sand; 3. involuted organic matter; 4. organic matter which has been over-run by sand; 5. moss in process of being over-run; 6. frozen

Terraces, with straight or slightly festooned fronts, generally between 30 cm and 1 m high, as well as some exceeding 1 m, are common in step--like fashion on till slopes. The surface of each terrace is hummocky and poorly drained; non-sorted circles are common. Vegetation forms a complete cover over the frontal scarp, or hangs over exposed gravel, cobbles, and boulders.

E1. LAKE-SHORE FEATURES

No "oriented lakes" of the type described from Alaska and the Mackenzie Delta, N.W.T. (Black and Barksdale, 1949; Hamelin and Cook, 1967) are present in the area, but the thawing of permafrost and consequent re-

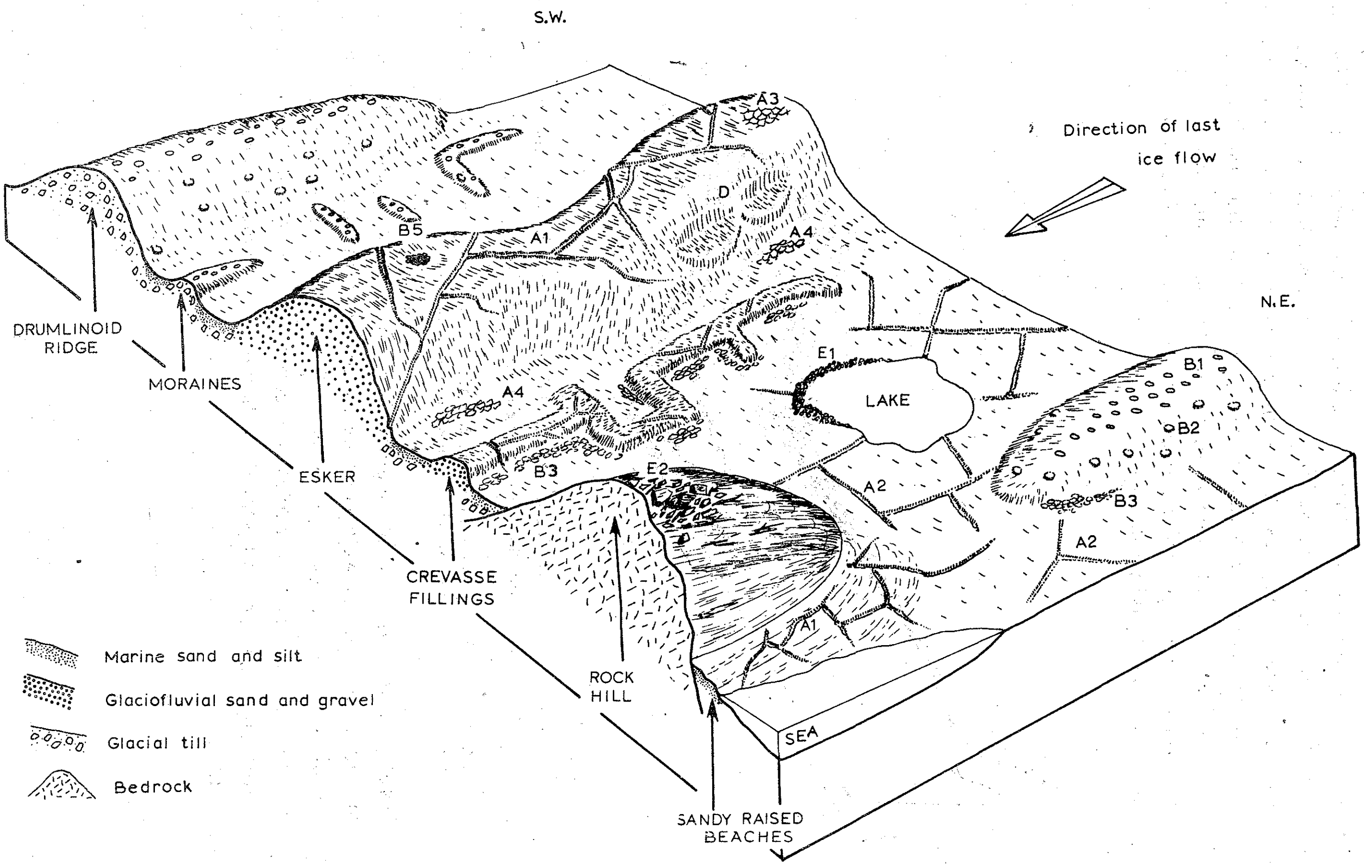


Fig. 12. Block diagram illustrating an idealized "model" of the Rankin Inlet landscape

The main glacial and periglacial forms are shown. Letters and figures refer to those of table I. Small features such as hummocks cannot be shown at this scale cession of lake-banks occurs in places where lake waters are driven by the prevailing wind.

Ice-pushed lake-ramparts are well developed on a number of lakes. Both wind-controlled and current-controlled movement of lake ice takes place. Boulders as large as 45 cm have been pushed with gravel to form ridges generally about 1.2 m high. Some ridges attain a height of as much as 3 m above summer water level where channels of swiftly flowing water which spill from one lake to another encounter such obstacles as morainic ridges. Bouldery terraces of a similar nature flank many slopes (for example, the sides of drumlinoid ridges) 32 km to the northwest of Rankin Inlet. They appear to be stranded ramparts from which lakes have drained.

E2. FROST-SHATTERED ROCK

The writer's investigations corroborate the evidence given by Birket-Smith that mechanical weathering of rock surfaces in the Barren Grounds is „not very marked" (Birket-Smith, 1933). Many rock surfaces in the Rankin Inlet area show no marked alteration; glacial striae are commonly well preserved. Frost-riving has caused blocks on some outcrops of greenstones to be displaced vertically by as much as 60 cm. A small outcrop of dolomite north of Rankin Inlet has been reduced to a rubble of shattered fragments. Other evidence of frost-shattering was found on glacial erratics lying on the surface, particularly in exfoliation of granite blocks.

CONCLUSION

The landforms, vegetation, and depth of active layer typically associated with each periglacial form are summarized in Table II. Figure 12 shows the distribution of periglacial features in relation to the various types of glacial landforms.

The most common periglacial features are frost-fissure polygons on both well drained and poorly drained sites, non-sorted circles, "steps", "vegetation nets", and hummocks. A predominance of non-sorted patterned ground forms in which vegetation comprises a major element is to be expected in such a "low arctic" environment with comparatively luxuriant vegetation. The most vigorous processes are those associated with the formation of non-sorted circles, "steps", and "vegetation nets"; they evidently represent a significant downslope movement of sandy deposits. Least stable surfaces are therefore those associated with deposits of fine and silty sand, and glacial till containing pockets of similar material. Most stable are ridges of fluvio-

Table II

	Periglacial form	Associated landform	Depth of active layer	Vegetation
A1	Fissure polygons on well drained sites	Fluvioglacial ridges, raised beaches. Some well drained ridges of till	1.2– 3 m	Lichen-heath and lichen-moss
A2	Fissure polygons in marshes	Ill-drained depressions such as dead-ice hollows	25–38 cm	Marsh tundra
A3	Lichen-border polygons	Fluvioglacial ridges	>1.5 m	Lichens in border furrows
A4	Sedge-border polygons	Ill-drained depressions	45 cm	Hummocky tundra – mainly sedges
A5	Miniature (desiccation) polygons	Surfaces of non-sorted circles	As B1	None
B1	Non-sorted circles	Morainic and drumlinoid ridges; other till surfaces; lower segments of sideslopes of fluvioglacial landforms	0.9–1.2 m	Thick lichen-moss and lichen-heath
B2	Steps	Sideslopes of drumlinoid and morainic ridges, and fluvioglacial landforms where pockets of suitable material occur	As B1	As B1
B3	Vegetation nets	Gentle slopes surrounding ill-drained depressions	38–60 cm	Hummocky tundra
B4	Sorted circles	As B3	As B3	As B3
B5	Sorted nets	Kettle holes on fluvioglacial ridges; swales between raised beaches	90 cm	Sedges

C1	Non-sorted stripes	Eskers	1.2 m	Thin cover of lichens; some heath plants
C2	Hummocks	All ill-drained, gentle solpes including lower segments of sideslopes of all glacial and fluvioglacial landforms	38–60 cm	Hummocky tundra
C3	Hummock garlands	Slopes of less than 2^0 with poor drainage .	As C2	As C2
D	Solifluction lobes and terraces	Flanks of both ridges of till and of eskers	0.9–1.2 m	Hummocky tundra on many lobes and terraces; thick lichen-moss; lichen--heath; and scant vegetation on some eskers
E1	Lake ramparts		Depth of thaw beneath ramparts not known	No vegetation
E2	Frost-shattered rock	Rock knobs and hills	Depth of thaw in rock not known	Lichens; mosses and vascular plants in depressions

glacial sand and gravel and raised beaches, which are characterized chiefly by frost-fissure polygons of the irregular pattern. The stability and favourable drainage conditions of these landforms are also reflected in the stage of soil development (James, in preparation).

As the geomorphological map (fig. 2) shows, drumlinoid, morainic, and fluvioglacial ridges are distributed widely throughout the area. The patterns of periglacial surface details associated with each of these, and with ill-drained intervening areas, which are illustrated in figure 12, are therefore also repeated throughout the area. No correlation was found to exist between the stage of development of periglacial features (or soils) and the time elapsed since the emergence of the land surface from the sea: local conditions of relief, slope, type of deposit, drainage, and vegetation everywhere determine the pattern and extent of development of periglacial features.

The relief of the periglacial surface details described in this paper is generally within the range of several centimetres to a metre; individually, they may not be striking, but collectively they comprise a significant element in a subtle landscape of low relief.

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