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SURFICIAL MATERIALS AND GEOMORPHOLOGICAL PROCESSES, WESTERN SVERDRUP AND ADJACENT ISLANDS, DISTRICT OF FRANKLIN

D.A. HODGSON

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SURFICIAL MATERIALS AND GEOMORPHOLOGICAL PROCESSES, WESTERN SVERDRUP AND ADJACENT ISLANDS, DISTRICT OF FRANKLIN
(including Amund Ringnes, southern Ellef Ringnes, Cornwall, Graham and King Christian islands)

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SURFICIAL MATERIALS AND GEOMORPHOLOGICAL PROCESSES, WESTERN SVERDRUP AND ADJACENT ISLANDS, DISTRICT OF FRANKLIN

Abstract

Amund Ringnes, Ellef Ringnes, Cornwall, Graham, King Christian, and adjacent islands are part of north-central Queen Elizabeth Islands, the northern group of the Canadian Arctic Archipelago. The islands are dominantly lowland or low dissected plateau (rarely greater than 200 m elevation), but relief is locally rugged. The islands and surrounding marine channels and basins are underlain by poorly indurated Mesozoic sandstone alternating with soft shale and siltstone, whereas areas of high relief are underlain by evaporite diapirs and igneous intrusions. Residual weathered rock and marine-reworked rock, chiefly sand to clay sized and unconsolidated, are the most widespread surficial materials.

Late Tertiary and Quaternary fluvial planation and dissection developed the present gross morphology; scattered high-level deposits remain from this episode. Quaternary glacial deposits are a minor element of the landscape. Dominant Quaternary events appear to replicate those of the Mesozoic: alternating marine and subaerial episodes over much of the present land area. Sea levels repeatedly rising to near 100 m have planed the margins of most islands. This coastal lowland and the interior fluvial landscape are the two most significant components of the physiography. A wedge of marine and deltaic sediments of Holocene and in part older age overlies the coastal lowland; sediment composition is controlled by underlying and upstream source materials, particularly rock.

Fluvial processes, ranging from rilling to lateral river channel corrasion, are presently the dominant subaerial processes, despite the sparse precipitation, short summer, and underlying permafrost. Mass wasting appears less significant, but rapid mass movement is locally highly active on fine grained materials.

Terrain sensitivity, hazards, and trafficability, assessed on the basis of materials, processes, and relief, vary greatly seasonally and between and within surficial materials units.

Résumé

Les îles Amund Ringnes, Ellef Ringnes, Cornwall, King Christian et les îles adjacentes sont dans la zone centre-nord des îles Queen Elisabeth, du groupe nord de l'Archipel arctique canadien. Les îles sont principalement formées de plaines ou de plateaux découpés (dépassant rarement une élévation de 200 m), mais le relief est localement accidenté. Les îles, les chenaux et les bassins marins environnants sont constitués d'un grès mésozoïque peu induré, alternant avec des schistes argileux et des grès tendres, alors que les régions à fort relief sont constituées de diapirs d'évaporite et d'intrusions ignées. Les roches altérées et les roches reprises par la mer, dont la taille du grain varie du sable à l'argile et qui sont inconsolidées, sont les matériaux de surface les plus répandus.

L'aplanissement fluvial et le découpage à la fin du Tertiaire et au Quaternaire ont donné l'allure morphologique actuelle et on peut encore voir de cette épisode des restes de dépôts éparpillés de niveau élevé. Les dépôts glaciaires quaternaires forment des éléments peu importants dans le paysage. Les principaux événements du Quaternaire semblent répéter ceux du Mésozoïque: une alternance d'épisodes marines et subaériennes sur la plus grande partie des terrains actuels. Les niveaux marins atteignant à plusieurs reprises près de 100 m ont aplani les marges de la plupart des îles. Les plaines côtières et les paysages fluviaux intérieurs sont les deux composants les plus importants de la physiographie. Un biseau de sédiments marins et deltaïques de l'Holocène et en partie d'âge plus ancien recouvre les plaines côtières; la composition des sédiments est contrôlée par les matériaux sous-jacents et ceux provenant de sources en amont, particulièrement les roches.

Les processus fluviaux allant de la formation de rigoles à la corrasion latérale des cours d'eau sont actuellement les processus subaériens dominants, malgré les rares précipitations, les étés courts et le pergélisol sous-jacent. Les pertes de masses semblent être moins importantes, mais les mouvements rapides de masses sont localement très actifs sur les matériaux à grains fins.

La sensibilité du terrain, les dangers inhérents et la résistance à la circulation, évalués à partir des matériaux, des processus et du relief, varient grandement avec les saisons et entre et à l'intérieur des unités de matériaux de surface.

INTRODUCTION

This report describes surface geological and geomorphological parameters vital to land management and to engineering and environmental impact studies in an area where natural gas has been discovered at a number of onshore and offshore sites. Two sets of surficial materials units are described: One set is based on the origin of landforms and is of value in Quaternary history studies; the other set provides a regional overview and emphasizes lithological variations, pertinent to engineering and land use studies, in particular the division of sand and gravel from clay, silt, and fine sand (Maps 1-1981, 2-1981).

The study area lies in the central and western Queen Elizabeth Islands, where the landscape, though polygenetic, is little modified by glacial processes. The nature and effects of geomorphological processes in this area are not widely known and are therefore described here in relative detail. Terrain sensitivity, hazards, and trafficability are assessed, and aggregate sources are discussed. Quaternary history is introduced to the extent necessary to describe the broad distribution and composition of materials.

The map area includes Amund Ringnes Island, Cornwall Island, Ellef Ringnes Island south of 78°30'N, Graham Island, King Christian Island, and other small islands in the vicinity (Fig. 1). The islands are included in 1:250 000 scale map areas 59 C, D, F, 69 C, D, E, F, 79 E. Ellef Ringnes and King Christian islands are also covered by 1:50 000 topographic maps. Adjacent Lougheed Island is described by Hodgson (1981).

Cornwall and Graham islands were located by Belcher on a Franklin search expedition in 1852-53 (Belcher, 1855); the Ringnes and King Christian islands, part of the Sverdrup Islands, were discovered by the Second Norwegian Polar Expedition of 1898-1902 (Sverdrup, 1904).

Procedure

Map unit boundaries were based chiefly on interpretation of 1:60 000 scale panchromatic airphotos and were revised after field checking. Satellite imagery proved to be of little value - especially as some areas still (at least to 1977) lacked good quality colour images due to poor weather or technical problems.

Field observations (Fig. 2) made in 1974, 1976, and 1977 were of three types.

1. surface observations of typical units or of problematic features identified on airphotos; pits were dug to the frost table and materials, and active and inactive processes were noted;

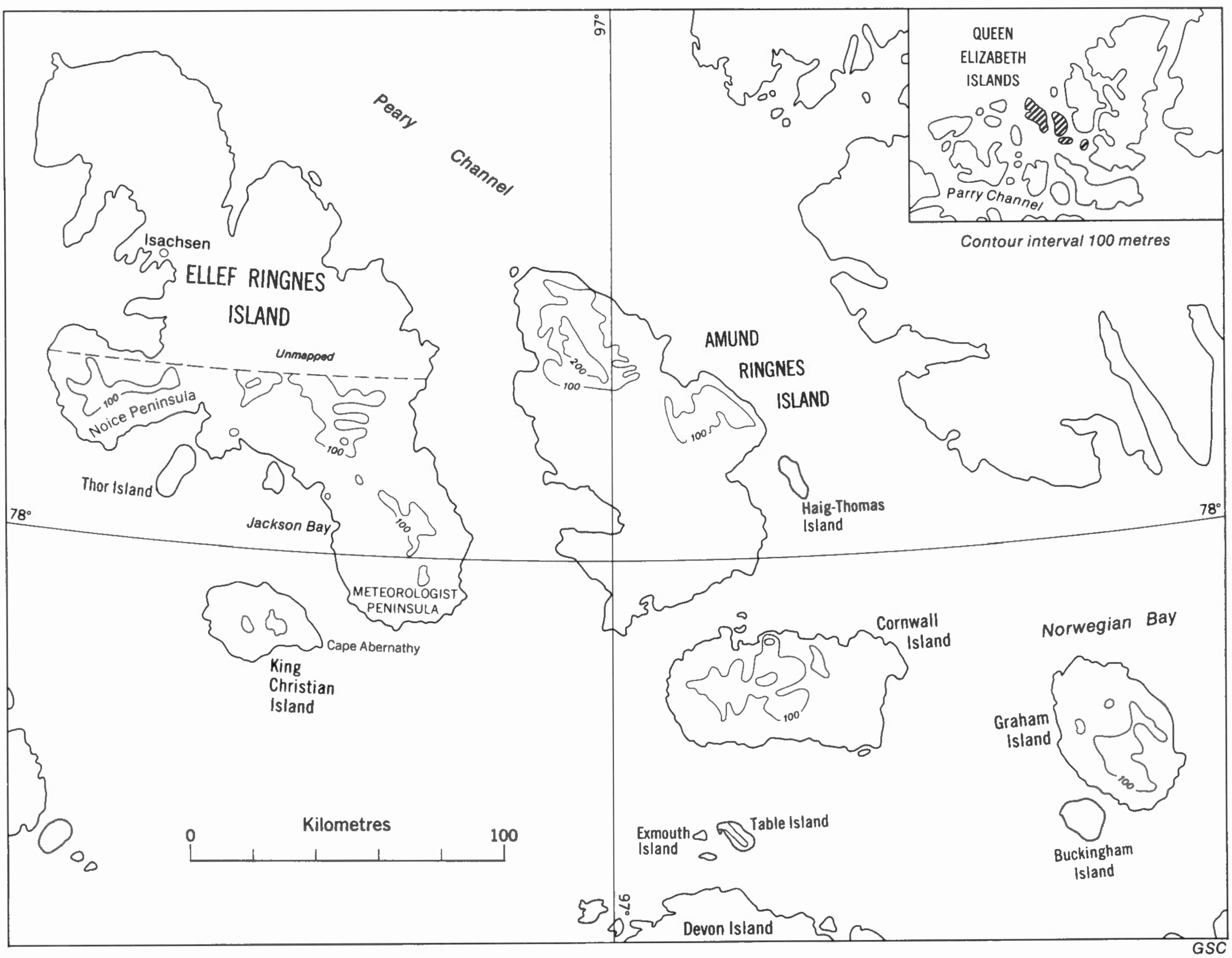


Figure 1. Location map of the study area, Amund Ringnes and adjacent islands.

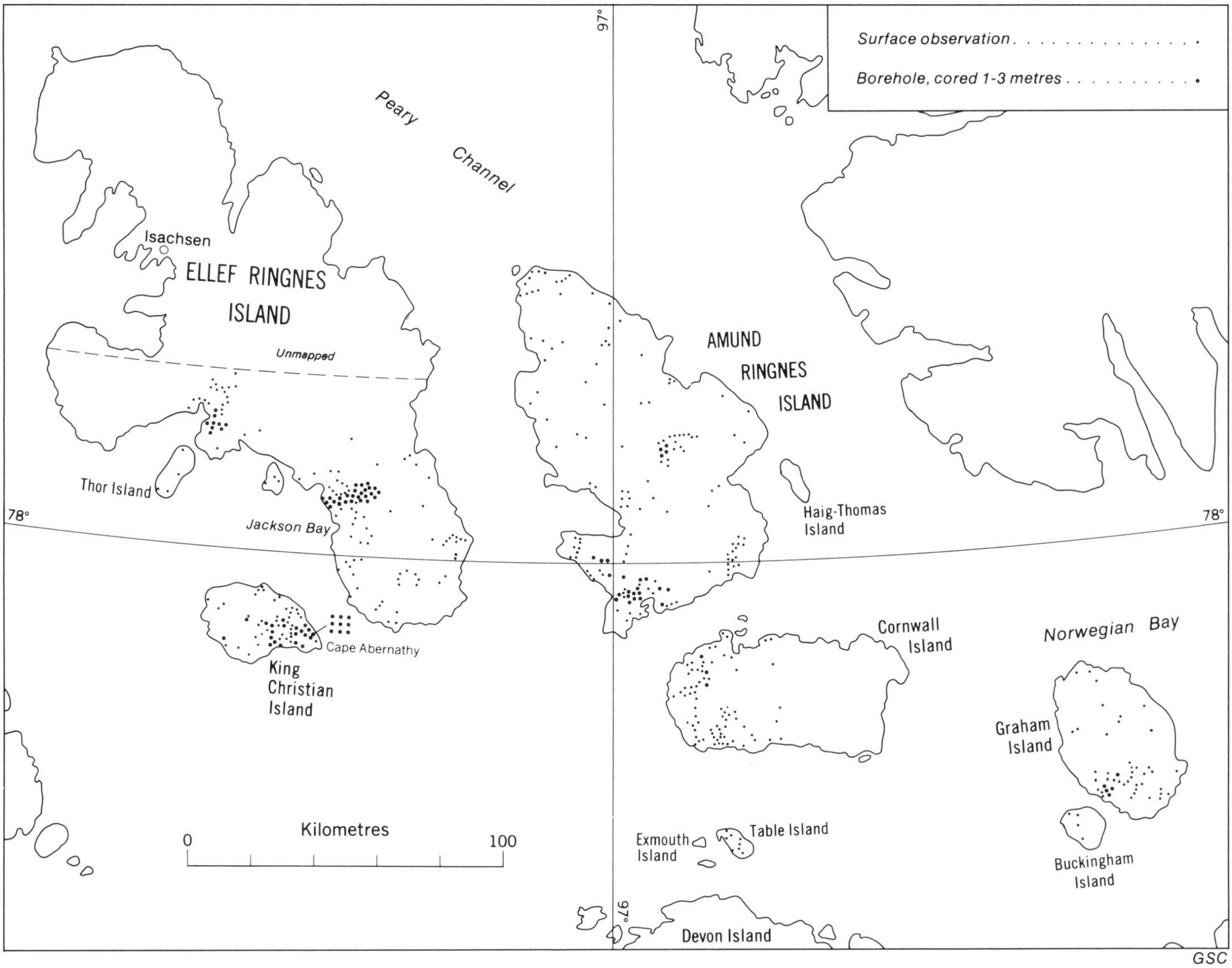


Figure 2. *Field observation locations.*

Figure 3

Permafrost coring equipment. GSC 203500-U

2. subsurface observations, below the frost table, made by drilling and coring to a maximum depth of 3 m (commonly less than 2 m) using a modified CRREL ice-coring auger (Veillette and Nixon, 1980) powered by a 3.5 hp Stihl chainsaw motor (Fig. 3). Cores showed the amount of excess ice (measured by volume of excess water and equated with the volume of visible ice where no sample was taken) and thickness of surficial materials;
3. site studies to examine geomorphological processes or to study Quaternary stratigraphy in exposures.

On Cornwall Island, observations were restricted to the west half as the distribution of surficial materials on the island is generally symmetrical about a north-south axis through the centre of the island.

Transport within the field area was by Honda all-terrain cycles (ATC; Fig. 3), by foot, and by Bell 206 Jet-Ranger helicopter. The ATCs travelled within a 30 km radius of camp in a day and on occasion pulled loader trailers weighing 150 kg. Camps were moved by a DHC-6 Twin Otter fitted with oversized tires.

Acknowledgments

Willing and able assistance in an unpleasant climate was given by A.C. Liard and W.G. Green (Graham Island, 1974); R. O'Breham and W.R. Archer (Ellef Ringners and King Christian islands, 1976); C.N.D. Hotzel and W.R. Archer (Amund Ringnes, Cornwall, and King Christian islands, 1977). Aircraft support in 1976 and 1977 was provided by Polar Continental Shelf Project of the Department of Energy, Mines and Resources.

The report was critically read by Dr. L.A. Dredge, who suggested a number of improvements and alternative interpretations.

GEOLOGICAL HISTORY

Bedrock

The islands overlie the central part of the Sverdrup Basin, a former regional depression containing an essentially concordant succession of marine and nonmarine sedimentary rocks up to 12 000 m thick, ranging from Lower Carboniferous to Upper Cretaceous. This succession was deformed in the Late Cretaceous to Early Tertiary into broad, shallow folds – or an arch in the case of Cornwall Island – with major anticlines commonly culminating in evaporite diapirs. Gabbroic dykes and sills are common on Amund Ringnes and Cornwall islands and in diapirs on Ellef Ringnes Island. The geology of the basin centre is described by Thorsteinsson and Tozer (1970) and by Balkwill (1974a, b).

Weathered rock is the dominant surficial material over half of the map area (Fig. 4). Bedrock has been modified by geomorphological processes and may differ greatly in terms of degree of consolidation and Atterberg limits from rock in fresh river-cut exposures or well cores which are the usual source for lithological descriptions. Both the unweathered and weathered state of lithostratigraphic units are described in the surficial materials section of this report.

Tertiary Deposition and Erosion

Basin subsidence up to the Late Cretaceous was followed by tectonism and regional uplift. Subsequent to this, Neogene Beaufort Formation fluvial sediments were deposited over at least the northern margin of the basin, including northern Ellef Ringnes Island (Tozer, 1970, p. 587). Concurrent or succeeding peneplanation produced a low rolling surface presently 100 to 200 m a.s.l. on the Ringnes islands, but higher farther east. The similarity in elevations of peneplain remnants between islands, together with their occurrence only at island or other prominent topographic high spots, indicates that the surface was once contiguous and thus predated formation of interisland channels and basins. Remnants of fluvial sand and gravel, found as far east as central Ellesmere Island, overlie this surface, and the scattered presence of wood fragments in these deposits indicates that at least some of them may be placed in the Beaufort Formation.

Fortier and Morley (1956) proposed that the present physiographic framework developed from Tertiary subaerial erosion by a largely dendritic drainage system; in the northern Archipelago flow was northwestward. Bornhold et al. (1976) substantiated the drainage system model for the southern Archipelago and noted that glacial modification there has been slight. The concept of rifting being the primary control over the physiography of Parry Channel and adjacent areas, however, is now established (e.g. Kerr, 1981); the main channels are undoubtedly rift valleys.

The dominant Quaternary sediments and landforms are the result of marine and subaerial erosional and depositional processes. Periods of marine submergence, or possibly fluvial planation associated with higher sea levels, have planed such extensive areas that high stands must have lasted many thousands of years and obviously preceded the Holocene. It is not known whether sea level changes were eustatic, isostatic, or tectonic in origin. Thick raised marine and deltaic sediments, containing in situ molluscs beyond the range of radiocarbon dating, are present on several islands.

Quaternary Events

Evidence for at least one widespread glaciation of the area is indicated on land by striae, rock basins, esker-like ridges, and scattered morainal deposits; offshore, glacial erosion is possibly responsible for undulating channel profiles and discordant levels at channel junctions (Horn, 1963). Little direct evidence exists, however, to support or dispute an ice cover here during the last advance of Laurentide ice south of the Queen Elizabeth Islands. Blake's (1970) proposal that the Innuitian Ice Sheet covered much of the Queen Elizabeth Islands was based firstly, on Holocene (i.e. last 10 000 years) uplift in the area representing recovery from an ice load and secondly, on the decrease in radiocarbon age of the highest Holocene shells from the westernmost islands to the east central area being a result of disintegration of ice from west to east. The absence of clear glacial or fluvioglacial erosional or depositional landforms, together with the deposition of pre- or early Holocene marine transgressive sediments, does not favour a late Quaternary ice cover over the Study area. Depression and subsequent uplift are possibly a result of more restricted ice caps on uplands to the south, east, and northeast of the study area. Nevertheless, ice caps with sub-freezing basal temperatures may have existed on the islands.

The early Holocene sea was far more extensive than at present (Fig. 4) and had a maximum level of about 100 m above sea level on Amund Ringnes, Cornwall, and Graham islands, possibly less to the west. Transgressive sediments have been tentatively identified immediately underlying the offlap cover of Holocene offshore, nearshore, beach, and deltaic sediments. The marine limit has no morphological form; it is detectable only as the highest elevation at which Holocene shells may be found. Emergence was most rapid in the early Holcene and at least half was accomplished between 9000 and 7000 years ago. Thus marine sediments are rare near marine limit and commonly feather out 30 to 60 m in elevation below it; correspondingly, the Holocene marine sediment wedge thickens towards the present shoreline.

Subaerial erosional and depositional processes have undoubtedly changed in relative importance as climate varied through the Quaternary. Fluvial processes at present appear dominant, with mass wasting less significant, and eolian processes of local significance.

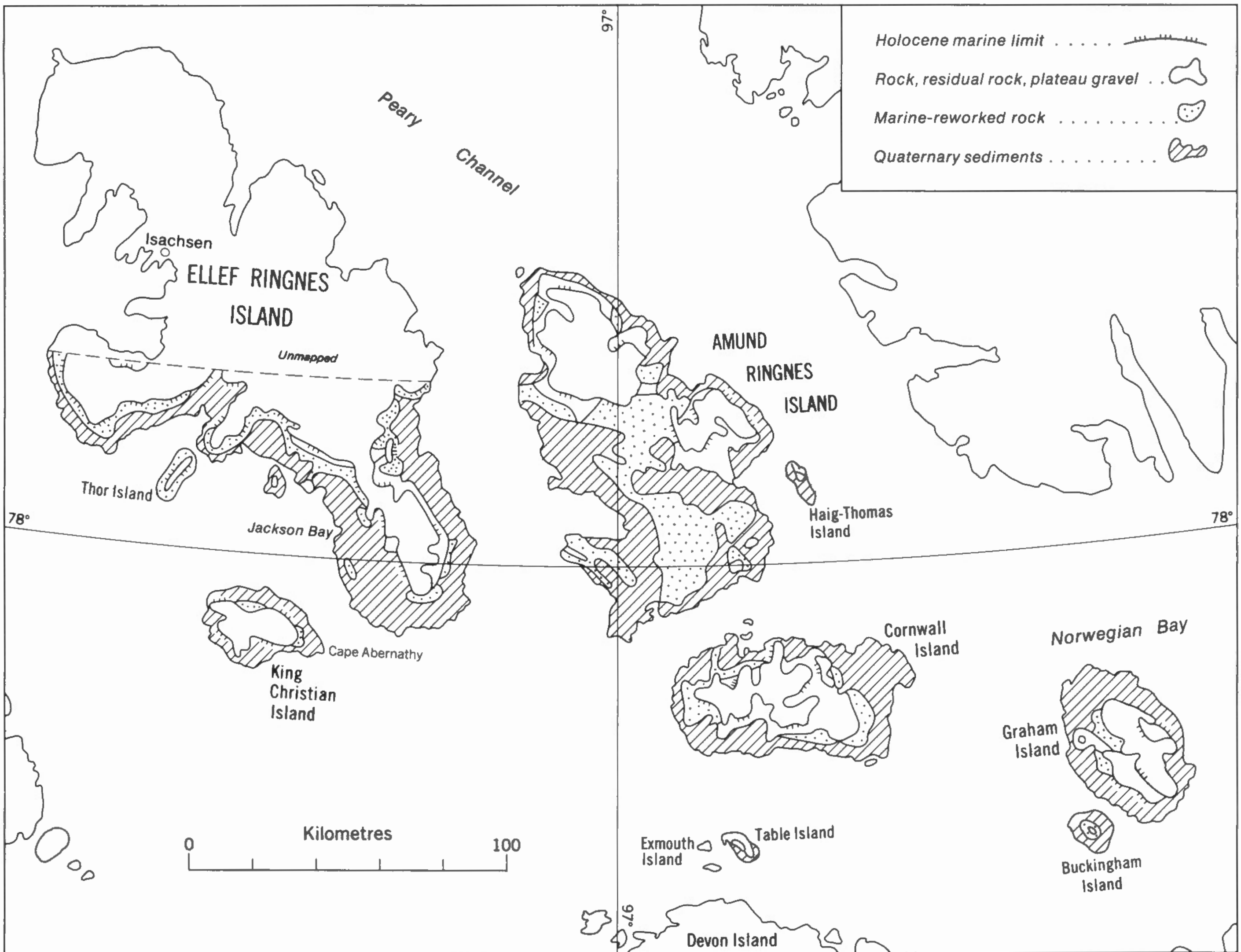


Figure 4. *Holocene marine limit and distribution of rock, marine-reworked rock, and Quaternary deposits in the study area.*

PHYSICAL SETTING

Physiography

The islands represent interfluves between former major fluvial, possibly ice-modified channels. Most land lies below 200 m (Fig. 1), apart from piercement domes and sills which are commonly about 300 m high (possibly a remnant erosion surface). An exceptional elevation is the 400 m summit of Mount Nicolay on northern Cornwall Island, developed on sandstone strengthened by numerous dykes and sills. Lithological changes between sandstone and shale have only local control over relief. The most significant physiographic division is between areas above and below the approximate limit of Quaternary (or older) marine planation, which approximates the Holocene marine limit.

The chief landscape elements above marine limit are ridges and valleys, scarplands, dissected plateaus, and low rolling terrain. Local relief is 20 to 100 m on sedimentary rock and up to 250 m on intrusive rock. Sandstone commonly erodes into a succession of major and minor escarpments, which are especially well developed on the Isachsen Formation. Shale and siltstone terrain is generally more rounded, though it may have as much relief as the sandstone, have massive strike-aligned escarpments (e.g. Kanguk Formation), or be finely dissected by gullies (Fig. 5).

Below marine limit the coastal plain is a gently inclined concave seaward slope, forming an apron around all islands, regardless of lithology, except for piercement domes, major sill or dyke systems, and northeast Amund Ringnes Island, where steep slopes are possibly apart of a fault-aligned relict glacial trough wall. It includes extensive, nearly flat (marine planed?) areas of rock veneered by marine sediment and also numerous areas of higher, dissected terrain, although this is rarely as rugged as that above marine limit. River dissection results in steep cutbanks, 2 to 30 m high, commonly cut in incompetent unconsolidated materials.

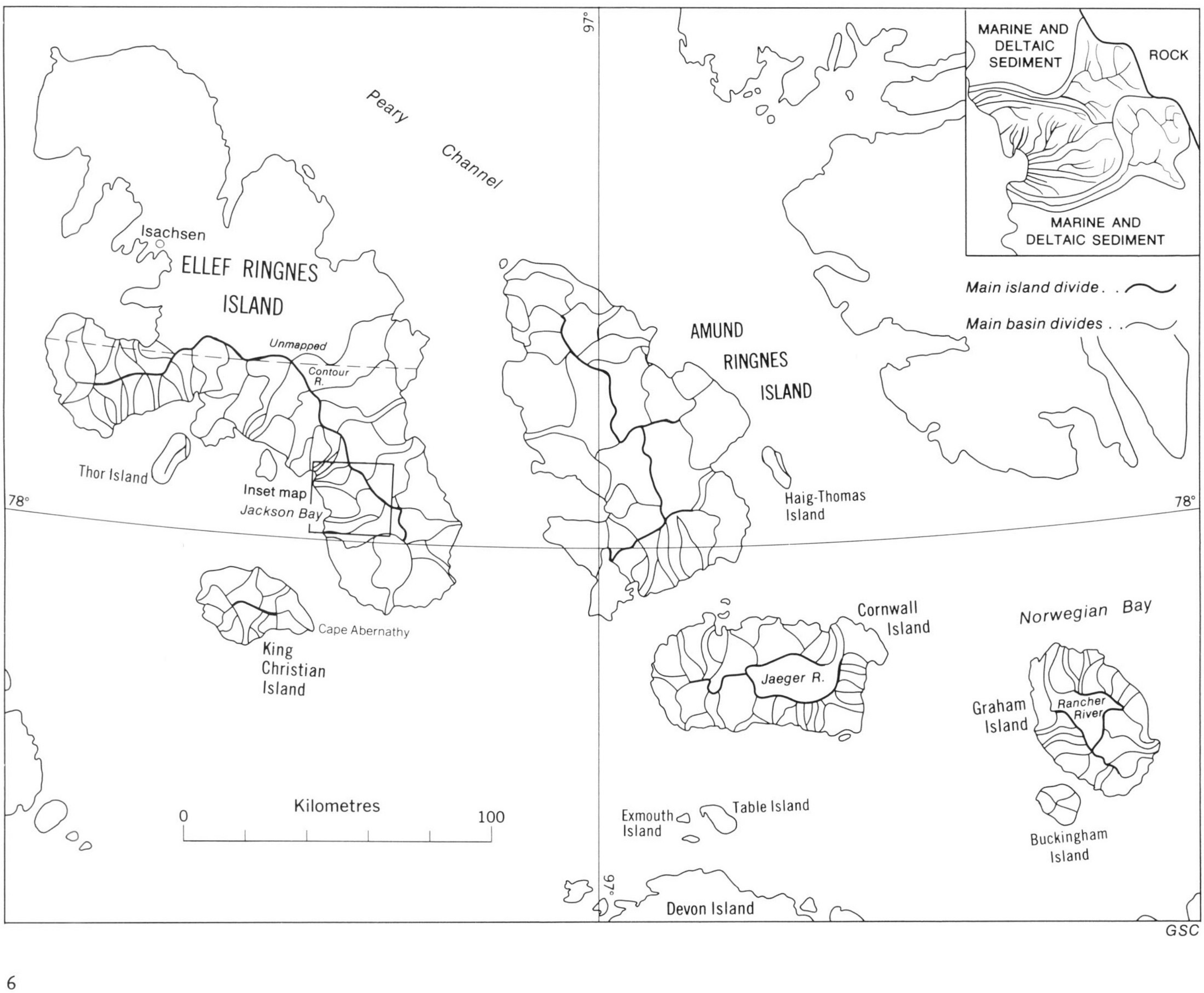
Primary watersheds follow central height-of-land axes of islands (Fig. 6), indicating a lengthy development period without derangement by glacial events. There are three exceptions: 1) Rancher River on Graham Island has cut back into fine grained sediments in a syncline. 2) the Jaeger River basin of eastern Cornwall Island for an unknown reason cuts across bedrock strike, forcing the main watershed to bifurcate; if sea level were 50 to 100 m higher, however, this

Figure 5.

Frost-fissure troughs and gullies on silty residual Kanguk Formation (shale), eastern Ellef Ringnes Island. Polygon width approximately 25 m. GSC 203500-Z

Figure 6. *(below)*

Major drainage basins in the study area; inset shows a typical drainage network.



effect would be far less marked. 3) Contour River on the northern boundary of the map area, transects the height of land (Contour Dome); St-Onge (1965, p. 26) concluded that this is due to superimposition from an older erosion surface.

Inland from the coastal plain, large basins are typically dendritic, with smaller areas of rectilinear drainage controlled by structure (especially on the Kanguk Formation). On the coastal plain, these small basins may be exceedingly narrow (Fig. 6, inset), a result of shoreline regression over the last 9000 years. The falling sea level (base level) causes channels to incise previously deposited deltaic sediments over distances up to 20 km. There has also been inadequate time for headward tributary erosion and capture. Areas between these main basin outlets are drained by subparallel streams, orthogonal to the shoreline and in a juvenile state of development also due to Holocene emergence. There are few gross variations in stream density across the islands; the perennially frozen ground below the maximum annual thaw depth of 40 to 100 cm greatly reduces the effect of variations in strength, permeability, and porosity of bedrock and Quaternary sediments.

The dominance of fluvial development and lack of glacial modification is emphasized by the extreme rarity of lakes above marine limit. At low elevations, the few lakes are generally the result of aggrading fans blocking drainage. Ponds formed by thermokarst or frost fissure processes are locally abundant but are mostly ephemeral.

Climate

The islands are in the same climatic region (Maxwell, 1981), although in summer many climatic parameters ameliorate from northwest to southeast, i.e. away from the Arctic Ocean. Summer fogs from the Arctic Ocean penetrate interisland channels on prevailing north and northwest winds, and visibility is commonly poor on north- and west-facing shores or slopes. The best period for field work, one to four weeks, is immediately following snowmelt (varies from late June to mid-July) and prior to sea ice cover flooding or breaking and providing a moisture source for fog or precipitation.

The only long-term climatic data (Fig. 7) is from Isachsen weather station, just north of the map area on Ellef Ringnes Island (Fig. 1). Summer temperatures at this station are a low representation for the region; July 1976 air temperatures at field camps on southern King Christian and Ellef Ringnes islands were slightly above the long term mean for Isachsen, even though the summer of 1976 was particularly cool. Year-round occupation of the Isachsen station was discontinued in August 1978.

Mean daily air temperatures are above freezing only from late June to mid-August. While air freeze-thaw periods are early June to mid-July and mid-August to early September, soil temperature data for Resolute (on Cornwallis Island to the south) show only one freeze-thaw cycle at 5 cm depth (e.g. June, July, August, September volumes, Atmospheric Environment Service, 1976).

Annual rainfall is extremely low, although a 24 hour rainfall of at least 15 mm has occurred in each summer month during the recording period at Isachsen. Snowfall is low, and much is blown into drifts leaving little cover elsewhere. The July atmospheric freezing level of 710 m (1964-72 average, Bradley, 1973) is well above the highest elevation of the islands and this, combined with the low precipitation, precludes glacierization.

Perennial snowbanks, however, are scattered in valleys and gullies at all elevations, and early in the summer of 1977 an incipient glacier 200 by 20 m and 10 m deep filled a gorge about 50 m a.s.l. on eastern Amund Ringnes Island.

Figure 7 also shows wind data for Isachsen and field camps. Not only are prevailing winds from the north and northwest, but mean speeds from these directions are higher than from other points.

Vegetation

Vegetation cover ranges from scattered well vegetated areas to extensive sparsely vegetated or barren areas. The amount of cover and occurrence of vascular plant species increase from northwest to southeast, probably in response to warmer summer temperatures, possibly linked to a decline in the dominance of north and northwest winds. Vegetation growth is inhibited in areas of eolian activity, evaporite sediments, quartzose sands, and very low pH. Vegetation cover and plant associations are described in Hodgson and Edlund, 1978.

SURFICIAL MATERIALS

Map Legends

Two methods for describing surficial materials are portrayed on Maps 1-1981, 2-1981. Neither method is strictly stratigraphic as correlation of units is incomplete.

(1) Morphogenetic map legend. Terrain is classified by origin of surficial deposits, combined with an assessment of the most significant land attributes, particularly morphology, properties of materials and their spatial variation, geomorphological processes (active, inactive, potential), and drainage. This is a modification of the system described in Fulton et al., 1974. In stratigraphic sequence the basic divisions are:

E - Eolian deposits

F - Fluvial-deltaic deposits

C - Colluvial deposits

W - Marine deposits

TQ, Q - Quaternary or older, probably fluvial, deposits

RW - Marine reworked rock

R - Bedrock and residual weathered rock.

These units commonly can be recognized in airphoto interpretation. The degree of refinement, including the addition of modifying terms (Table 1), can change as ground observations become available; for example, textural modifiers can be a simple coarse grained/fine grained division, a gravel/sand/silt/clay division, or can be omitted.

This is the more detailed of the two legends and is of most value in Quaternary history studies. But it often results in a large number of unique units which form an unwieldy framework for the addition of other information such as terrain sensitivity ratings or vegetation types.

(2) Lithogenetic map legend. Using the lithogenetic system, the basic morphogenetic units are regrouped on the basis of grain size and are given alpha-numeric designations (Table 2, Fig. 8). This greatly reduces the number of units in comparison to the morphogenetic legend and gives a broader view of the map area, making comparison between geographical areas easier. Textural information is useful for land use and engineering studies. This method, however, demands more information than is normally available from airphotos and thus must be supplemented by ground observations.

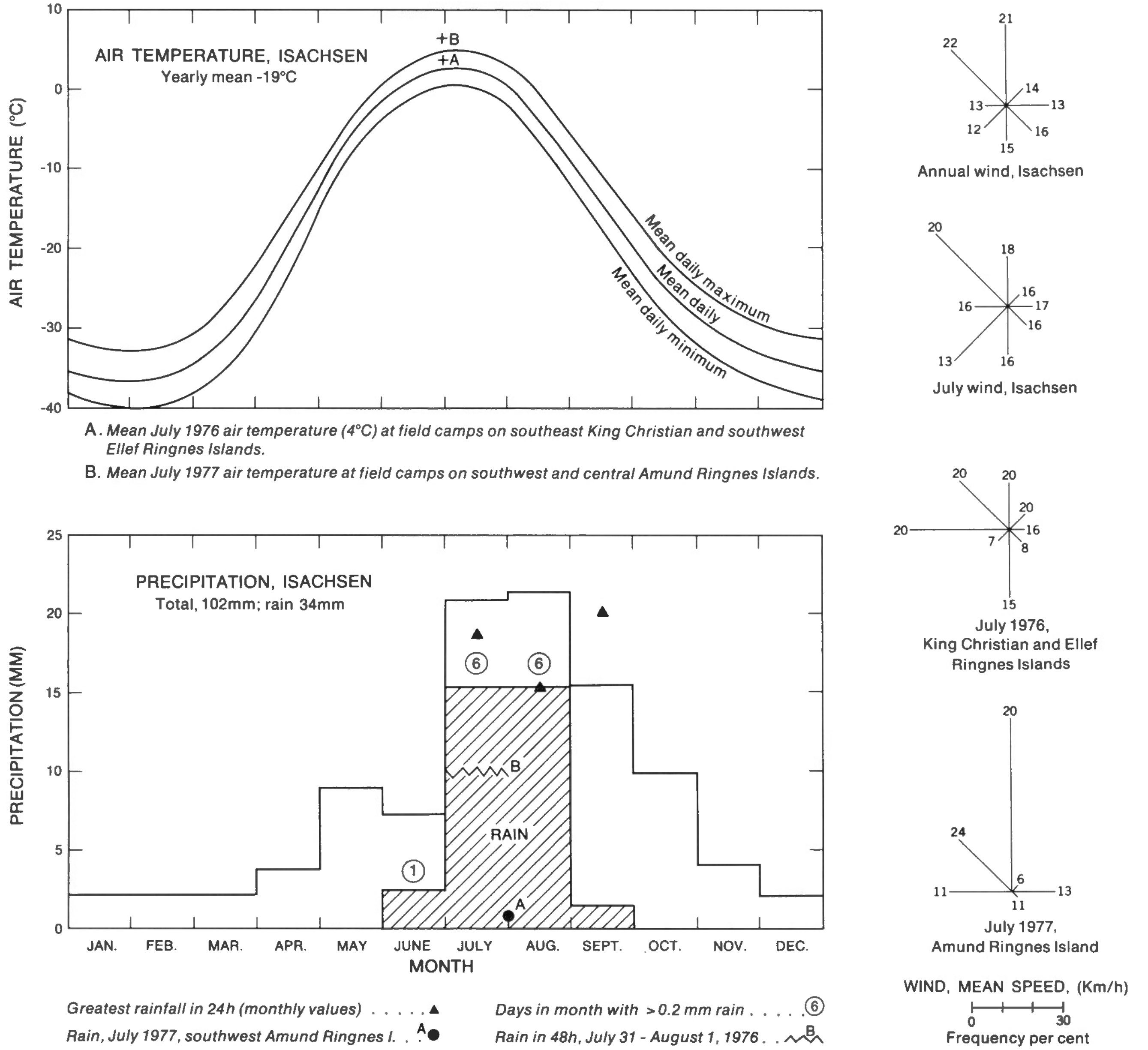


Figure 7. Climatic data for Isachsen, Ellef Ringnes Island (78°47'N, 103°32'W; 25 m a.s.l.) for the period 1948-70 (Atmospheric Environment Service, 1975a, b, 1976; Meteorological Branch, 1968); plus data from field camps on Amund Ringnes, Ellef Ringnes, and King Christian islands, July 1976 and 1977. Temperature and wind data from field camps are means of 1200 and 2400 h (G.M.T.) readings.

Map Unit Descriptions

The lithogenetic legend is followed in this report except for marine and fluvial deposits where differences between morphogenetic and lithogenetic units are greatest, and thus both sets of units are described. Where data exist, map units are described in terms of:

1. Distribution (of units within the map area, see Table 2).
2. Lithology/composition: unconsolidated material is commonly divided into a coarse fraction composed of gravel (round to subround fragments), rubble (subangular to angular), and sand; and a fine fraction of silt, clay, and possibly fine sand. In granulometric analyses (Appendix 1) and in some unit descriptions, coarse and medium sand is divided from fine sand, as the latter is more closely related to silt in behaviour, particularly when saturated. Both unaltered and weathered rocks are described. Most unconsolidated surficial units form veneers (less than 2 m thick) over other materials, generally rock, and are rarely greater than 10 m thick. The map unit designator gives the average composition; a unit may be uniform in composition or have large spacial variations (but not be divisible at the scale of mapping).
3. Topography: in general slopes of less than 3° are described as low, from 3° to 15° as moderate, from 15° to 35° as steep, and greater than 35° as cliffed.
4. Drainage and river bed and bank characteristics.
5. Active geomorphological process: further descriptions are given in the process section of this report.
6. Thermal characteristics, including ice content and active layer thickness; additional ice content data are available in the core logs described in Appendix 2.
7. Character of the modern shoreline.
8. Origin and age.

Rock and Residual Weathered Rock

Rock units include all pre-Quaternary materials, whether consolidated or not, with the exception of high-level fluvial gravel deposits, apparently pre-Quaternary in age, but younger than the Miocene Beaufort Formation. Descriptions of unweathered and in some cases weathered (residual) rock are grouped by rock-stratigraphic units (Table 1). A rock formation, which may be composed of more than one distinct member or bed, is not the most satisfactory mode for presenting lithological information; however it is commonly the base unit on published maps of the area.

Chief sources of information are listed below by islands, although many of the reports cover wider areas.

Amund Ringnes Island:	Balkwill, 1973, 1974b, in press; Roy, 1973, 1974; Balkwill et al., 1977.
Cornwall Island:	Balkwill, 1974a, b, 1979, in press.
Ellef Ringnes Island:	Stott, 1969; Roy, 1974; Hopkins and Balkwill, 1973; Balkwill and Hopkins, 1976.
Graham Island:	Greiner, 1963.
King Christian Island:	Balkwill and Roy, 1977.
Table Island:	Tozer, 1961.

Table 1. Components of morphogenetic units

Texture of surface materials		Morphogenetic core term		Rock Lithostratigraphic superscript*	
c	clay	E	Eolian deposits	KTe-u	Eureka Sound Formation (informal upper member)
m	silt				
¢	silt and clay, undifferentiated	Fp	Fluvial plain	KTe-l	Eureka Sound Formation (informal lower member)
m̰	silt and fine sand, undifferentiated	Ft	Fluvial terrace		
f	fines (clay, silt, fine sand, undifferentiated)	Fpt	Fluvial plain and terrace	Kk	Kanguk Formation
s	sand	Ff	Fluvial fan	Kh	Hassel Formation
g	gravel	Fd	Fluvial delta		
b	boulders			Kc	Christopher Formation
r	rubble	C	Colluvium,	Ki	Isachsen Formation
				K	Cretaceous rock, undifferentiated
o	outcrop of rock			JKd	Deer Bay Formation
		W	Marine deposits, undifferentiated	Ja	Awingak Formation
		Ws	Strandline flat	Jr	Ringnes Formation
		Wb	Beach	Js	Savik Formation
				Jj	Jaeger Formation
		M	Diamicton	Jb	Borden Island Formation
				Ŧhu	Heiberg Formation (Upper Member)
		Q	Gravel ridges		
		TQ	Plateau gravel	Ŧhl	Heiberg Formation (Lower Member)
		RW	Marine-reworked rock		
		R	Bedrock and residual weathered rock	Ŧba	Blaa Mountain Formation
				Ŧs	Schei Point Formation
				Ŧb	Bjorne Formation
				Pe	Diapiric dome
				I	Igneous rock

* Formations are in stratigraphic order

Table 2. Occurrence of lithogenetic units

Unit	Lithologic Unit Designator	Islands: Amund Ringnes	Cornwall	Southern Ellef Ringnes	Graham	King Christian	Table
Fluvial and deltaic deposits - coarse	14	x	x	x			x
Fluvial and deltaic deposits - fine	13	x	x	x	x	x	
Deltaic deposits - coarse/fine	12	x	x	x		x	
Colluvial deposits	11	x	x		x	x	x
Marine deposits - coarse veneer/coarse rock*	10/6	x	x	x		x	x
Marine deposits - coarse veneer/fine rock*	10/5	x	x	x		x	x
Marine deposits - thick, coarse	10	x	x	x	x	x	x
Marine deposits - fine veneer/coarse rock*	9/6	x	x	x	x	x	
Marine deposits - fine veneer/fine rock*	9/5	x	x	x	x	x	
Marine deposits - thick, fine	9	x	x	x	x	x	
Diamicton deposits - gravelly	8b		x		x		xx
Diamicton deposits - clayey	8a	x					
Gravel ridges	7b	x		x		x	
Plateau gravel	7a	x	x	x	x	x	
Coarse marine-reworked rock*	6	x	x	x	x	x	x
Fine marine-reworked rock*	5	x	x	x	x	x	
Igneous dykes and sills	4	x	x	x			
Clastic rock*							
Coarse grained							
Eureka Sound Formation (informal upper member)	3r		x				
Hassel Formation	3o	x		x	x	x	
Isachsen Formation	3m	x	x	x		x	
Awingak Formation	3j	x	x				
Jaeger Formation	3g		x				
Borden Island Formation	3f		x				
Heiberg Formation (Upper Member)	3e	x	x				
Schei Point Formation	3b						x
Bjorne Formation	3a						x
Fine grained							
Eureka Sound Formation (informal lower member)	2q	x		x			
Kanguk Formation	2p	(x)		x	x		
Christopher Formation	2n	x		x		x	
Deer Bay Formation	2k	x	x	x		(x)	
Ringnes Formation	2i	x					
Savik Formation	2h	x	x				
Heiberg Formation (Lower Member)	2d		x				
Blaa Mountain Formation	2c		x				
Cretaceous rock – undifferentiated	2+3			x			
Diapirs	1	x		x			

* The letters for clastic rocks in the unit designator denote stratigraphic order of rock formations (cf. Table 1); these letters are also applied to rock units underlying a marine veneer and to marine-reworked rock.

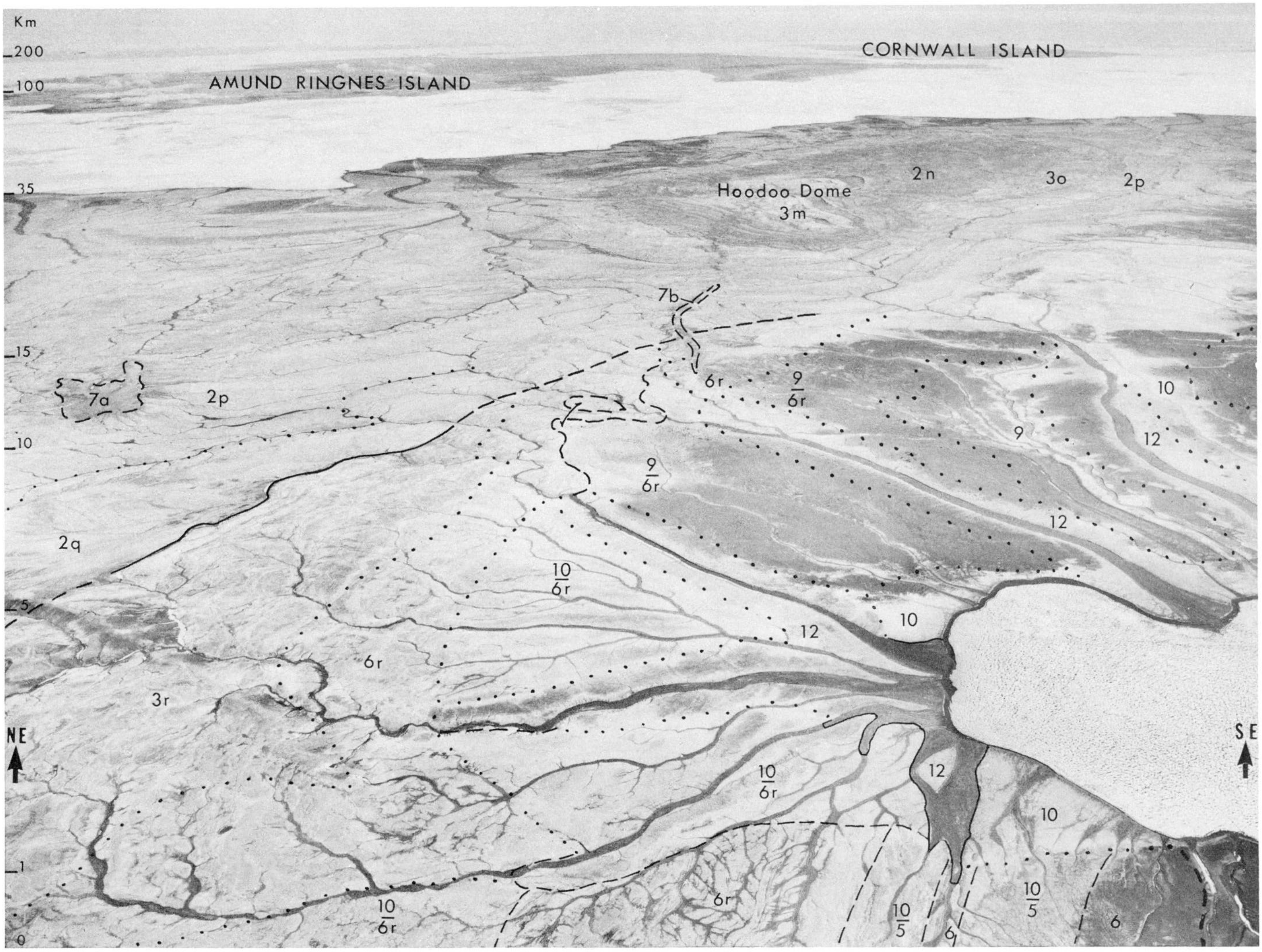
x unit present xx exposed in section only (x) marine-reworked rock only

Rock is exposed over most of the area above marine limit (Fig. 4). Below marine limit, marine-washed rock or rock with a veneer of marine or fluvial sediment is widespread; unmodified rock is present in rugged areas. Most stream incisions greater than 2 m deep, other than in thick deltaic sediments, expose underlying rock.

Diapiric Domes

Diapiric domes are found on Amund Ringnes and Ellef Ringnes islands (Fig. 9). Surface rock is chiefly gypsum, but anhydrite occurs in fresh exposures. Minor beds of intercalated limestone, and dykes and sills are common. The strata of peripheral formations are steeply inclined, but little altered. Diapirs weather to blocks and crystalline granules of gypsum, to solution-pitted gypsum and anhydrite outcrop, and to a lesser degree to limestone and dolomite rubble, gabbro blocks, and sand and fine grained colluvium.

The domes commonly rise to 250 m above adjacent units, and reach a maximum elevation of more than 330 m in northern Amund Ringnes Island. Terrain, including microrelief, is extremely rugged, and dome margins are fluted by ravines and gullies (Fig. 10). Crowns of large domes have lower local relief, particularly where igneous intrusive rubble or colluvium is present.



2n – Christopher Formation;
2p – Kanguk Formation;
2q – Eureka Sound Formation, informal lower member;
3m – Isachsen Formation;
3o – Hassel Formation;
3r – Eureka Sound Formation, informal upper member;
7a – plateau gravel;
7b – linear gravel;
9 – thick, fine grained marine sediment;
9/6 – fine marine sediment veneer over coarse rock;
10 – thick, coarse grained marine sediment;
10/5 – coarse marine sediment over fine rock;
10/6 – coarse marine sediment over coarse informal rock;
12 – deltaic sediments, coarse over fine.

Figure 8. *View east across Meteorologist Peninsula, Ellef Ringnes Island, from over Malloch Dome showing lithogenetic map units. Geological boundary ———- - - - - - · · · (position defined, approximate, assumed). RCAF Photo T428R-113*

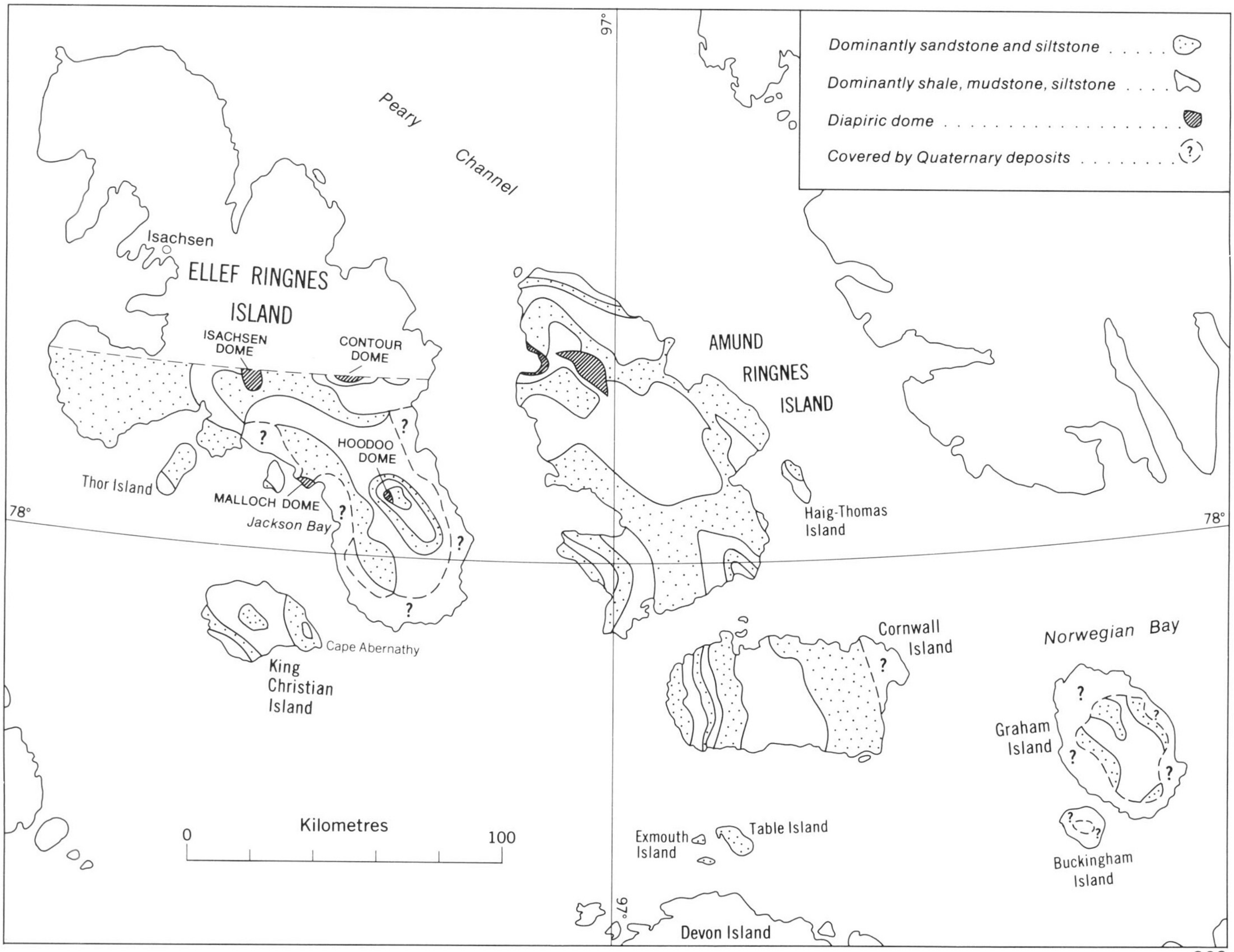


Figure 9. *Gross bedrock lithology, Amund Ringnes and adjacent islands.*

Figure 10

Diapiric intrusion exhibiting typical rugged relief (ca. 200 m), Isachsen Dome, Ellef Ringnes Island. GSC 203500-B

Radial drainage patterns are common, and stream density is higher on evaporites than on intrusive igneous rocks. Evaporites are well drained where highly dissected, but moderately to poorly drained on gentle slopes; igneous rocks are well to moderately well drained. Lakes and ponds are absent. River valley flats are straight to sinuous, with few terraces; bedload is coarse grained – chiefly rubble, gravel, and sand. High order channels are deeply incised, with banks of outcropping rock cliffs or rubble at the angle of repose.

Evaporites are highly susceptible to solution pitting and gullying. Rockfalls and talus creep occur on long steep slopes, whereas material is moved by long rills on gentle colluvial slopes. Solifluction lobes 1 to 2 m thick occur on coarse materials.

At the shoreline, cliffs may extend below sea level, but more commonly a bouldery or gravel beach berm has developed. Flights of raised berms are present where valleys meet the shore and slopes are low.

Fine Grained Clastic Rock

Thick, fine grained rock units alternate with coarse grained rocks on all islands (Fig. 9, Table 2). Extensive outcrops occur in central and northern Amund Ringnes and central Cornwall islands.

The shale, siltstone, and minor sandstone is poorly to well lithified and flat lying to moderately inclined. The upper 1 to 2 m is commonly weathered to silt, clay, and small platy shale or siltstone fragments. A continuous to scattered, angular to round, granule- to boulder-size lag composed of shale, mudstone, siltstone, or sandstone fragments is present. Unweathered outcrop of shale, siltstone, or sandstone is minor. Mudstone or ironstone concretions to 5 m diameter are locally abundant. Dykes and sills intrude sediments on Amund Ringnes and Cornwall islands. Bedrock and weathering products vary from slightly basic to highly acidic depending on the formation.

Gently to moderately inclined rectilinear to convex slopes result in rounded terrain. The broad strike-aligned divides are commonly as high as adjacent sandstone units, and local relief is 20 to 100 m. River and major stream spacing is less than 1 km. Divides and slopes are moderately well drained in a dry summer but poorly drained in a wet year; although local areas of ponding occur over frost fissures, lakes are absent except in central Cornwall Island. Extended snowmelt and seepage occur at the base of steep slopes (including river bluffs). When rainfall is above average, the active layer may be moist or saturated until freezeup; in normal or dry years, the active layer dries downwards, and a desiccated crust develops over saturated or moist unfrozen material. Channel morphology varies between rivers and may do so on the same river. Channel zones are straight to slightly sinuous and wide to narrow; high order streams are locally incised and sinuous. The drainage pattern is moderately or steeply inclined. Bedload is silt, clay, and minor gravel where only fine grained material is drained, but where coarse materials outcrop, they may dominate the bedload for many kilometres downstream. Channel banks are gently inclined to cliffed and are relatively stable where bedrock is lithified or silty; but slope failures are common in weathered clayey material.

Fluvial processes dominate – chiefly rilling, sheetwash, and gullying. Mass movement is more active than on coarse grained rock, although solifluction lobes are rare and movement rarely obscures frost-fissure troughs. Where rock on moderate or steep slopes has completely disaggregated to silt or clay (especially the Christopher Formation), earthflows may occur when the active layer is saturated. Eolian erosion is locally significant on silty unvegetated material (especially the Kanguk Formation). Frost-fissure polygons with varying trough sizes cover 75 per cent of fine grained rock. The active layer is commonly 30 to 60 cm thick, although it may be less where vegetation cover is complete. Average visible ice content in the 2 m below the frost table varies from 5 to 90 per cent (Appendix 2); frost fissures are commonly ice filled but otherwise ice lenses greater than 20 cm thick are rare.

Lithological description of rock-stratigraphic units and variations from the general comments follow.

Blaa Mountain Formation

The formation is limited to central Cornwall Island. The flat-lying to gently inclined shale, siltstone, and poorly consolidated fine grained sandstone weather to a dark grey clayey silt. The resulting surficial material is neutral to slightly alkaline (pH 8 to 10). The Blaa Mountain and Lower Heiberg formations have been invaded by thick gabbroic sills and numerous dykes, hence areas of rubble and sand are present.

The flat to rolling terrain is locally dissected with local relief 20 to 100 m and although the unit is generally recessive, intrusions support scattered ridges and hills. Wide (up to 3 m) frost-fissure troughs have developed in flat-lying areas.

Heiberg Formation (Lower Member)

The flat-lying to gently inclined, interbedded fine sandstone and shale are poorly consolidated, except where invaded by dykes and sills. The sandstone weathers to sand, silt, and minor clay and rubble; the shale weathers to clayey sandy silt and fissile shale fragments. Distribution and topography are similar to those of the Blaa Mountain Formation.

Savik Formation

Unmodified rock outcrops only on Cornwall Island, but extensive marine-washed outcrop is present in central and southeast Amund Ringnes Island. The shale with minor thin sandstone and siltstone beds weathers to grain sizes ranging between silty clay and sandy clayey silt (pH 4 to 8), plus platy shale fragments. This recessive, locally gullied, valley-forming unit is sandwiched between higher sandstone units.

Ringnes Formation

The Ringnes Formation is limited to central Amund Ringnes Island. The papery shale and thin beds of platy sandstone are poorly lithified and weather to clayey silt and a discontinuous lag of flaggy sandstone and mudstone fragments.

Deer Bay Formation

The formation is widely distributed on Amund Ringnes Island with smaller outcrops on southern Ellef Ringnes Island, east and west Cornwall, and east King Christian islands. The papery shale includes minor sandstone and calcareous siltstone nodules, whereas an intraformational fine sandstone unit is present on Cornwall and southeast Amund Ringnes islands. The shale weathers to clayey silt and a discontinuous lag of siltstone and mudstone fragments (pH 3 to 8). Kaolinite and illite are co-dominant minerals (Horn, 1967). Where this formation is immediately adjacent to a diapir or is intruded by a dyke, it is partly covered by coarse grained colluvium. The succession of dissected strike-aligned ridges has local relief of 10 to 50 m.

Christopher Formation

The formation is widely distributed on Amund Ringnes, Ellef Ringnes, and King Christian islands. This soft papery shale includes minor sandy shale and siltstone beds, and a sandstone unit on Ellef Ringnes and King Christian islands. There are numerous calcareous siltstone and ironstone concretions (up to 2 m diameter), especially on King Christian Island. The shale weathers to silty clay or clay, plus lithified fragments (pH 5 to 9), with montmorillonite being the dominant clay mineral (Horn, 1967). Liquid limits and plasticity indexes of samples from this subunit are generally higher than Atterberg limits from any other unit, rock or otherwise (Fig. 11). On the surface, granule- to boulder-size mudstone and ironstone fragments form a scattered lag, locally concentrated in stream beds.

Terrain is rolling and slightly more resistant strata underlie wide strike-aligned ridges, which are more rounded than adjacent sandstone units though not topographically lower. Local relief is 20 to 100 m. Drainage is not normally incised except at the inland margin of the coastal plain. Mass movement is more active on the Christopher Formation than on any other rock unit, owing to the high clay content and the presence of a partial vegetation cover which lengthens the period of active layer saturation. Earthflows are common in wet summers at the heads of first order stream courses.

Kanguk Formation

The formation is widely distributed on southern Ellef Ringnes Island and Graham Island, with small outcrops in northern and southwestern Amund Ringnes Island. The flaky to soft silty shale has minor siltstone beds and abundant ironstone nodules in the upper part. It weathers to slightly plastic clayey silt and flaky shale fragments and is covered by a discontinuous veneer of ironstone nodules and fragments. Unmodified and weathered rock is highly acidic (pH 3 to 5); a core provided a pH value of 3.6 at both 20 and 150 cm depths, i.e., above and well below the frost table at 35 cm (Station HCA-76-29/7-1A, Appendixes 1, 2). Included in the Kanguk Formation on Graham Island is a light-coloured fused lignitic shale that weathers to platy blocks and fines.

The shale is recessive; gentle slopes or level areas develop where beds are flat lying. The siltstone beds, however, support prominent strike-aligned escarpments, commonly 20 m and locally 50 m high and continuous for up to 50 km except for water gaps. Fluvial dissection is locally significant; gullies advance headwards along the rectilinear pattern of frost-fissure troughs which are so distinctive on this formation (Fig. 5).

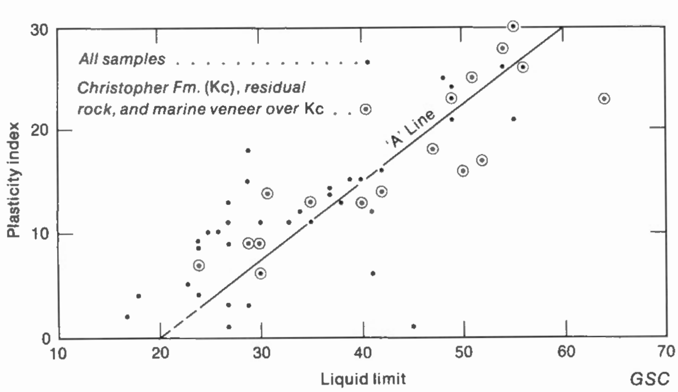


Figure 11. *Plasticity chart for selected samples between 0 and 3 m depth in the study area.*

Eureka Sound Formation (informal lower member)

This subunit is limited to southern Ellef Ringnes Island, where poorly consolidated sandstone, mudstone, and shale unit is transitional from the Kanguk Formation. It weathers to a range of grain sizes between fine sand and silty clay including minor sandstone, mudstone, and shale rubble. Vegetated rills, having a distinctive 'horsetail' pattern on airphotos, have developed on the long slopes common on this subunit.

Coarse Grained Clastic Rock

Thick sandstone units alternate with shale and siltstone on all islands (Fig. 9, Table 2). Outcrops are particularly extensive on the Noice Peninsula of Ellef Ringnes, on southern Amund Ringnes, and eastern Cornwall islands. This unit comprises flat-lying to moderately inclined, partly cemented fine to coarse grained sandstone and minor shale and siltstone. The upper 1 to 2 m has commonly weathered to sand, silt, and minor clay, intermixed or in discrete strike-aligned bands, and a continuous to scattered gravel-size lag is present. Outcrop of moderately weathered to unweathered well cemented beds is more common the older the formation.

The surface varies from moderate slopes, including steep and cliffed facets in a succession of deeply dissected scarps, to gently inclined slopes including moderate or steep facets only at major rivers. Local relief is 20 to 100 m, but isolated areas rise to 300 m. Major scarps controlled by resistant beds may be traced for up to 50 km, broken only by a few water gaps.

Coarse materials are well to moderately well drained; fine beds may be poorly drained on divides, long slopes, and at the foot of slopes. The snowmelt period is greatly extended at the foot of snowbanks, scarps, and incised river banks. Lakes are absent; rare ponds exist on fine grained beds. River and major stream spacing is commonly less than 1 km. Drainage lines are structurally controlled where bedrock is moderately to steeply inclined; channel zones are wide and straight to slightly sinuous (minor meander reaches); and bedloads are largely sand and gravel, though reaches dissecting resistant beds are dominantly rubble or gravel. Subsequent to snowmelt, surface flow occurs only in large rivers. Channel banks are gently inclined to cliffed, with minor lateral erosion.

Fluvial processes are dominant; i.e. rilling and sheetwash; gullying is highly active locally. Disaggregation by frost riving is obvious on resistant beds, but mass movement by rockfall, talus creep, and solifluction below snowbanks is relatively minor. Eolian processes lead to local concentrations of sand ripples, etching of consolidated rock, and rare low dunes. Frost fissures are possibly widespread, but have poor surface expression.

Active layer thickness commonly reaches 50 to 80 cm and locally 1 m. Visible ice content is 0 to 25 per cent in the 50 cm below the frost table, and generally only pore ice is encountered at greater depths. Frost fissures rarely have a pure ice filling; most wedges are ice and mineral soil or entirely mineral soil.

Coarse grained rocks only extend to sea level on northern Cornwall Island and on Table Island. The land/sea interface is either a cliff with talus or a steep slope ending in a narrow modern gravel beach berm.

Lithological descriptions of rock stratigraphic units and variations from the general comments follow.

Bjorne Formation

The medium to fine grained quartz sandstone that outcrops on the western side of Table Island and on nearby Exmouth Island is poorly to well cemented and weathers to sand and minor sandstone rubble. Outcrop is present only in gulleys draining the adjacent, higher, more resistant Schei Point Formation.

Schei Point Formation

The calcareous siltstone and quartz sandstone found on central Table Island and nearby Exmouth Island is commonly indurated and resistant. It weathers to angular granule- to boulder-size fragments, and minor silt and sand.

On Table Island, the main structure is a west-facing scarp, 100 to 200 m high, and an east-facing dip slope. Mass wasting is more widespread than on any other formation and includes rockfall and talus creep on scarps and solifluction lobes elsewhere.

Heiberg Formation (Upper Member)

The Heiberg Formation strikes north-south in both west-central and east-central Cornwall Island. The sandstone contains minor pebble lenses, is dominantly fine to medium grained, and is poorly cemented. It weathers to sand and a discontinuous lag of granule- to pebble-size sandstone fragments. Minor well cemented outcrop occurs in places.

The formation is dissected and recessive relative to adjacent formations but includes some major and minor scarps. Although it partially underlies Mount Nicolay on Cornwall Island, it is intrusive igneous rock that controls this feature. Remarkable fields of rock pillars occur (Fig. 12).

Jaeger Formation, Borden Island Formation

These formations strike north-south in both west-central and east-central Cornwall Island. The two formations are combined into one surficial map unit as they have similar surface characteristics, including a high per cent cover of mosses and lichens (rare on other coarse grained units). The poorly to well cemented sandstone includes minor pebble and shale lenses and weathers to fine to coarse gravel, silty sandy with sandstone and siltstone rubble, and minor clay.

Awingak Formation

Quartzose sandstone containing minor siltstone, pebble lenses, and shale outcrops on Cornwall and southeast Amund Ringnes islands. The formation is commonly poorly cemented, though locally is well cemented, and it weathers to fine to coarse grained sand, minor silt, and a discontinuous lag of flaggy sandstone and mudstone fragments.

Isachsen Formation

The formation is widely distributed on Amund Ringnes, Cornwall, Ellef Ringnes, and King Christian islands. This dominantly quartzose sandstone, commonly poorly cemented but locally well cemented, contains some siltstone and minor interbedded shale, carbonaceous beds, and conglomerate. It weathers to strike-aligned bands of fine to coarse sand, silt, and minor clay. A lag of granule- to cobble-size sandstone and siltstone is common.

A closely spaced succession of fluvially dissected strike-aligned scarps has developed. This unit is particularly subject to differential erosion due to great variations in the resistance of individual beds; mesas, buttes, and rock pillars occur.

Figure 12. *Hoodoos developed in Heiberg Formation sandstone, west Cornwall Island. GSC 203501*

Hassel Formation

The formation outcrops widely on Ellef Ringnes, Graham King Christian, and northern and southwest Amund Ringnes islands. The brightly coloured fine to coarse grained quartzose sandstone, which includes minor siltstone, is commonly poorly cemented. It weathers to sand having a discontinuous sandstone lag, and to silt and minor clay in discrete deposits or intermixed with sand. Basalt breccia intrusions are ridge-formers in northern Amund Ringnes Island. The dissected scarpland is similar to that of the Isachsen Formation, but relief is less pronouced as the Hassel Formation has fewer resistant beds.

Eureka Sound Formation (informal upper member)

Chief occurrences of this unit are on southern Ellef Ringnes and southwest Amund Ringnes islands. This unit of fine to medium grained sandstone, minor mudstone, gravel, lignite, and carbonized wood, is cemented to completely nonindurated. It weathers to sand beneath a discontinuous gravel lag.

Dykes and Sills

Intrusions are abundant in the Blaa Mountain Formation and Lower Member of the Heiberg Formation in central Cornwall Island, and dykes alone are common in central and northern Amund Ringnes Island. No dykes or sills occur in surface rocks elsewhere in the map area, except in diapirs. Sills proved difficult to identify and outline on airphotos and have been included in adjacent sedimentary units.

Intrusions ranging in composition from gabbro to quartz diorite cut the Kanguk Formation and older rocks with little alteration of adjacent sediments. The fine to coarse grained dykes and sills are exposed as moderately to highly weathered angular rock fragments of varying size together with minor silt, sand, and clay. Blocks commonly overrun a 5 to 200 m wide zone of the adjacent unit as a veneer of colluvial material.

Dykes core linear features 10 to 150 m high, having rugged, locally castellated outcrop on the crest; steep or cliffed slopes of outcrop or rubble grade to gently or moderatly inclined colluvial material. Sills in central Cornwall Island have more subdued relief. Outcrop and rubble are well drained, but colluvial slopes are poorly drained owing to seepage from late snowmelt or from upslope rubble interstices.

Outcrop disaggregates by frost riving; rubble moves downslope as rockfall and talus and also forms solifluction lobes. Colluvial slopes are subject to rilling, sheetwash, and mass movement including earthflows (especially over fine grained sediments) and rubble stripes. The active layer is 30 to 60 cm thick in colluvium. No ground ice data were collected, but interstitial ice is expected in rubble, and segregated ice contents of 50 per cent are probable in the upper 1 to 2 m of fine grained colluvium.

Marine-reworked Rock

This unit is a morphologically subdued form of the rock formations previously described. It is composed of residual rock reworked by marine processes, generally less than 2 m thick, but locally overlain by marine, deltaic, or fluvial sediments. Underlying bedrock structure is commonly visible on aerial photographs (Fig. 13), particularly where beds are moderately or steeply inclined.

Fine Grained Marine-reworked Rock

Occurrence of this unit is discontinuous in a zone 0 to 100 m above modern sea level. Extensive areas in central Amund Ringnes Island are developed on the Deer Bay, Ringnes, and Savik formations. The surficial material is chiefly silt and clay, containing minor fine sand, platy shale or siltstone fragments, and (especially over the Kanguk Formation) ironstone nodules. The unit may include discrete areas of sand or gravel, but these are rarely more than 50 cm thick.

Relief is lowest where the coastal plain is widest; here, only major drainage lines are incised (5 to 20 m). Where the plain is narrow, both major and minor drainage lines are incised. River and major stream spacing is 1 to 3 km. Drainage is generally poor and ponding is common in frost-fissure troughs on level areas, otherwise drainage characteristics are the same as those on fine grained rock.

Active geomorphological processes are no different from those on unwashed fine grained rock, except that (1) the rare areas of palsen that occur in ponds are underlain by ice lenses up to 1 m thick and (2) frost fissures are locally sand filled where eolian processes are active.

Coarse Grained Marine-reworked Rock

The unit has discontinuous occurrence in a zone 0 to 100 m above modern sea level on all islands. Particularly extensive areas are found in south and west Amund Ringnes Island and east and west Cornwall Island. Surficial material is chiefly fine to coarse sand, minor silt, clay, and gravel, but a discontinuous veneer of fine grained marine sediment may be present. Consolidated sandstone or siltstone outcrops in places, particularly riverbanks. Active sandy fluvial channel zones and fans cover about 10 per cent of the unit. The presence or absence of marine shells may be the only difference between marine-reworked and residual weathered rock.

Relief is similar to that on fine grained marine-reworked rock. Much of the unit is well drained subsequent to snowmelt, though a 10 to 20 cm-thick zone above the frost table may remain moist to saturated, and zones of subsurface seepage occur under the numerous channel zones. No lakes or ponds are present. Channel banks are gently inclined to cliffed; channels are straight to slightly sinuous and are wide in proportion to stream flow, with first-order beds (normally dry after snowmelt) 2 to 10 m wide. Bedload is sand, except gravel is locally dominant.

Fluvial processes dominate, chiefly unconfined seepage, rilling, sheetwash, minor gullying, and lateral erosion. Eolian processes are active in forming gravel lag, although sand, which commonly drifts into fluvial channels, is reworked during the snowmelt flood stage. Visible ice was rarely recorded other than in the 50 cm below the frost table. Frost fissures are probably widespread, but surface troughs are rarely visible; the fissure filling is commonly sand, although ice and sand may be intermixed.

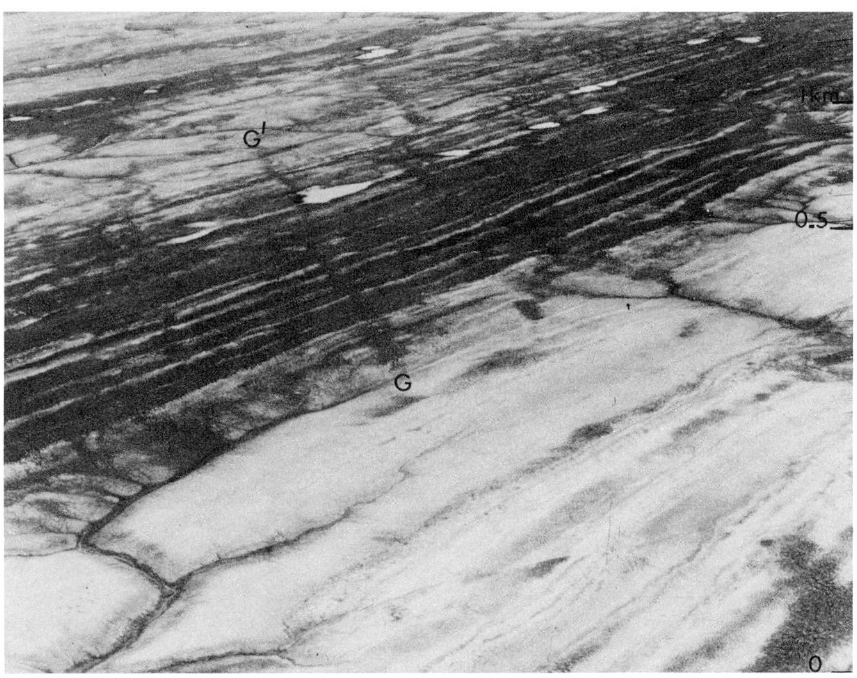


Figure 13

Marine-planed Deer Bay Formation shale, western Amund Ringnes Island, showing a sea-ice scour groove (G-G'). GSC 203500-N

High-level Fluvial Deposits

Two divisions of high-level fluvial deposits are recognized, chiefly on the basis of morphology and composition and to a lesser extent, structure. Plateau gravel surfaces are flat lying to gently inclined, commonly at the height of land, whereas gravel ridges are subdued esker-like ridges. St-Onge (1965) has described these deposits on Ellef Ringnes Island. It is difficult to assign some of the small deposits to either division on the basis of airphoto interpretation. Limits of deposits are indefinite, as mass transport moves gravel downslope over underlying and adjacent bedrock units.

Plateau Gravel Deposits

The largest occurrences of plateau gravel deposits are on west-central Cornwall Island and central Graham Island, with small areas on Ellef Ringnes, Amund Ringnes, and King Christian islands (Fig. 14, Table 2). Deposits may be silty sandy gravel, sand, or gravelly fines, 2 m to more than 5 m thick; exposures are rare. On Cornwall and Graham islands, the fluvial deposits are overlain by clayey gravelly silt, described in the morainal deposits section of this report. Gravel is granule to boulder size; round to angular; dominantly quartzose sandstone plus minor siltstone, gabbro, carbonate, quartzite, and granite (commonly pink) clasts, and rare noncarbonized but compressed wood. Most boulders, which can exceed 1 m in diameter, are subround. The deposits unconformably overlie Mesozoic rock formation. At low elevations, material has been reworked by marine processes.

Deposits occur on regional topographic highs, preferentially on the primary watersheds. On Cornwall Island the plateau gravel deposit is level to rolling and varies in elevation from 100 to 200 m. Small deposits on other islands are remnants of level to gently inclined plateaus at 90 to 230 m, in places reduced to knobby mounds, with moderately to steeply inclined margins. The gravel functions as a protective capping, and adjacent fine grained units may be 100 m lower in elevation (Fig. 15).

Margins of deposits are well drained, whereas level interior sites are locally poorly drained. Snowmelt is generally later and more extended than on adjacent (chiefly lowland) areas. On Cornwall and Graham islands, stream channels are wide and straight and lie in shallow valleys except at plateau margins where courses are incised. Bedload is chiefly granule- to boulder-sized material. The maximum thickness of the active layer ranges from 40 to 100 cm. Few data exist on ice content, although frost fissures are widespread and are probably filled with ice or with mineral soil and ice.

The surface and basal topography, similar maximum elevations of deposits, abundance of subround boulders, presence of exotic lithologies (granite, quartzite) and scattered wood, and occurrence of similar though much thicker deposits in western Axel Heiberg and eastern Ellesmere islands (Balkwill and Bustin, 1975) support the hypothesis that the deposits are remnants of an extensive sheet of fluvial sediments of Late Tertiary age, possibly the Beaufort Formation. An alternative origin is glacial or proglacial deposition in the early or mid Pleistocene, i.e. remnants of morainal or outwash material have been preserved from erosion on a peneplain, while deposits elsewhere were eroded. A glacial origin does not explain the abundance of rounded cobbles and boulders but neither does a fluvial origin explain how some of this material has become striated. The only explanation that can be offered is that the uppermost layers of fluvial sediments have been glacially reworked.

Gravel Ridges

Linear gravel ridges are scattered over Amund Ringnes, Ellef Ringnes, and King Christian islands (Fig. 14). Gravelly silty sand to silty gravel is 5 to 20 m or more thick. The gravel is granule to boulder size, round to subangular, chiefly sandstone, siltstone, and minor gabbro and carbonate rocks. Below marine limit, the uppermost 2 m may be marine reworked. No exposures were observed and thus the internal structure is unknown. At Cape Abernathy, King Christian Island, the deposit is composed of gravelly (granule to pebble size) coarse and medium grained sand, including rare marine shells in the upper 2 m.

The linear to slightly sinuous subdued ridges are 5 to 30 m high, 50 to 500 m wide (Fig. 16), and up to 15 km long though commonly broken by water gaps. Orientation is preferentially between northwest and southwest. Ridge height may greatly exceed the deposit thickness as adjacent sediments have been eroded at a greater rate than the underlying materials protected by gravel. Ridges are invariably located on local topographic highs and minor drainage divides, 60 to 150 m in elevation, with the exception of the Cape Abernathy ridge which declines almost to modern sea level. Most ridges are well drained; however, a lengthy period of seepage is common from snowbanks on ridge flanks. Surface materials are generally stable relative to adjacent sediments, though rills and frost fissures are widespread. Active layer thickness is 60 to 100 cm.

Morphology and materials indicate a fluvioglacial (esker) origin. The similarity of the lithologies of clasts to those of the plateau gravels (though no granite or wood was found) indicates that the plateau gravel deposits are a likely source. No sense of direction of sediment transport was determined. It is unlikely that deposition occurred preferentially on local topographic highs (where gravel is now found), and thus a measure of erosion subsequent to deposition is available. For example, the gravel ridge northwest of Hoodoo Dome, Ellef Ringnes Island, intersects the main escarpment developed in Kanguk Formation and also functions as a watershed (Fig. 17). The 50 m-high scarp face has retreated at least 1 km (chiefly by rilling and lateral river erosion) since gravel deposition. This observation, together with the subdued form of the ridges, rules out at least a late Wisconsin glacial age for deposition.

Diamicton Deposits

Diamicton is exposed on four islands (Fig. 14, Table 2), but cover only 1 per cent of the area mapped. As significant differences in this unit exist between islands due to provenance or age, deposits are subdivided by islands.

Amund Ringnes Diamicton

Moderately plastic, structureless, dark grey silty stony sandy clay overlaps Cretaceous rocks on the extreme northeast coast of the island. The deposit is highly acidic (pH 3.1 to 3.5), up to 10 m thick, and includes granule- to boulder-sized, subround to angular, sandstone, siltstone, and gabbro clasts. Striated pink granite boulders up to 1.5 m diameter are scattered over the surface.

The deposit overlies an overall moderate slope to Massey Sound, between sea level and 100 m elevation. This seaward slope is dissected 2 to 30 m in depth by numerous gullies. The inland margin is a west-facing rill and nivation eroded cliff. The closely spaced rills, gullies, and streams provide moderately good drainage.

Fluvial processes dominate; some earthflows have occurred in stream incisions, though the rock-cut slope foot

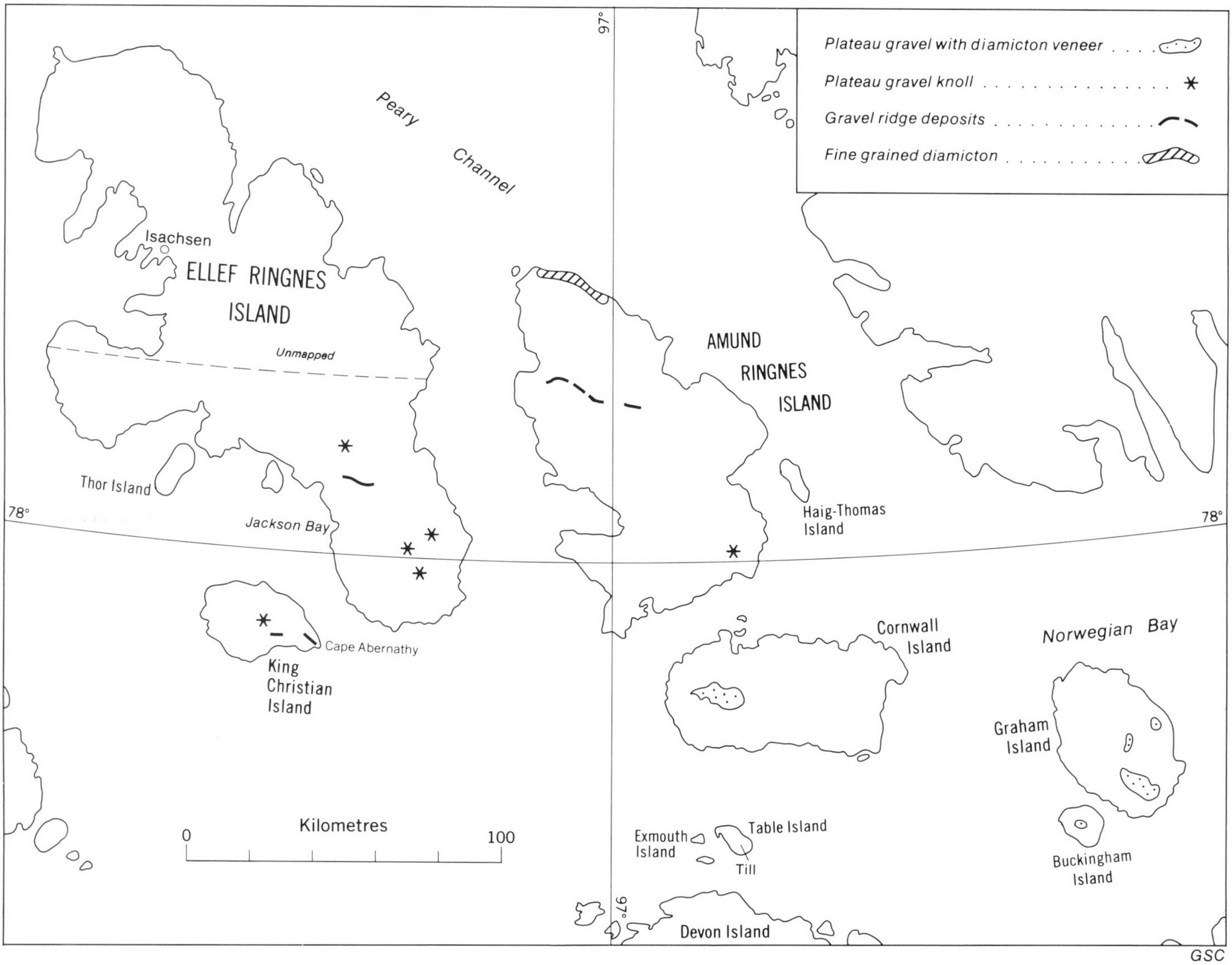


Figure 14. Distribution of high-level fluvial deposits and diamicton in the study area.

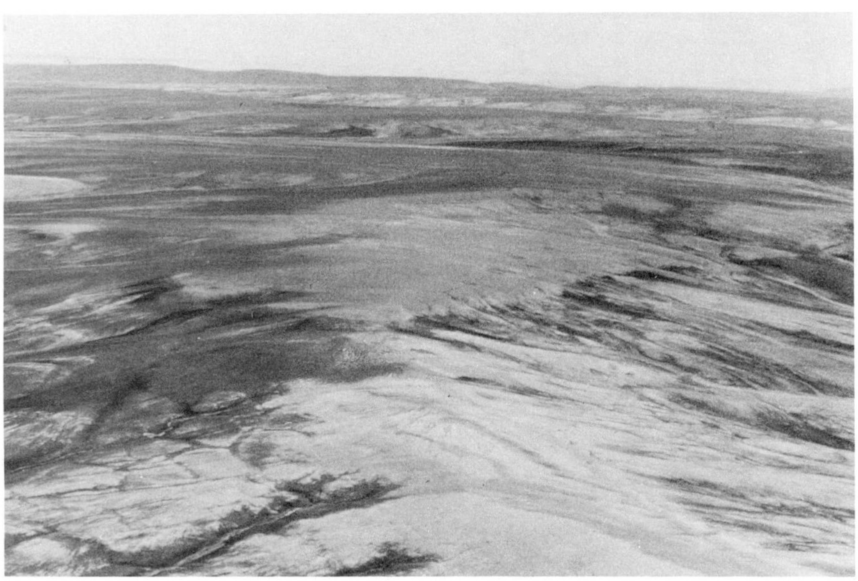


Figure 15

Plateau gravel overlying and protecting inclined weak rock formations, western Cornwall Island. GSC 203501-A

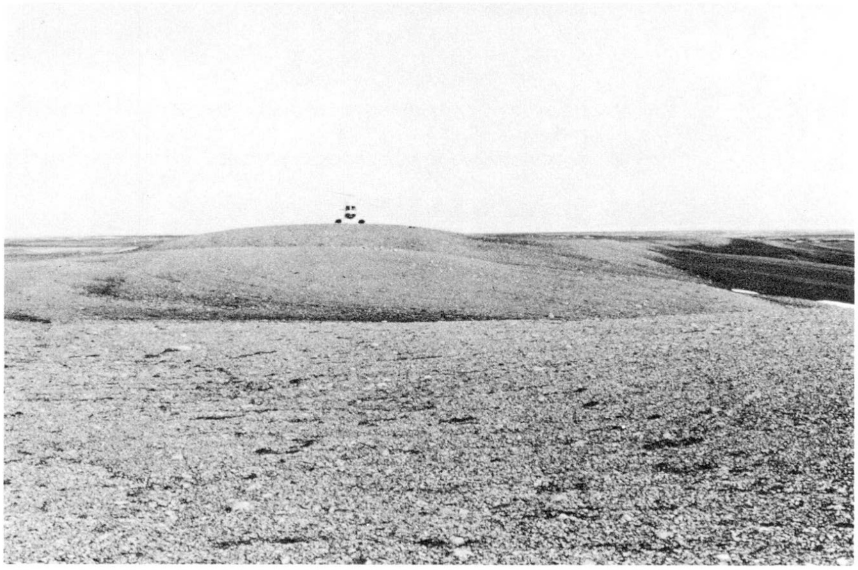


Figure 16

Esker-like gravel ridge, southeast King Christian Island. GSC 203500-T

minimizes stream undercutting. Active layer thickness is 50 to 70 cm. The seaward slope is gently inclined at the emergent – or possibly stable – modern shoreline and has a discontinuous thin sand veneer. The shore is highly disturbed by ice push, and ridges to 2 m high may be pushed up to 50 m inland.

Composition, lack of structure, and absence of marine shells support a glacial rather than a marine or glaciomarine origin. Morphology and degree of weathering favour a mid rather than late Quaternary age. Glacial ice passing northwestwards through Massey Sound may have deposited the clay.

Cornwall and Graham Diamicton

Fines and gravel in a diamicton, 1 to 2 m thick, form a discontinuous cover over plateau gravel (Fig. 14). The gravel is chiefly subround; some of the hardest clasts are striated. A glaciomarine rather than a glacial depositional origin is possible; deposits on both islands are locally overlain by shelly gravelly beach sediments. The diamicton is older than the last Laurentide ice maximum as the overlying shells are more than 40 000 radiocarbon years old.

Table Island Till

The only unquestionable morainal deposit found in the map area is exposed in a stream cut on the east side of Table Island. Two stony silty sand tills are overlain by marine and fluvial sediments containing shells beyond the range of radiocarbon dating.

Marine Deposits

Morphogenetic System

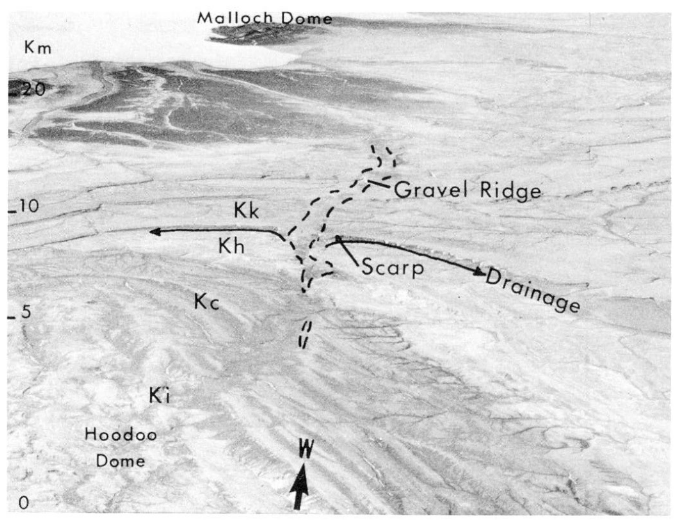
Undifferentiated Marine Deposits

Marine deposits ranging from clay to fine gravel are widespread on coastal plains of all islands. The thickness rarely exceeds 5 m and commonly decreases inland to a feather edge. Deposits are generally underlain by bedrock; the contact may be transitional or sharp.

The flat-lying surface or gently inclined seaward slope is featureless or low rolling. Much of this subunit lies between sea level and 50 m elevation, though scattered deposits are present to 100 m. The degree of drainage is highly variable according to relief and materials. Main drainage lines may be incised; fine materials are locally highly dissected. Streams and rivers are closely spaced on slopes, unorganized on flats.

Fluvial processes are dominant, but rapid and slow mass movement may be highly active on fine grained materials. Eolian processes are locally significant. Active layer thickness and ice content are highly variable according to materials.

Nearshore and offshore relict marine deposits and small areas of reworked bedrock are included, together with beach, deltaic, fluvial, and eolian deposits where these are inseparable at the scale of mapping. Most exposed marine deposits are part of the offlap sequence developed during Holocene emergence.



Ki – Isachsen Formation; Kc – Christopher Formation;
Kh – Hassel Formation; Kk – Kanguk Formation.

***Figure 17**. Scarp recession relative to a gravel ridge, west of Hoodoo Dome, Ellef Ringnes Island. RCAF Photo T428R-84*

Undifferentiated Marine Veneer Over Rock

Near the inland margin of thick marine sediments or where coastal plain slopes are moderate or steep, a relict marine deposit, generally less than 2 m thick, veneers bedrock. The underlying rock is commonly exposed in stream cuts and on crests of divides. The marine veneer may be quite different in texture from the underlying rock if the sediment has originated in an adjacent or inland area. Wedges of sediment may extend upstream in valleys, and many predate Holocene (or earlier) immersions.

Strandline Flats

Strandline flats are found to a limited exent on all islands in a zone extending up to 5 km inland from the modern shoreline and to 20 to 30 m elevation. This unit of dominantly fine to medium grained sand, minor silt, coarse sand and gravel overlies sandstone or siltstone. Thickness ranges from 1 to 3 m.

The surface is planar (level or gently inclined) with little incision of drainage, and although fluvial transport and deposition dominate (numerous fans and wide channels), eolian processes are active. Active layer thickness is 40 to 90 cm. Visible ice content in the 1 to 2 m below the frost table is up to 50 per cent. Sand below the frost table may be unfrozen and friable, and at one location water-saturated sand was found 1 to 2 m below the normal frost table depth. Frost fissures commonly extend close to the storm water line (except on active fluvial or ice pushed surfaces), but surface expression is commonly obscured by windblown sediment. Fissure fillings vary from wholly sand to largely ice.

This raised intertidal and beach zone is distinguished by a closely spaced striped pattern of relict strandlines, commonly visible only from the air (Fig. 18). The stripes, spaced at 1 to 15 m, have little or no morphological expression on the ground and appear to represent moisture differences. It is likely that low sandy beach berms, similar to those at the modern shoreline, have been eroded by wind action and the moisture changes are perhaps due to differences in grain size or packing beneath former berms or swales.

Beach Berms and Swales

A single sand beach berm marks the modern shoreline over more than half the coastline in the map area, including many areas where coastal plain deposits are fine grained. Raised deposits are restricted to those areas where resistant coarse grained bedrock outcrops below marine limit, except for the few gravel beaches scattered above the Holocene marine limit on Cornwall and Graham islands. Beach ridges are dominantly sand or gravel or more rarely, shale, mudstone, or siltstone fragments. Swales may be veneered with fines or, particularly on Graham Island, have a thin accumulation of organic material.

Modern and relict beach berms are rarely more than 1 m high or 3 m wide and are limited in size by the short open water season, short fetches in ice-infested waters, eolian erosion, and the rarity of coarse sand and gravel source deposits. Modern berms extend across fan and delta mouths, broken only by active fluvial channels. Berms may be continuous if channel flow is low or if the beach is built up during summer and early winter open water.

Flights of relict berms and swales overlie gently to moderately inclined seaward slopes. Beaches are commonly well drained, though ponding occurs in swales where well developed berms cross level or gently inclined terrain. Gravel is stable, but relict sand beaches are subject to sheetwash and eolian erosion. The modern shoreline may be greatly disturbed by ice push – though sand berms quickly form again, given open water and strong winds. The active layer can be up to 100 cm thick. Frost fissures, in places with wide deep troughs, are widespread on gravel to the storm water line.

Lithogenetic System

Both fine and coarse grained marine deposits (Table 2) are subdivided into three groups:

1. thick (> 2 m) deposits
2. veneer over fine grained rock
3. veneer over coarse grained rock

Fine Grained Marine Deposits

Thick deposits. Thick (> 2 m) deposits of fines are widespread on coastal lowlands of south and west Ellef Ringnes, Graham, and King Christian islands, and are scattered below the marine limit on the other islands. The dominantly nearshore and offshore relict deposits and minor deltaic and fluvial deposits are composed of unstructured to finely interbedded

Figure 18

Prograding delta and strandline flats, southern Amund Ringnes Island GSC 203500-M clay to very fine sand. Thick sand units are incorporated into generally fine grained deltaic deposits on King Christian Island, and a discontinuous thin organic veneer is present on Graham Island. Fine grained deposits are moderately plastic, have a low to high liquid limit, and are slightly acidic to neutral.

The surface may be level or have a gently inclined rectilinear or concave seaward slope, into which main streams are incised 2 to 10 m. Relief is locally to 5 m due to earthflows and may be chaotic close to the coast where earthflows and ice-push ridges intermix (especially on King Christian Island).

Rivers and large streams are straight to slightly sinuous and locally sinuous; intervening areas are drained by subparallel rills and broad runs, but some areas have no organized drainage. Drainage is poor in a wet summer, and the active layer remains moist or saturated until freezeup. Drainage is poor to moderately good in a dry summer, and a desiccated crust develops. Lakes are rare, but ponds are numerous locally where frost-fissure troughs are wide or where earthflows temporarily dam streams. River and stream banks are moderately inclined to cliffed, and cliffs may extend across the width of the coastal plain. The sediment load of water courses heading in this unit and other fine grained units is chiefly fines, but coarse material is introduced locally where coarse beds (including dykes) are intersected. Streams originating in coarse units generally have a sand, silt, or gravel bedload.

Mass movement is more active on this subunit than on any other. Slope failures are common and include wide (up to 100 m across slope) detachment slides, and long, narrow bimodal failures which start as slides and end as flows; a few solifluction lobes have been observed. Fluvial processes include rilling, backwasting from shallow runs, and gullying adjacent to stream courses. Frost-fissure trough networks are discontinuous; where present, fissures are ice filled. Active layer thicknesses range from 30 to 60 cm. Ice content in the 2 m below the frost table is commonly 25 to 50 per cent, plus icy strata up to 30 cm thick.

The seaward slope is gently inclined at the emergent – or possibly stable – modern shoreline. There may be a discontinous thin sand veneer, or where sand is available from adjacent or inland areas, a sand beach berm develops. The shore is commonly disturbed by ice push, and ridges to 2 m high may be pushed up to 50 m inland.

Veneer over fine grained rock. This subunit has wide occurrence on coastal plains of most islands. Undifferentiated fine grained marine and deltaic deposits, 1 to 2 m thick, overlie marine-planed shale, siltstone, mudstone, and minor sandstone. The contact between overburden and rock is rarely clear.

Relief is commonly low, as on thick marine deposits; Amund Ringnes Island has particularly extensive level to low rolling areas where local relief is less than 20 m. Drainage characteristics are similar to those on thick, fine marine deposits, but in addition numerous clusters of ponds are present on Amund Ringnes Island and moist to saturated areas of thin organic veneer on Graham Island.

The active layer is 30 to 60 cm thick, but is 10 to 30 cm thick under ponds or a continuous vegetation cover. Ice content is similar to that in thick, fine marine deposits, apart from the scattered localities where palsen have developed in and adjacent to ponds. Palsen are commonly 50 cm high and 2 to 5 m in diameter; drilling and coring showed 1 m of underlying ice. The pingos in central Amund Ringnes Island are unique to that locality.

The modern shoreline is similar to that developed in thick fine deposits.

Veneer over coarse grained rock. The fine grained marine and deltaic deposits, 1 to 2 m thick, overlie marine-planed unconsolidated to cemented sandstone, siltstone, and minor shale. The deposits are scattered on all islands, generally adjacent to thick marine deposits.

Relief is commonly low, as on thick marine deposits, but on Cornwall Island in particular slopes are gentle to moderate, locally steep, and dissected to 20 m by streams. Drainage characteristics are similar to those on thick marine deposits. Fluvial processes dominate this unit but earthflows are locally active, especially in the veneer on riverbanks.

Coarse Grained Marine Deposits

Thick deposits. A generally narrow zone of thick (> 2 m) deposits of coarse-grained marine sediments is present close to the modern shoreline on south and east Amund Ringnes, east and west Cornwall, west and southwest Ellef Ringnes and east King Christian islands. The dominantly nearshore, raised beach, strandline flat, and minor fluvial sediments are composed of fine or medium sand or, less commonly, coarse sand and gravel and may include some fine grained strata.

The surface is level or has a gently, locally moderately inclined seaward slope. Low rolling areas are present where the subunit extends farthest inland, but relief is rarely greater than 20 m. Major rivers are incised 2 to 10 m; however, most stream cuts are less than 2 m deep. Rivers and major streams are closely spaced (less than 1 km) and are subparallel where slopes are gentle or moderate; on flats spacing is greater and the pattern less organized. Drainage is good subsequent to snowmelt, though the 10 to 20 cm zone immediately above the frost table may remain moist or saturated, and dry stream beds may be underlain by a zone of seepage. Ponds are locally concentrated in low rolling areas or in beach swales.

Fluvial processes are dominant; channels, fans, and active deltas (locally more than 1 km wide) cover 10 to 50 per cent of this subunit. The sediment load is dominantly sand. Unconfined flow is widespread and sheetwash on sandflats commonly leaves extensive areas of microripples. Eolian erosin and deposition are active, but have little influence on morphology.

The active layer is 40 to 90 cm thick. Visible ice content in the 1 to 2 m below the frost table ranges from 0 to 50 per cent. Sand below the frost table may be unfrozen and friable, and at one location water-saturated sand was found 1 to 2 m below the normal frost table depth. Frost fissures commonly extend close to the storm water line (except on active fluvial or ice-push surfaces), but surface expression is commonly obscured by windblown sediment. Fissure fillings vary from wholly sand to largely ice.

The emergent or possibly stable modern shoreline is generally gently inclined and marked by a nearly continuous low sand or sand and gravel berm.

Veneer over fine grained rock. Nearshore, strandline flat, and beach sediments, 1 to 2 m thick overlie planed shale, siltstone, mudstone, and minor sandstone. Thick coarse or fine grained deltaic sediments are present locally. The subunit is generally well drained as on other coarse units, but level areas may be poorly drained and may contain numerous ponds, particularly where raised-rim frost fissures have developed. Stream bedloads are commonly sand and minor fines, but where the bed cuts fine grained rock, the bedload may be fines with a thin veneer of sand. Streams may incise to 15 m, and earthflows can develop in the fines and work back into the coarse veneer.

Veneer over coarse grained rock. Nearshore, strandline flat, and beach sediments, 1 to 2 m thick, overlie planed unconsolidated to cemented sandstone, siltstone, minor shale, and intrusive rocks, which are exposed at the base of deep drainage incisions. Other characteristics are similar to those on thick coarse marine deposits, except that major and some minor streams are incised 2 to 10 m and have steep or cliffed stable rock-based banks.

Colluvial Deposits

Colluvium is defined here as material displaced or altered by slopewash, rills, or mass movement to such a degree that it markedly differs in composition or structure from subjacent source material. The description covers both thick colluvium and colluvial veneer (less than 2 m thick). Small areas are mapped as discrete morphogenetic units, but in the lithogenetic legend colluvial deposits are normally included with the source material unit.

Most colluvial deposits of a mappable scale are veneers of gravel and sand or fines derived from plateau or linear gravel deposits or veneers of rubble and fines derived from intrusive rocks, including diapirs. Deposits most commonly occur on moderately inclined, locally steep, or cliffed slope segments, up to 1 km long. Such slopes are poorly to moderately well drained via numerous rills and shallow runs, and seepage may continue through the summer. Unconfined and confined fluvial processes are most significant. Mass movement occurs in the form of talus creep, solifluction block streams, and minor earthflows.

Active layer thickness is estimated at 30 to 80 cm. No ice content data are available; however, a high ice content is expected in fines, and interstitial ice occurs between blocks.

Fluvial Deposits

Morphogenetic System

Only those fluvial deposits wider than 100 m are shown on Maps 1-1981, 2-1981. Fluvial processes and sediments are discussed further in the geomorphological processes section of this report.

Fluvial Plain: Channel Zone and Floodplain

Mappable fluvial plain deposits occur primarily in the lower courses of most rivers greater than 10 km long and are generally more than 1 m thick over deltaic sediments or rock. Deposits vary from clay to boulders but are chiefly fine and medium grained sand. Channel sediment composition only partially reflects the underlying or adjacent material as material from headwaters, particularly where coarse grained, may dominate over the entire course; even a minor outcrop of indurated rock may introduce gravel- or boulder-sized material which dominates the bedload for many kilometres downstream.

Below marine limit, valley flats are commonly straight, wide in proportion to length, low gradient, and contained between moderately inclined to cliffed bluffs of unconsolidated material 1 to 30 m high. Bluffs of the anastomosing courses within the channel zone are rarely more than 1 m high. Above marine limit, channels are narrower, steeper in gradient, sinuous, and commonly contained in a rock-cut valley. Rivers have an extreme nival regimen and channel zone flow is greatly reduced after the snowmelt stage; however the active layer commonly remains saturated. The active layer under the channel zone ranged from 50 cm to 2 m thick at the few locations checked. No data were obtained below the frost table.

Fluvial Terrace

Terraces are defined here as inactive fluvially worked surfaces at a higher elevation than the laterally adjacent valley flat. Terrace surfaces overlying fluvial deposits have been separated from inactive delta surfaces overlying complex deltaic structures.

Deposits of mappable width flank only large rivers where material is similar to that of the adjacent valley flat. The flat to low rolling terrace surface is separated from the valley flat by a bluff 1 to 30 m high. The terrace may merge with adjacent units, or stream or gully incision may define the contact. There is little organized drainage, other than seepage along inactive channel beds. Drainage varies from excellent to poor, depending on material type, slope, number of depressions from inactive channels, and presence or absence of frost-fissure troughs. Ponds may develop on level surfaces, even in areas underlain by sand.

Fluvial Fan

Subaerial fan-shaped fluvial deposits, which are thin and have a relatively simple structure, are common over coarse grained marine sediment, especially strandline flats, on southern Amund Ringnes and south and west Ellef Ringnes islands. Fans may include material of any size, but units of mappable size are invariably fine to coarse sand, probably less than 2 m thick. The surface is near level to gently inclined and crossed by anastomosing channels rarely incised more than 1 m.

Fans commonly develop in lightly incised river courses at points where the gradient decreases, or where eolian sediment deposition overloads the channel capacity.

Delta

Deltas of mappable size form at the mouths of most rivers greater than 10 km in length and are thus common as active and raised features on coastal plains of all the large islands. The most common structure is fine grained bottomset beds, overlain by transitional fine to coarse foresets, overlain by coarse (commonly sand) topsets. The fine to coarse volume ratio is largely dependent on source materials in the drainage basin, and in extreme cases the entire delta may be either coarse or fine grained. Sediment thickness may exceed 30 m in large deltas.

Active arcuate river-dominant deltas prograde up to 2 km beyond the adjacent coastline along a front up to 3 km wide (Fig. 18), and coalescent delta complexes develop where two or more large rivers run into the head of an embayment. Relict deltaic sediment may extend 20 km inland across the coastal plain in a zone rarely greater than 3 km in width. These inactive surfaces are generally planar in a direction transverse to the coast (i.e. parallel to the river course), unlike the 'stepped' surfaces common elsewhere in the Arctic. The relict surface, which is well to poorly drained, as with fluvial terraces, is commonly higher than laterally adjacent coastal plain sediment (Fig. 19). The active channel zone is incised 2 to 30 m into the relict sediments, and the two surfaces are separated by a moderately inclined to cliffed bluff.

The progradation evident in modern and relict deltaic sediments is due to sediment deposition combined with the relative fall in sea level through the Holocene. The planar form of inactive surfaces indicates that few lateral channel deflections at delta mouths have occurred through the Holocene; this is consistent with low energy coastal processes such as those at the modern shoreline. Bottomset sediments on southwest Cornwall and northeast King

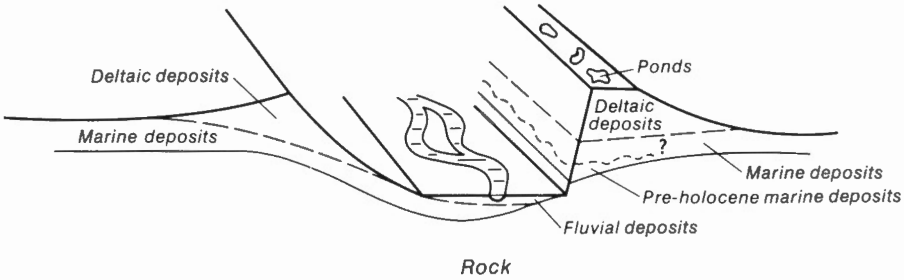


Figure 19.
Cross-section of typical relict delta.

Christian islands overlie possible early Holocene transgressive beach and nearshore deposits and thick marine and deltaic silty clay to sand deposits beyond the range of radiocarbon dating. The present rivers at these and other locations appear to be re-excavating older rock-cut valleys (Fig. 19).

Lithogenetic System

Fine Grained Fluvial Deposits

This subunit includes those fine grained valley plain, terrace, and deltaic deposits that form part of a large complex or have a texture significantly different from adjacent units. Fine fluvial sediments occur only where the entire drainage system is developed in fine grained materials (Table 2). Deposits are of silt, very fine sand, minor clay, and minor sand or gravel, and may include a large percentage of shale fragments. Inactive surfaces may have a discontinuous sand veneer, less than 50 cm thick, developed as a topset bed or by eolian processes. Fine or coarse grained rock may be exposed in deep cuts.

Channel zone flow is greatly reduced after snowmelt. The valley flat may dry out, or the active layer may remain moist or saturated (and quick). Inactive surfaces are moderately well to poorly drained. Banks are subject to lateral channel erosion, slumping, much gullying, and minor earthflows. Active layer thickness is estimated at 50 cm.

Parts of the subunit have a low sand beach berm over fines; elsewhere fine grained deposits extend to the waterline.

Coarse Grained Fluvial Deposits

This subunit is limited to those coarse grained valley, plain, terrace, fan, and deltaic sediments that form part of a large complex or have a composition significantly different from adjacent units. Most fluvial deposits on all islands are coarse grained – chiefly fine to medium grained sand, but including minor (locally dominant) interbedded fines or gravel.

Valley plains are generally dry after snowmelt, though a saturated zone 10 to 30 cm thick may remain over the frost table and level surfaces may locally develop numerous ponds in frost-fissure troughs or in depressed polygon centres. Eolian erosion is active, and deposition commonly occurs in the channel zone. Banks are subject to lateral channel erosion, slumping, and gullying.

Where the surface is well drained, visible ice content is 0 to 20 per cent, and frost fissures are filled with sand or sand and ice. Where drainage is poor, ice contents may exceed 50 per cent, and frost fissures are ice filled. A single low sand beach berm is present at the modern shoreline, except where large active channels discharge into the sea.

Relict and Modern Deltaic Deposits: Coarse Over Fine

Active delta surface of this type are composed of sand and minor fines and gravel. Relict top and foreset beds are composed of 0.5 to 5 m of stratified fluvial sediment, dominantly sand, interbedded with fines, gravel, or plant debris, and are overlain by a discontinuous gravel lag. These beds are underlain by 1 to 25 m of fine grained marine or deltaic sediment, locally including coarser strata.

Inactive surfaces are subject to eolian erosion; deposition occurs in active channels, as they are the topographically lowest areas. Banks are undercut by lateral channel erosion, gullying is widespread, and earthflows are common in wet summers where the lower fine grained unit is thick. Active layer depth varies from 30 to 90 cm. Total ice content in the 2 m below the frost table has been recorded at 10 to 70 per cent; frost fissures are filled with ice or ice and sand. The modern shoreline is marked by a sand berm, broken only by large active channels.

Eolian Deposits

This designation only occurs in combination with other morphogenetic or lithogenetic units. Sand or coarse silt eolian sediment is commonly superficially indistinguishable from the source material, hence the term is used only where an eolian deposit has a different texture (usually coarser) than the underlying material. Thickness rarely exceeds 50 cm.

ACTIVE GEOMORPHOLOGICAL PROCESSES

Some of the dominant geomorphological processes are described below, with emphasis on aspects unique to the northern arctic islands or having potential to affect land use. Processes directly responsible for units described in the map legend (e.g. deltaic deposits) are described in the surficial materials section of this report. St-Onge's (1965) survey of the geomorphology of Ellef Ringnes Island is the only prior description of surficial geology in the Ringnes islands and remains a basic study of cryomorphology in the arctic islands. French (1976) provides a wider survey of geomorphological processes and landforms in the Canadian Arctic.

Weathering

Weathering is not a prerequisite for erosion or mass transport over much of the map area, as most surficial material is unconsolidated to poorly cemented; however consolidated rock is broken down chiefly by physical disintegration by freeze-thaw. Cores commonly show that fragmented rock is present to depths of 1 to 2 m, well below the present maximum seasonal thaw depth. Unless ground ice is a factor, this indicates a formerly thicker active layer and a warmer climate, not necessarily of Holocene age.

Little information exists on chemical weathering. Certainly the unchanged pH values above and below the frost table in the Kanguk Formation (see surficial materials section) indicate little activity. Surface (evaporation) salt deposits in the form of a white crust or yellow powder, however, are common on fine grained rock; Christie (1967, p. 28) described analyses of similar deposits from northeastern Ellesmere Island. The most obvious indication that widespread chemical changes do occur is in colour variation of active layer materials. Despite the variety of colours of underlying bedrock, much surficial material is close to very dark greyish brown (Munsell notation 10 YR 3/2). The uniformity in colour is more common below rather than above marine limit, so marine reworking and deposition are in part responsible for the uniformity. The lack of cementation in Quaternary and many older deposits, and the apparent absence of paleosols are indicative of a long period of supressed illuviation and groundwater flow. Whether this is due merely to a cool climate or, additionally, to the presence of permafrost is not known.

There is no information on the effect of prior burial and overconsolidation on weathering rates of bedrock now exposed, although this may be particularly relevant to the clayey shale of the Christopher Formation.

Fluvial Processes

Rivers have an extreme nival regimen: the flow period starts with snowmelt in June or early July. Rivers do not experience a break-up phase; however, narrow incised courses may be filled with snow resulting in flow over a snowbed for more than two weeks if thaw is slow. Peak discharge is restricted to one to two weeks, after which only heavy (and rare) rain or warm temperatures cause secondary discharge peaks. A low discharge level is maintained through the summer by 1) active layer thaw, which proceeds downwards at a diminishing rate until freezeup from the surface commences; 2) percolation of snowmelt absorbed by the active layer; and 3) low summer precipitation. Freezeup occurs in mid to late August and all river flow ceases as lakes are rare and no unfrozen water sources remain. Regional and local variations in porosity and permeability are discussed in the preceding surficial materials section.

Rilling, and to a lesser extent sheetwash, is the single most important geomorphological process. It is also a component of nivation. During snowmelt, slopes on all but the coarsest materials are traversed by subparallel rills 0.5 to 2 m apart (Fig. 20). Slight linear depressions or, less commonly, vegetated stripes (Fig. 21) are the only indication of rillwork during the rest of the summer.

Gullies are best developed in fine grained material which has a high silt content, for example Kanguk Formation shale (Fig. 5).

Channels of rivers and streams appear disproportionately wide in comparison with drainage systems in the sub-Arctic or temperate latitudes. This is partly a function of: 1) the high snowmelt discharge occurring within a short period; 2) the shallow frost table, which restricts downcutting and emphasizes lateral erosion; and 3) the prevalence of unconsolidated material combined with the general lack of vegetation to permit rapid lateral erosion. The effects of flow regime and sediment load on channel form are beyond the scope of this paper, and are summarized by French (1976, p. 174). Floodplains, in the sense of an overflow zone, only occur in the upper reaches of those large rivers where flow continues through the summer; elsewhere, the entire valley plain constitutes the snowmelt-stage channel zone, after which flow is reduced to successively fewer anastomosing channels and finally to one or two channels with water depth rarely more than 1 m. A few measurements of active layer thickness taken in sandy channel zones of intermediate size showed the frost table to be at a depth of 0.5 to 2 m. The disproportionately low ratio

Figure 20. *Rills, spaced 1 to 3 m apart, formed during snowmelt, Cornwall Island. GSC 203500-E*

Figure 21. *Vegetated stripes following snowmelt rills on clayey residual Christopher Formation shale, Dome Bay, Ellef Ringnes Island. GSC 203500*

of clay and silt to coarse material in channel sediment compared to that found in surficial materials in general is possibly due to turbulent snowmelt flow flushing suspended fines almost entirely out of the drainage system; this is feasible each spring, for no river in the map area exceeds 40 km in length. Dry sandy channel beds may be unstable due to seepage in the active layer, and loading such sediments produces a quick condition.

Nivation

Weathering and erosion beneath and adjacent to annual or perennial snow patches is defined as nivation. The process is not generally separated from the numerous constituent processes such as frost riving, rilling and slopewash, or mass wasting. St-Onge (1965, p. 11; 1969), however, has presented a convincing case for singling out nivation as a significant erosional agent on Ellef Ringnes Island at least; possibly the strong directional winds that blow the limited snowfall into drifts at similar locations each year are a unique factor in this area. He demonstrated that a series of landforms including amphitheatre bowls, hollows, and ledges, as well as some asymmetrical valleys and sandstone pillars, are controlled by nivation. The rock pillars, isolated along joints picked out by seepage and rills, occur in scattered 'fields' of hoodoos in well to poorly cemented subhorizontal sandstone of the Heiberg and Isachsen formations (Fig. 12). The enlarged fissures trap further snow to continue the processes, possibly assisted by wind abrasion. The 'fields' may include hundreds of pillars up to 20 m in height.

Mass Wasting

Whereas fluvial processes have often been underestimated in periglacial regions, the effects of mass wasting on lowlands of the Arctic Islands are frequently overemphasized (e.g. Horn, 1963, p. 5). Mass wasting requires a slope (a fraction of a degree may be adequate for some processes), an active layer, and normally a high 'soil' water content. Water content is highest at any point immediately after snowmelt and may be maintained through a late, cool, 'wet' summer or may be greatly reduced in a 'dry' summer. Thus the efficacy of mass wasting may vary greatly from year to year.

Mass wasting may result in slow movement such as seen in solifluction, creep, and sorting or rapid movement such as in earthflows and rockfalls.

Solifluction and creep. Clear evidence of solifluction is rare. Lobes, rarely thicker than 50 cm, are generally confined to steep rubbly slopes or to gentle fine grained slopes that are at least partially vegetated (i.e. commonly the southern and eastern islands, Fig. 2). Creep is probably less significant than solifluction, owing to the small number of freeze-thaw cycles per year. Evidence against a general downslope movement of the active layer is the clarity of lithologic boundaries on airphotos and in field observation, even where rock is deeply weathered, and the widespread occurrence of troughs, locally with raised rims, over frost fissures on gentle and moderate slopes.

Sorting. Most sorted stripes in the map area are attributed to fluvial processes, particularly rilling; however the stone streams that include up-ended blocks, common in colluvium adjacent to dykes, appear to be a result of both mass wasting and fluvial action.

Earthflows. This term encompasses a variety of slides, flows, and bimodal failures. Although spatially and temporally restricted, earthflows are one of the more spectacular and potentially hazardous processes in the map area. The most common type of failure – bimodal – occurs on slopes of less than 1° to more than 15° and is widespread in thick, fine grained marine and deltaic sediments (Fig. 22), although numerous earthflows do occur above marine limit on the Christopher Formation. The basal shear zone is at the frost table, usually in silt or clay or less commonly in fine sand. The thickness of the detached slab is rarely greater than 50 cm, but the surface area may be as great as 500 m^2. Although individual failures are not deep, recurrent failures (probably at least a year apart) could excavate a deep depression. The most common location for an earthflow on a river bank is the zone between an undercut bank and a gentle slip-off slope. In 1976, hundreds of earthflows occurred along only 20 km of river bank (the limit of the observation area) cut into marine and deltaic sediments north of Jackson Bay, Ellef Ringnes Island (Hodgson, 1977). The failures

Figure 22

Earthflows in fine grained marine and deltaic sediments, southwest Ellef Ringnes Island. GSC 203500-J

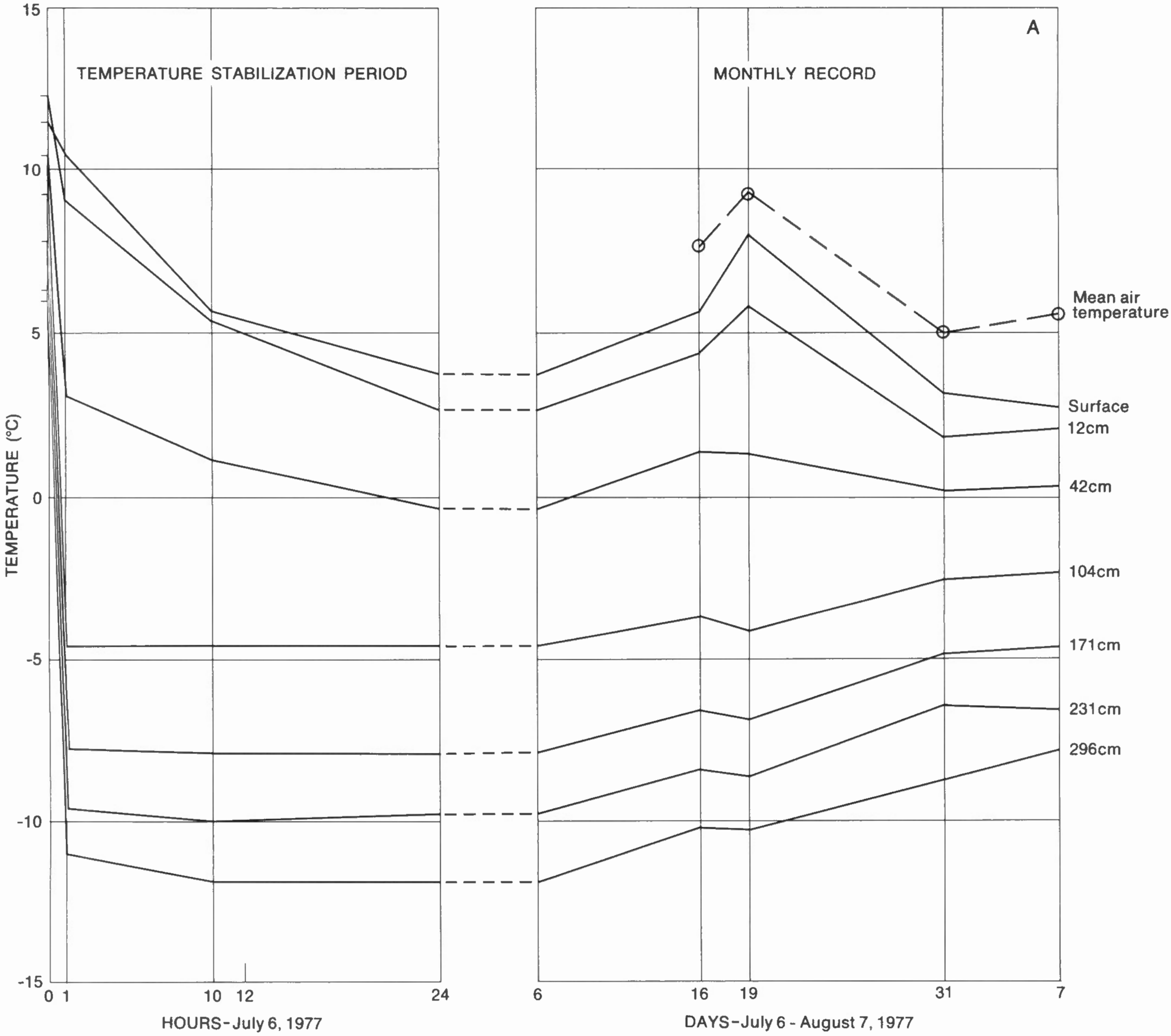
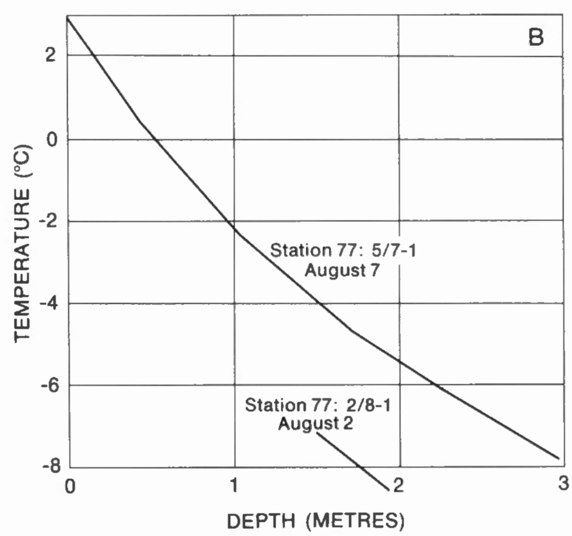


Figure 23A

Ground temperatures at various depths recorded via thermistor cable in a 3 m-deep, 9 mm diameter, air-filled borehole at station 77:5/7-1 on southwest Amund Ringnes Island between July 6 and August 7, 1977. The material is unvegetated marine sand and fines overlying marine-washed unconsolidated sandstone (unit 10/6o). Mean air temperature is the mean of 1200 and 2400 h (G.M.T.) dry bulb readings 2 m above the surface at the borehole.

Figure 23B

Ground temperatures in first week of August 1977 on southwest Amund Ringnes Island from unvegetated sand and fines over sand (station 77:5/7-1, unit 10/6o) compared to vegetated (100% moss, lichen, few vascular plants) sand and fines over fines (station 77:2/8-1, unit 10/5n).



occurred during 48 hours of intermittent rain (ca. 10 mm recorded at Isachsen, 100 km northwest) on July 31 and August 1 (Fig. 7). This was about two weeks after the end of a particularly late snowmelt season and the depth of thaw had reached at least 40 cm but the active layer still retained a high water content. In 1977, by contrast an exceptionally dry year (Fig. 7), no active earthflows were observed anywhere in the map area. It appears that this type of failure is a catastrophic event, probably triggered only by the type of conditions encountered in 1976 (i.e late thaw, heavy rain). Retrogressive thaw flowslides of the type described by Lamothe and St-Onge (1961) around Isachsen (i.e. backwasting into ground ice) were observed only in a small area of massive ice wedges at the head of Dome Bay, Ellef Ringnes Island.

Rockfall and talus creep. These processes are restricted to the small area of consolidated rock, chiefly dykes and sills, resistant Mesozoic sandstone beds, and diapiric domes.

Thermal Regime

Permafrost. The entire land area is underlain by permafrost; no published data are available from deep water interisland channels; however, permafrost is 253 m thick at Linckens Island, a sand bar probably surrounded by shallow water, about 15 km off the southwest extremity of Amund Ringnes Island. The average thickness of permafrost at five well sites in the map area is 336 m (Taylor et al., 1979). Figure 23A shows ground temperatures recorded in a capped borehole in dry, low ice-content (Appendix 2), unvegetated silty clayey sand overlying sand (unit 10/6o) at the 1977 base camp in southwest Amund Ringnes Island. Maximum temperatures for the recording period were -2°C at 1 m depth, -6°C at 2 m, -8°C at 3 m. Temperatures from a borehole 5 km away, in fine grained marine sediment and rock insulated by a complete moss/lichen and vascular plant cover, are 3°C cooler (i.e. -9°C) at a 2 m depth (Fig. 23B). The five day difference between observations is not considered significant.

Active layer. The summer thaw zone has a maximum depth of 30 to 70 cm in most surficial units. Despite lower summer temperatures, this thickness is representative of many areas of the low Arctic, probably due to the sparseness of (insulating) vegetation in the map area. Significantly, the active layer is shallowest on Graham Island, which for a given materials unit has the densest vegetation cover of all the islands. Maximum depths are encountered in gravel and coarse sand, which are normally poorly bonded by ice and have a higher conductivity due to good drainage and air-filled pore spaces or due to a relatively rapid flow of interstitial water. Silt, and particularly clay, has thinner active layers, again partly a function of conductivity combined with a denser vegetation cover. Unfrozen saturated sand to a 2 m depth is common under fluvial channels, and a borehole in marine sand close to sea level on eastern King Christian Island (Station 6/7-1, Appendix 2) showed a talik at least 75 cm thick below 75 cm of frozen sediment. Aspect does not appear to be a factor in active layer thickness.

Ground ice. Ninety-five boreholes were drilled and cored to depths of 1 to 3 m (Fig. 2) to investigate ground ice in a variety of units on all the main islands; summary logs are provided in Appendix 2. Too few holes were bored in proportion to the number of materials units to permit statistical manipulation of data. Massive ice was rarely encountered other than in some frost fissures and under isolated occurrences of palsen and pingos. Estimated total ice content of most cores ranges from 5 to 50 per cent by volume. Sand and gravel have low values, silt and clay have higher values.

Frost fissures and ice wedges. Polygonal and quadrangular frost-fissure systems are widespread – possibly covering 50 to 75 per cent of the map area – and have been identified on all map units except active fluvial surfaces, modern beach berms, and consolidated rock outcrop. A more precise inventory is difficult as fissures can only be identified where secondary surface features such as troughs, raised rims, or depressed centres have developed, and these are not always visible on 1:60 000 scale airphotos. Fissures range from 1 to 5 m wide. There are no data on maximum depth; however, ice-filled fissures (ice wedges) extend 8 to 9 m deep in fine grained sediments at Eureka on Ellesmere Island, where the climate is similar to that of the map area. Fissures in fine grained sediments and poorly drained coarse sediments have ice or ice and mineral soil fillings. Fissures in coarse sediments or poorly vegetated fines on which eolian processes are active have sand or sand and ice fillings. Surface manifestation of fissures has been influenced by material characteristics, slope and drainage, and possibly Holocene climatic changes, but no clear relationships have been established. The highest flanking ridges (exceptionally 1 m) develop on coarse sand and gravel; the widest and deepest troughs consistently develop in weathered Kanguk Formation shale (Fig. 5). Exceptional for these islands are the highly localised areas of 2 to 5 m wide degrading ice wedges northeast of Dome Bay and at a few other locations north of the map area on Ellef Ringnes Island. The wedges are present at 30 m a.s.l. in probable deltaic sediments of early Holocene age or much older. Why and when erosion started is not clear, though wind-eroded organic-rich strata near the surface indicate desiccation and consequent breakdown of their insulative value because of either stream backcutting during Holocene emergence or climatic change.

Desiccation cracks and hummocks. Polygonal networks of desiccation cracks, 20 cm to 2 m diameter are widespread in fine grained material but are less common in sand and gravel. Their surface form has been noted by many workers in high latitudes (e.g. St-Onge, 1965, p. 9; Hamelin and Cook, 1967, p. 153), and subsurface observations have been made by Price et al. (1974). Cracks open in summer, possibly enlarge further due to thermal contraction in winter, but seal during snowmelt. Desiccation cracks have been noted to continue a few centimetres below the frost table as ice veins (and to stand above the frost table as icy ridges). Polygonal cracks are the first stage in the development of earth hummocks, which at their most extreme are 50 cm high (Fig. 24). Unlike hummocks widely described in periglacial literature (e.g. French, 1976), those in the northern Queen Elizabeth Islands develop independently from vegetation factors or cryoturbation. The controlling process is surface runoff from snowmelt, which erodes and transports material along desiccation cracks. Hummocks develop preferentially on gentle slopes below snowbanks but may also occur on extensive level areas; deflation may aid erosion on level areas. Hummocks are restricted to fine grained (i.e. cohesive) materials, whether completely vegetated or barren. Like frost-fissure troughs, hummock troughs provide protection and moisture storage for vegetation.

Ice-cored mounds. Pingos. Pingos were identified at only one location in the map area – in central Amund Ringnes Island (78°20'N, 96°20'W). The cluster was first described by Balkwill et al. (1974). They lie 60 m a.s.l. on (marine?)

planed Savik Formation shale overlain by a veneer of fine grained early Holocene (radiocarbon dated) marine sediments. The largest pingo (Fig. 25) is 13 m high and 80 m in diameter and lies over the line of a discontinuously outcropping dyke. Pure ice was cored from 0.5 to 2.2 m (base of hole) under the small summit depression (station 11/7-101, Appendix 2). A 1.5 km-long row of 10 smaller, clearly individual pingos, up to 9 m high, lies 3 km east-southeast of the large pingo. Balkwill et al. (1974) doubted that the surrounding level terrain and the location of the pingo on the crest of a broad pericline were suitable factors for development of open-system pingos; they suggested a closed-system origin, not withstanding the absence of lakes or ponds other than in frost-fissure troughs immediately after snowmelt. Seepage along fractures leading from higher dyke outcrop (i.e an open-system) might result in the growth of ice under the large isolated pingo. Neither hypothesis, however, adequately explains the row of pingos nor the absence of pingos elsewhere in the map area. A third hypothesis can be developed from the presence of both the pericline and the dykes. Fractures in or close to a relatively coarse grained dyke could permit upwelling of subpermafrost water, possibly confined under pressure by permafrost capping the dome. Marine sediments mask bedrock around the small pingos, and the closest dyke outcrop is 1.5 km to the east. Significantly this dyke is in line with the row of pingos. Pissart (1967) described rows of pingos paralleling faults on Prince Patrick Island (600 km to the west) and suggested that water from structures at considerable depth was injected up via the faults resulting in the growth of the pingos.

Palsen. Small ice-cored mounds, 1 to 5 m diameter and up to 1 m high, were noted in some level and poorly drained fine grained deposits insulated by a complete moss/lichen cover. Palsen are most numerous on fine grained marine sediments (unit 9/5n) in southwest Amund Ringnes Island. A 75 cm-high mound that was cored (station 16/7-2, Appendix 2) comprised a 20 cm organic-rich active layer,

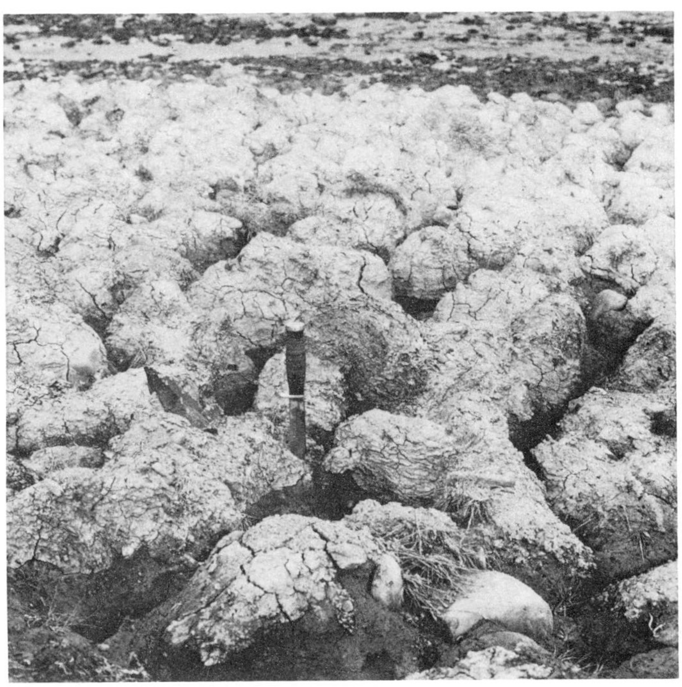


Figure 24. *Earth hummocks developed in silt by snowmelt erosion of desiccation cracks. GSC 203500-F*

60 cm of icy fines and sand, and 35 cm of pure ice, underlain by fines having low ice-content. The palsa was located in one of the few areas of raised-rim (i.e. actively growing) frost-fissure polygons. Artificial ponding on materials favourable to wet-site vegetation may lead to palsa growth.

Coastal Processes

Most of the modern shoreline is on a gently inclined emergent coast; uplift has slowed to a near-equilibrium position. There is little coastal erosion; even the few steep or cliffed coasts commonly have slope-foot beaches at the shoreline. The mean tidal range is small (25 cm), and surface water movement is dominated by the prevailing north and northwest winds.

The average ice cover in August and September, when open water is at a maximum, varies from 9 or 10 tenths around the Ringnes islands to 6 to 8 tenths in Norwegian Bay, southeast of Cornwall Island (Energy, Mines and Resources, Canada, 1974). Thus fetch is greatly limited, and furthermore, grounded ice commonly protects a shore from wave action.

The low, narrow sand beach berm (see unit 10), which is the dominant modern shoreline form, is partially wave formed but is also greatly modified by ice push and deflation. All coasts are subject to ice push (Fig. 26, 27), but particularly north-facing shores, which are exposed to thick multiyear Arctic Ocean ice. On northern Amund Ringnes Island, ice pans were observed pushing 50 m inland over a 100 m front.

Littoral currents are weak or nonexistent and little evidence exists of longshore drift. For example, prograding deltas are symmetrical about their active channel axes, and lithological boundaries, which are orthogonal to modern and relict shorelines, commonly can be traced by textural changes in overlying relict marine sediments. But where bedrock contacts parallel the shore, regressive shoreline deposits obscure these contacts.

Evidence of relict seabottom ice gouging is preserved in two areas (Fig. 28). In west-central Amund Ringnes Island, west and northwest oriented grooves are visible as tonal differences on airphotos (Fig. 13), but could only barely be detected on the ground as surface moisture variations in a silty clay marine veneer. Sea level fell below the 30 m elevation of these grooves approximately 6000 radiocarbon years ago. Similar, though north-trending, grooves are visible at a much lower elevation at Cape Allison, southwest Ellef Ringnes Island.

Eolian Processes

Like mass wasting, the importance of eolian action varies greatly between summers; an early snowmelt and low rainfall promote wind action – the inverse of optimum conditions for mass wasting. In the dry summer of 1977 (Fig. 7), windblown sand at times reduced visibility up to an altitude of 300 m over southwest Amund Ringnes Island. The critical wind speed for raising the sand was about 18 knots (35 km/h). No eolian processes were active in the equally extreme, but wet, summer of 1976.

The effects of wind are restricted to poorly vegetated or bare areas of unconsolidated sand or silt without clay, as well as peripheral areas. The most favourable areas are below marine limit, particularly wide fluvial deposits and strandline flats. As few eolian landforms are present in the map area, and much sand is blown into stream channels and reworked in the snowmelt flood. Eolian sand rarely exists as a discrete stratigraphic unit.

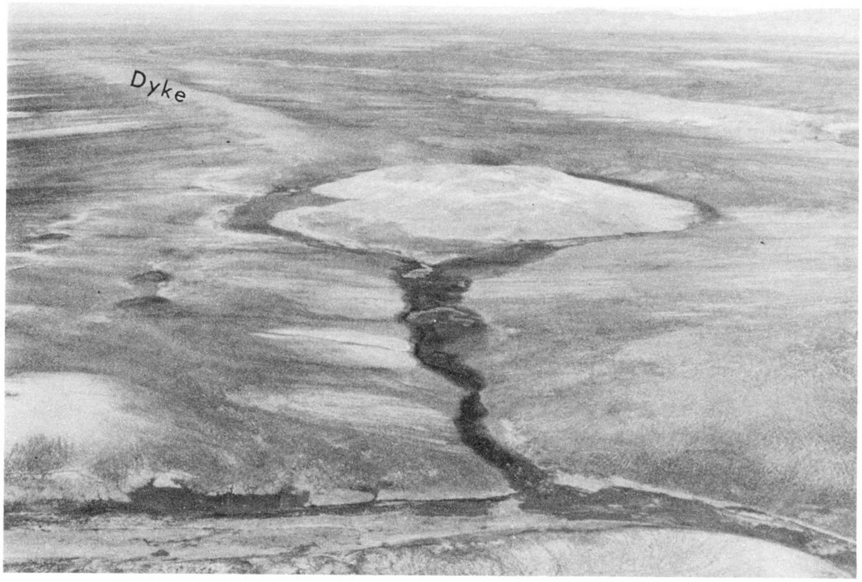
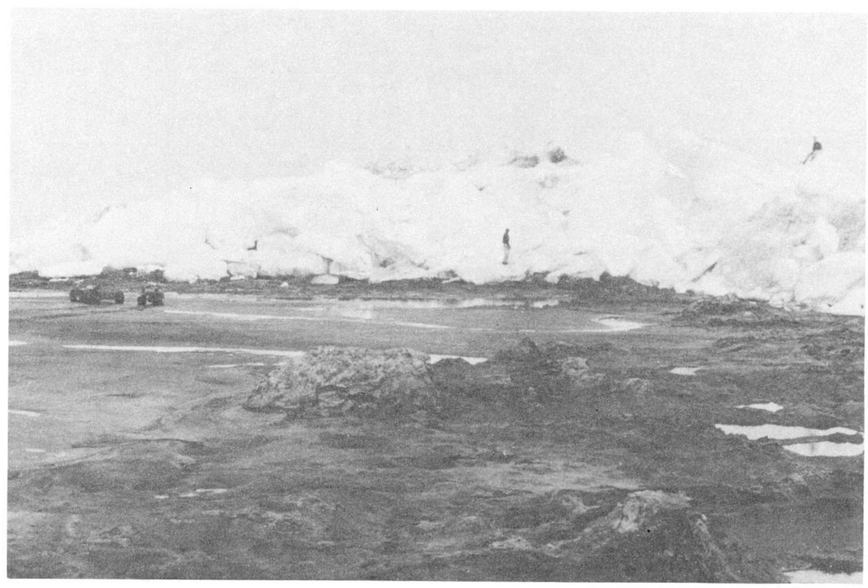


Figure 25

A pingo, 13 m high, 80 m diameter, on marine-washed shale of the Savik Formation, central Amund Ringnes Island. GSC 203500-K

Figure 26

Ice push at the modern shoreline, northwest King Christian Island. GSC 203500-V



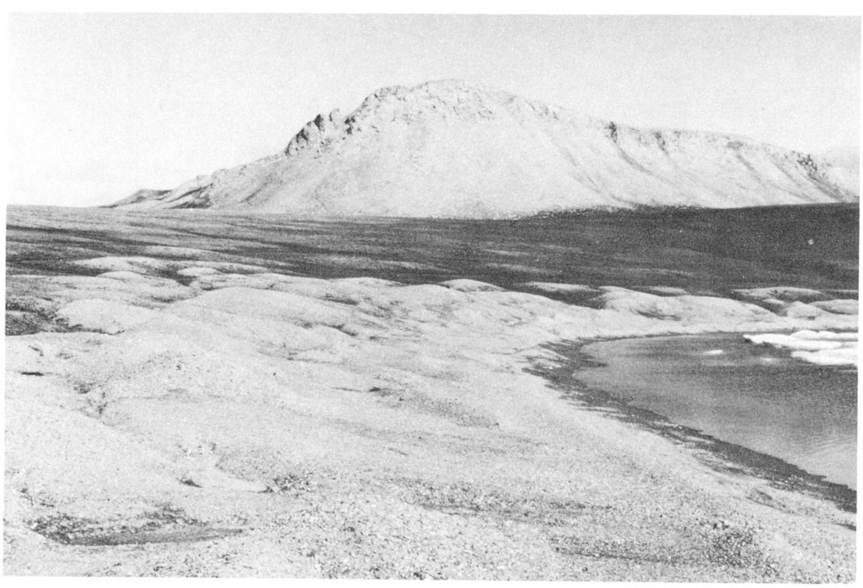


Figure 27

Modern and raised relict gravel ice-push ridges, Malloch Dome, Ellef Ringnes Island. GSC 203500-H

Specific eolian action include:

- abrasion of consolidated sandstone and siltstone, differentially eroding structures;
- sculpturing of low amplitude (few centimetres) sand waves on unconsolidated, low relief, unvegetated sand;
- deposition of sand 'tails' in the lee of banks, especially fluvial-cut bluffs, and on a lesser scale deposition on the lee side of vegetation clumps;
- deflation of deltaic sediments that contain plant debris strata which commonly resist erosion and which may stand out as residual pillars or clumps up to 2 m high; differential erosion of strata deformed by frost-fissure growth;
- deflation of the finer fraction from gravelly sediments to leave a granule or larger size lag;
- deposition of barchan dune chains, identifiable on airphotos of southwest Amund Ringnes Island but too low in relief to be readily identified on the ground.

Particularly clear on airphotos as tonal differences are areas of deflation and deposition separated from slightly better vegetated terrain by linear boundaries up to 5 km long. The boundaries are independent of underlying material composition or structure. Orientation is exclusively north to northwest (Fig. 28), the direction of the prevailing and, more significantly, strongest winds (Fig. 7). Deflation indicates an increase in aridity from a former slightly better vegetated Holocene period. Pissart et al. (1977) suggested that eolian activity on Banks Island was initiated about 4000 years ago, as result of a change to a drier and cooler climate; a similar event may have occurred on the Ringnes islands.

Sand drifting may locally be a problem for artificial structures. In 1977 at the Amund Ringnes base camp, dunes 50 cm high developed on windward and leeward sides of tents in a ten-day period of strong northwest winds (mean speed 29 km/h).

APPLICATION OF SURFICIAL GEOLOGY TO LANDUSE

Terrain Disturbance and Sensitivity

Disturbance is a man-initiated change in the surface character whereas sensitivity is considered to be a measurement of the degree to which terrain responds to disturbance. The type of landuse is important in determining sensitivity ratings; however, such disparate activities as road and airstrip construction, trenching, and damming are considered collectively here.

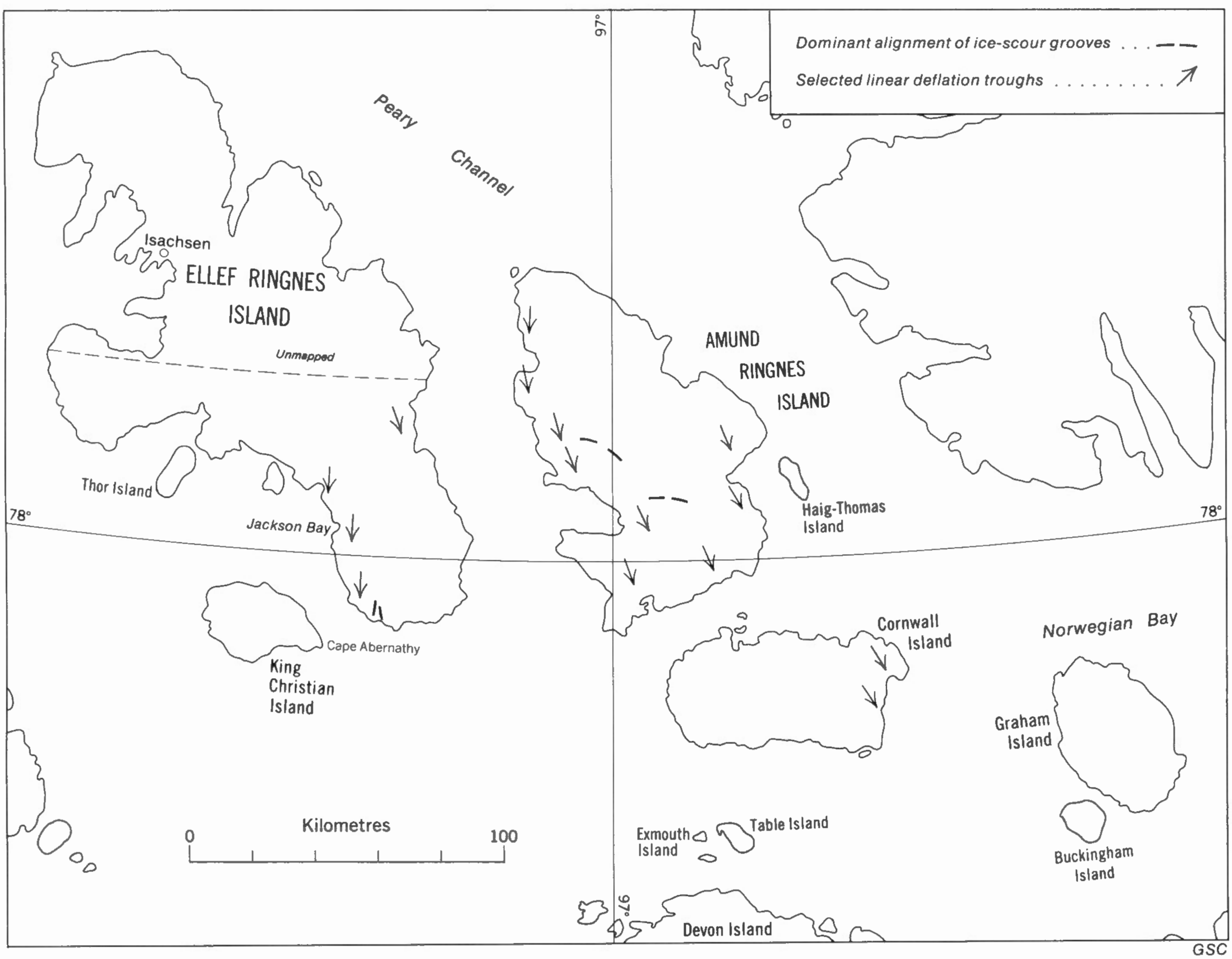


Figure 28. Orientation of deflation features and relict sea-ice scour grooves, western Sverdrup and adjacent islands.

Disturbance may be caused directly by man or may occur subsequently to such action as a result of a change in equilibrium of a natural process. In the latter case, most physical changes of the surface occur during the snowmelt or summer seasons, even if the initiating activity takes place in winter. Original surface conditions eventually may be naturally restored, though it is more likely that change will be permanent.

The sensitivity to disturbance and the type of disturbance that occurs have been assessed for each map unit (Table 3). Three levels of sensitivity have been established:

1. low or minor disturbance, possibly moderate or high locally during snowmelt or prolonged or heavy rain;
2. moderate disturbance of part or all of the area of activity, but processes are not expected to expand disturbance beyond this area; possibly high locally or seasonally.
3. high disturbance of all or a substantial part of the area of activity, and processes likely to expand disturbance beyond this area; continued activity of man is expected to be hindered.

The three most common forms of disturbance are:

1. disruption of surface drainage, especially by:
   - concentrations of flow, leading to erosion (e.g. diverting many rills or gullies into a few culverts).
   - ponding, leading to overflow and erosion as well as thermal erosion under and adjacent to standing water.
2. thermal erosion: the initiation or acceleration of ground ice thaw, which is especially critical over ice wedges. It is caused by stripping vegetation, excavation, or ponding of water.
3. slope failure: the potential for instability after excavating or loading and includes areas where rapid and slow mass movement processes are active.

An indication of which type of disturbance will occur in each unit is given in Table 3.

Hazardous Processes

Hazardous processes are those that, acting on a certain material, may place the integrity of an artificial structure at risk. The relationship between susceptibiity of terrain to disturbance and hazardous processes ranges from direct (e.g. unit 9, terrain susceptible to earthflows, rated high for both indexes) to the inverse (e.g. unit 14, in which active channels have low sensitivity but are hazards to construction). The most common potential hazardous processes grouped by materials unit in Table 3, are:

- fluvial processes, especially scouring and lateral erosion, and disruption of surface drainage as described under terrain sensitivity
- thermal erosion as described under terrain sensitivity
- slope failure as described under terrain sensitivity
- eolian erosion, abrasion, and deposition
- corrosion by acid water on or downstream from highly acidic rock units

Table 3. Terrain disturbance, hazardous processes, and trafficability ratings

Unit[1]	Disturbance[2]		Hazardous Processes[3]	Trafficability[4]	
	Sensitivity	Result		Roughness	Traction
14	Low	dt	dt e	T/D	T*
13	moderate	dts	dts c	T/D	T/D*
12	moderate	dts	dtse	T/D	T/D
11	moderate	d s	d s	T/D	T/D*
10	low		d e	T	T*
10/6	low		d e	T/D	T*
10/5	low	ts	dtse	T/D	T/D*
9	high	dts	dts	T	T/D*
9/6	moderate	dts	dts	T/D	T/D*
9/5	moderate	dts	dts	T/D	T/D*
8b	low	t	t	T	T/D*
8a	moderate	d s	d s	D	T/D*
7b	low			T	T*
7a	low			T/D	T*
6	low	d	d e	T/D	T*
5	moderate	dts	dts c	T/D	T/D*
4	low	d	d e	T/D	T*
3	moderate	dts	dts c	T/D	T/D*
2	low	d s only on	d s	D	T*
1	low	d s colluvium	d s	D	T*

[1]Unit: Surfacial materials, see Table 2 and Maps.

[2]Disturbance: Sensitivity: low, moderate, high.
Result: d = drainage disruption; t = thermal erosion; s = slope failure.

[3]Hazardous processes: d = fluvial disturbance; t = thermal disturbance; s = slope failure; e = eolian action; c = corrosion.

[4]Trafficability: T = traversable; T/D = traversable with some difficulty; D = difficult or impassible; * = severe difficulty during snowmelt or heavy rain.

Trafficability

Terrain is assessed (Table 3) in terms of performance by arctic tracked vehicles. The values also provide a rating of suitability for prepared or unprepared airstrips. Values are qualitative, based on ground and airphoto observations.

Macrorelief based on roughness or grade is classified in Table 3: most level areas and gentle and moderate slopes are rated traversable, steep or cliffed segments are rated difficult. The majority of materials units include elements of both types of relief. In winter, snowdrifts may make difficult terrain traversable.

The ability of the active layer surface to bear a vehicle, i.e. traction, is also assessed. The evaluation in Table 3 is for summer; an asterisk indicates a greater degree of difficulty during snowmelt or heavy or prolonged rain. Traction is not normally a problem in winter.

Trafficability ratings based on roughness and traction are: (1) traversable; (2) traversable with slight or local difficulty; and (3) difficult.

Aggregate Sources

Sand. Sand is widely distributed in fluvial, deltaic, and marine deposits, high-level fluvial deposits, and unconsolidated beds within coarse grained bedrock (i.e., units 14, 12, 10, 10/6, 10/5, 7a, 7b, 6, 3). Sand is commonly quartzitic, fine grained, and accompanied by substantial quantities of silt and clay. Medium and coarse grained sand beds are scattered through most of the above units. Except where drainage is poor, maximum active layer thickness is 60 to 80 cm, and segregated ice content low, though grains are normally bound by pore ice.

Gravel. The amount of gravel in the map area is less than superficial inspection might indicate. The widespread granule- to boulder-sized gravel deposits on the surface are commonly an eolian lag or marine veneer, only a single clast thick, over sand, silt, or even clay. The lag can be concentrated by dragging, as has been done at airstrips at Isachsen and Eureka, but this leaves any underlying ice-rich sediments vulnerable to thermokarst erosion as has occurred at Sachs Harbour, Banks Island (French, 1975). The largest volume of unconsolidated gravel is in plateau and gravel ridge deposits (units 7a and 7b). Composition, however, is not uniform; clasts may exceed 1 m in diameter and the matrix ranges from coarse sand to clayey sandy silt.

Gravel beds, locally more than 1 m thick, occur in some fluvial and deltaic sediments. Gravelly modern and raised beaches are present at the few locations where exposed, relatively high-energy shorelines are adjacent to granular materials (e.g. Table Island, Malloch Dome, north Cornwall Island).

Unconsolidated to poorly cemented granule and pebble beds are scattered throughout many coarse bedrock formations.

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APPENDIX I

GRANULOMETRIC DATA AND OTHER INDEX PROPERTIES

Unit[1]	Sample No.	NTS Grid Reference	Depth[2] m	>2 m	Grain Size[3] coarse sand %	fine sand %	silt %	clay %	Consistency[4] LL	PL	PI	Carbonate Content %	pH
AMUND RINGNES ISLAND													
5h	HCA-77: 11/7-101A	NB 610 952	0.3a										4.5
5h	11/7-101B	NB 610 952	0.45p						29	26	3		4.8
5h	11/7-102A	NB 610 952	0.3a						37	23	14		4.4
5h	11/7-102C	NB 610 952	1.6p	11	4	35	26	34					7.9
5i	12/7-9	NB 625 915	0.1a	3	5	21	40	34	24	20	4	4.1	5.2
5p	19/7-4A	NB 399 699	0.1a	0	< 1	5	56	39				9.3	3.1
5p	19/7-4B	NB 399 699	0.55p										3.9
6m	18/7-3A	NB 615 516	0.3a	1	12	45	25	18				3.0	8.4
6m	18/7-3B	NB 615 516	1.0p										7.7
6m	18/7-4A	NB 640 518	1.3p									1.3	6.2
6m	18/7-6C	NB 629 470	1.85p	0	1	48	32	18				4.9	7.6
6o	16/7-4B	NB 506 546	0.6a	7.1	96	3	<1	< 1				7.9	6.9
7b	7/7-1B	NB 628 755	0.5a	15	41	37	14	8					
8a	8/7-8	NC 292 461	0.1a	1	5	17	43	35				6.3	3.5
8a	8/7-9	NC 307 467	0.1a	26	6	11	29	54	49	25	24	8.5	3.3
8a	26/7-2	NC 227 481	0	1	5	14	39	42				7.9	3.1
9/5h	11/7-2A	NB 610 952	0.2a	1	7	6	35	52	49	28	21	8.7	5.9
9/5h	11/7-103B	NB 610 952	0.45p										5.2
9/5h	11/7-103C	NB 610 952	0.6p	0	5	3	40	52				8.1	4.0
9/5h	11/7-103E	NB 610 952	1.5p	17	29	44	14	13				6.1	7.7
9/5h	13/7-2A	NB 623 958	0.2a	3	7	11	38	44	42	26	16	8.2	6.1
9/5h	13/7-2B	NB 623 958	0.35a										8.9
9/5h	13/7-2D	NB 623 958	0.75p	14	6	11	44	39				8.1	7.7
9/5k	7/7-3	NB 565 850	0.2a	<1	6	17	44	33	27	24	3	3.7	5.2
9/5n	16/7-2A	NB 564 540	0.2a	0	16	27	26	31	24	17	7	5.0	
9/5n	16/7-2B	NB 564 540	1.2p										8.9
9/5n	16/7-2C	NB 564 540	1.8p	1	2	5	29	64	55	25	30	13.1	8.4
9/5n	16/7-3A	NB 567 540	0.2a	1	36	38	14	12				1.8	6.1
9/5n	16/7-3B	NB 567 540	1.3p						31	17	14		8.0
9/5n	16/7-3C	NB 567 540	1.8p	1	2	9	29	60	54	26	28	14.0	9.1
9/5p	16/7-6B	NB 567 540	1.6p						30	19	11		6.4
10/5n	17/7-2C	NB 511 644	1.8p										9.0
10/5n	2/8-1A	NB 546 510	0.2a	<1	19	43	22	16	18	14	4	1.8	8.3
10/5n	2/8-1B	NB 546 510	1.0p	<1	21	36	22	21				3.0	8.6
10/5n	2/8-1C	NB 546 510	2.0p	17	23	33	26	18				4.7	8.6
10/5n	2/8-4	NB 543 498	1.9p	1	10	22	38	30	29	11	18	4.2	8.4
10/5n	2/8-5A	NB 543 498	1.9p	1	28	47	16	9				0.9	7.2
10/5n	3/8-1A	NB 523 500	1.9p										7.9
10/5n	3/8-1B	NB 523 500	2.3p	0	< 1	14	61	25	39	24	15	8.3	8.5
10/5n	3/8-1C	NB 523 500	2.5p										8.5
10/6o	5/7-1A	NB 480 485	1.45p	<1	32	25	20	23				2.5	9.7
10/6o	5/7-1B	NB 480 485	1.95p	0	43	55	1	< 1				1.5	5.6
10/5p	19/7-2A	NB 437 583	0.3a	8	51	33	6	10				0.7	4.4
10/5p	19/7-2B	NB 437 583	1.3p	0	< 1	25	41	34				16.5	4.7
10/5p	19/7-2C	NB 437 583	2.1p										3.7
13	7/7-6	NC 600 159	0.2a	0	9	17	28	47	34	22	12	5.5	6.7
CORNWALL ISLAND													
2c	HCA-77: 24/7-16	VS 573 084	0	0	0	2	60	38	38	25	13	8.8	10.0
3f,g	20/7-12	VS 397 128	0	6	52	26	11	10				3.7	4.9
5d	24/7-4	VS 432 287	0	15	14	59	15	12				1.1	8.7
8b	20/7-11	VS 320 162	0.5a	<1	14	28	25	33	25	15	10	3.2	8.3
8b/7a	5/8-101A	VS 355 210	0.2a	21	10	26	32	31	27	16	11	5.0	8.4
8b/7a	5/8-101B	VS 355 210	0.85p						26	16	10		7.9
8b/7a	5/8-101C	VS 355 210	1.0p										8.7
8b/7a	5/8-101D	VS 355 210	1.6p						27	18	9		8.2
9/5 c,d	24/7-8	VS 445 081	0	16	4	14	47	35	33	22	11	23.8	8.8
9/5k	20/7-9	VS 303 083	0.1a	2	11	53	20	16	17	15	2	2.0	7.2
10	20/7-1	VS 365 353	0									9.2	6.0
10/5h	6/8-105A	VS 355 237	1.2p	0	17	29	30	24				5.2	6.7
10/5h	6/8-112A	VS 336 295	0.4p	16	8	68	15	9				3.5	6.9
10/5h	6/8-112D	VS 336 295	1.95p	0	2	20	44	34					7.6
10/5k	20/7-5	VS 300 274	0	5	14	58	18	10				1.2	6.3

1 Units are described in Table 2.

2 Depth below surface in metres
a = sample from active layer
p = sample below frost table at time of sampling.

3 >2 mm expressed as percentage of total sample weight
Coarse sand: 2.0 - 0.125 mm
fine sand: 0.125 - 0.063 mm
silt: 0.063 - 0.004 mm
clay <0.004 mn

4 Consistancy/Atterberg limits
LL = liquid limit
PL = plastic limit
PI = plasticity index

Unit[1]	Sample No.	NTS Grid Reference	Depth[2] m	>2 m	Grain Size[3] coarse sand %	fine sand %	silt %	clay %	Consistency[4] LL	PL	PI	Carbonate Content %	pH
ELLEF RINGNES ISLAND													
2n	HCA-76: 29/7-6	MB 712 783	0	0	1	0	29	70	51	26	25	8.4	
2n	30/7-2A	MB 714 782	0.2a	<1	< 1	0	23	77	50	34	16		5.5
2n	30/7-2B	MB 714 782	0.65p	0	0	0	27	73					5.8
2n	30/7-2C	MB 714 782	1.7p	0	0	0	22	78					4.9
2n	13/8-4A	ES 569 979	0.2a	2.7	< 1	< 1	54	45					8.6
2n	13/8-4E	ES 569 979	1.8p	18	0	0	62	38					8.7
2p	28/7-5A	MB 671 781	0.1a	<1	< 1	2	50	48					4.2
2p	28/7-5B	MB 671 781	0.45p	0	< 1	1	56	42	55	34	21	15.1	
2p	28/7-5C	MB 671 781	1.2p	0	< 1	17	50	33					
2p	29/7-1A	MB 679 796	0.1a	0	< 1	11	55	33	45	44	1	3.6	
2p	29/7-1C	MB 679 796	1.5p	42	5	17	42	36	41	35	6		3.6
2p	7/8-11	MB 705 867	0.1a	0	< 1	3	63	33					4.8
5p	28/7-1A	MB 666 783	0.2a	0	1	4	54	41				7.8	
5p	28/7-2A	MB 666 783	0.7p	8	6	41	30	23					7.3
7a/2p	77: 23/7-3	MB 845 530	0	16	19	8	37	36	41	29	12	9.2	7.0
9	76: 14/8-5A	ET 551 017	0.7p	0	< 1	3	35	62	48	23	25	8.7	
9/5n	13/8-1A	ES 536 995	0.4p	0	< 1	4	35	60					7.2
9/5n	13/8-2A	ES 544 988	0.2a	1	14	23	31	32	30	21	9	1.1	
9/5n	13/8-2B	ES 544 988	0.4p	<1	12	19	38	31	29	20	9	6.5	
9/5n	13/8-2E	ES 544 988	2.1a	0	< 1	9	54	37	35	22	13		
9/5n	14/8-1A	ES 539 988	0.1a	2	12	9	41	37	30	24	6	7.4	
9/5n	14/8-1B	ES 539 988	0.9p	0	< 1	1	43	56	40	27	13		6.6
9/6r	24/7-2A	MB 647 780	0.4a	<1	15	16	46	23					
9/6r	24/7-3A	MB 631 770	0.2a	3	19	24	37	19					3.9
10	77: 23/7-4	MB 790 505	0	31	43	9	24	24					
10/5q	76: 24/7-1A	MB 651 722	0.3p	<1	17	14	48	21	27	26	1		4.5
11/2n, 3o	29/7-5A	MB 710 790	0.2a	0	2	31	35	32				6.6	
12	25/7-102A	MB 587 765	0.2a	0	11	29	39	20				5.5	
12	26/7-2A	MB 590 773	3.0a	<1	3	4	44	49					6.8
12	27/7-1A	MB 567 765	0.2a	3	32	25	24	18				5.8	
KING CHRISTIAN ISLAND													
2k	HCA-77: 9/8-1H	MB 519 336	3.0a	72	< 1	6	61	32				6.4	8.2
2n	76: 17/7-101A	MB 434 365	0.4p	0	1	4	36	59	47	29	18	8.5	
2n	17/7-101B	MB 434 365	0.9p						52	35	17		
2n	17/7-102A	MB 430 364	0.1a	0	< 1	2	12	85	56	30	26	6.6	
2n	17/7-102B	MB 430 364	0.3p	0	< 1	2	16	82					6.9
2n	17/7-103B	MB 407 370	0.3p	0	< 1	7	22	71	64	41	23	7.7	
2n	18/7-2	MB 402 342	0.1a	0	< 1	0	33	66	49	26	23	10.3	
2n	18/7-103A	MB 378 362	0.1a	<1	1	17	60	21	42	28	14	7.3	
2n	18/7-103B	MB 378 362	0.4p	0	0	12	58	30					5.5
5k	9/7-102A	MB 493 340	0.1a	0	< 1	1	61	38					3.3
5k	9/7-102C	MB 493 340	1.4p	4	1	5	52	42					4.6
6m	10/7-4A	MB 487 341	0.3a									0.3	
7a	18/7-101A	MB 403 344	0	1	6	18	34	42				9.9	
7b	19/7-11	MB 441 322	0	?	47	11	22	21					
7b	77: 13/8-1	MB 520 318	0.5a	14	88	7	3	2					
9	76: 18/7-10A	ES 680 280	0.1a	0	2	21	43	33	24	15	9	5.7	
9	18/7-10B	ES 680 280	0.7p	0	1	18	46	35					7.7
9	19/7-3A	MB 405 295	0.75p	0	5	10	41	44	37	23	14	7.8	
9	19/7-101A	MB 405 296	0.1a	3	4	6	44	46	35	24	11		6.9
9	19/7-101B	MB 405 296	0.7p	4	5	8	37	50					7.5
9	19/7-102A	MB 405 295	0.1a	2	2	3	42	52	40	25	15	7.4	
9	19/7-103A	MB 402 303	0.1a	<1	< 1	< 1	32	67	54	28	26	9.7	
9	77: 11/8-1A	MB 376 485	0	0	2	8	66	24				9.1	6.8
9	11/8-1B	MB 376 485	0	0	4	16	45	35				3.9	8.4
9/5k	76: 5/7-2A	MB 519 332	0.2a	<1	17	44	30	9					5.5
9/5k	10/7-101A	MB 493 341	0.5p	<1	9	28	38	25					5.3
9/5k	19/7-105A	MB 506 354	0.1a	<1	3	7	43	47					5.4
9/5k	19/7-105D	MB 506 354	1.7p	8	< 1	2	53	45					8.7
9/5k	77: 9/8-1A	MB 520 336	0.2a	<1	14	36	36	14				1.9	6.2
9/5k	9/8-1B	MB 520 336	0.7p	<1	8	37	35	20					8.4
9/5k	9/8-1C	MB 520 336	1.05p										8.2
9/5k	9/8-1D	MB 520 336	1.2p										7.6
9/5k	9/8-1E	MB 520 336	1.65p						27	14	13		7.4
9/5k	9/8-1F	MB 520 336	2.4p	0	4	6	58	32				3.5	3.8
9/5k	9/8-1G	MB 520 336	2.75p										6.3
9/5k	13/8-2A	MB 509 331	0.2a	<1	14	17	37	32	24	15	9	6.6	5.9
9/5k	13/8-2B	MB 509 331	0.95p										6.9
9/5k	13/8-2C	MB 509 331	1.35p										8.9
9/5k	13/8-2D	MB 509 331	1.8p	0	1	6	58	35	29	14	15	6.3	7.4
9/5n	76: 19/7-8B	MB 381 323	0	0	0	< 1	33	67					7.5
10	7/7-102A	MB 537 334	0.4p	0	36	62	<1	1				0.5	
10/6m	77: 12/8-1	MB 524 340	1.2p	0	19	67	10	4				0.5	6.4
12	10/8-5B	MB 468 422	6.0	0	1	6	44	49				7.1	9.1

[1] Units are described in Table 2.

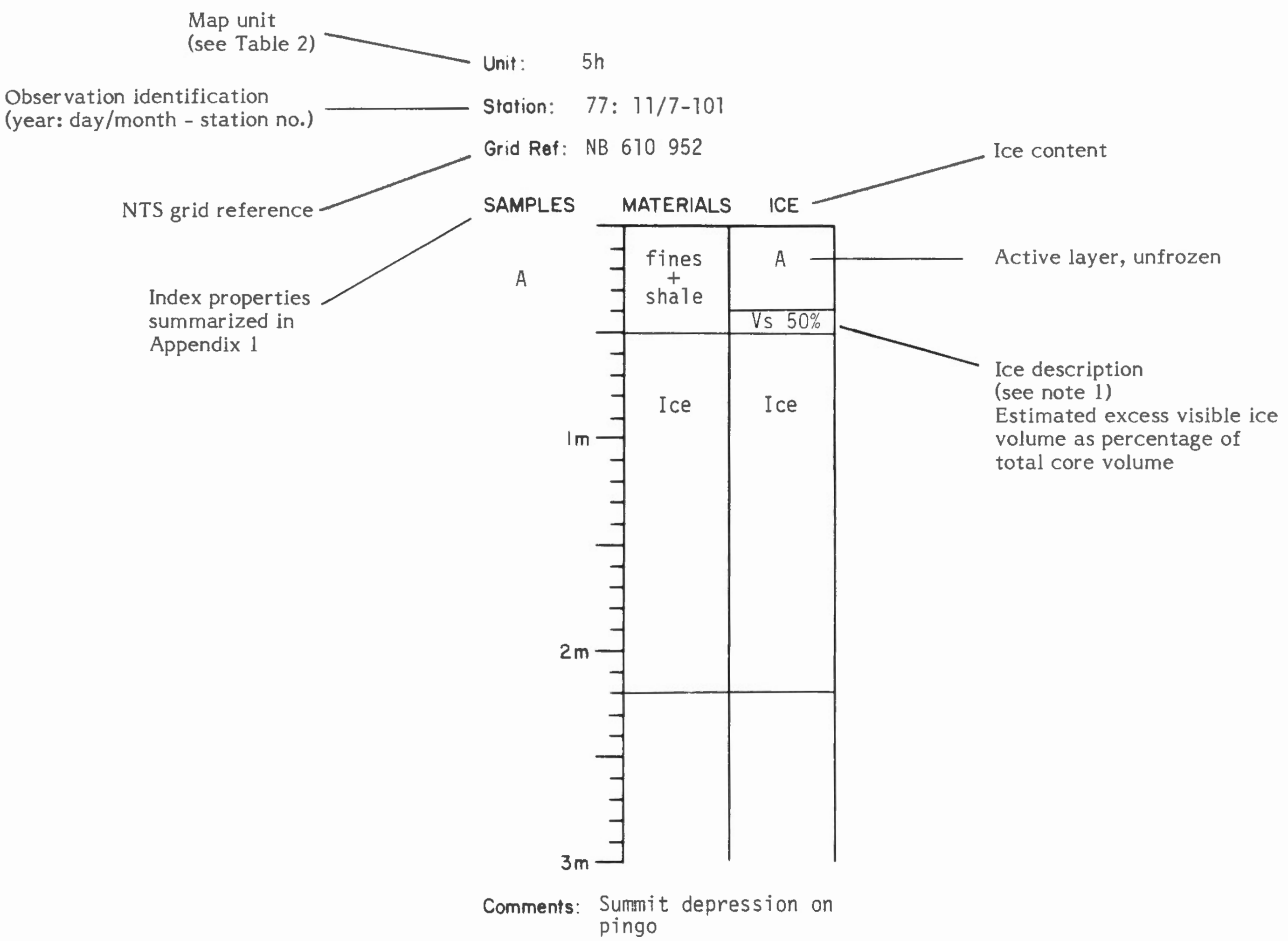
[2] Depth below surface in metres
a = sample from active layer
p = sample below frost table at time of sampling.

[3] >2 mm expressed as percentage of total sample weight
Coarse sand: 2.0 - 0.125 mm
fine sand: 0.125 - 0.063 mm
silt: 0.063 - 0.004 mm
clay <0.004 mn

[4] Consistancy/Atterberg limits
LL - liquid limit
PL = plastic limit
PI = plasticity index

APPENDIX 2

SHALLOW BOREHOLE CORE LOGS

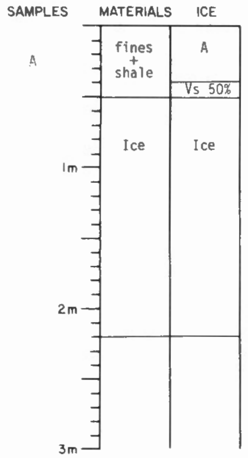


Note 1: Ice Description

GROUP SYMBOL	SUBGROUP Description	Symbol
N (ice not visible)	Poorly bonded or friable - no excess ice Well bonded - excess ice	Nf Nbn Nb Nbe
V (visible ice less than 1 inch thick)	Individual ice crystals or inclusions Ice coatings on particles Random or irregularly oriented ice formations Stratified or distinctly oriented ice formations	Vx Vc Vr Vs
ICE (visible ice greater than 1 inch thick)	Ice with soil inclusions Ice without soil inclusions	ICE + soil type ICE
Source: Pihlainen and Johnston 1963, Table I		

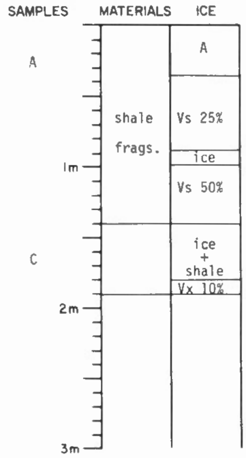
AMUND RINGNES ISLAND

Unit: 5h
Station: 77: 11/7-101
Grid Ref: NB 610 952



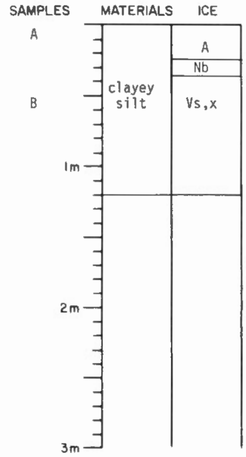
Comments: Summit depression on pingo

Unit: 5h
Station: 77: 11/7-102
Grid Ref: NB 610 952



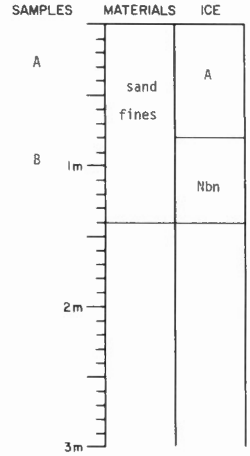
Comments: Flank of pingo

Unit: 5p
Station: 77: 19/7-4
Grid Ref: NB 399 699



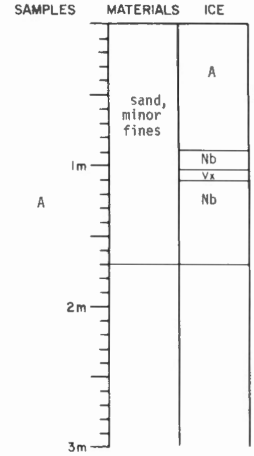
Comments:

Unit: 6m
Station: 77: 18/7-3
Grid Ref: NB 615 516



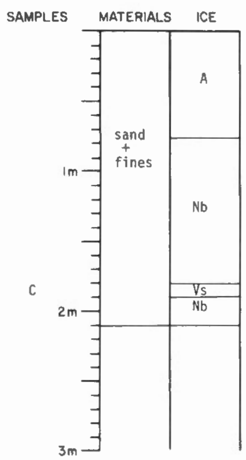
Comments:

Unit: 6m
Station: 77: 18/7-4
Grid Ref: NB 640 518



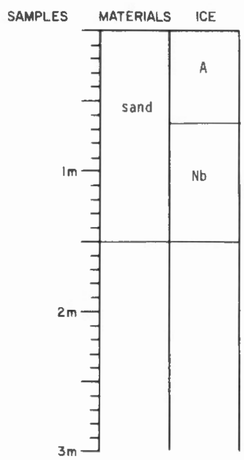
Comments:

Unit: 6m
Station: 77: 18/7-6
Grid Ref: NB 629 470



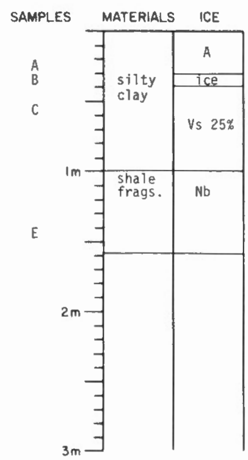
Comments:

Unit: 6 o
Station: 77: 16/7-4
Grid Ref: NB 510 555



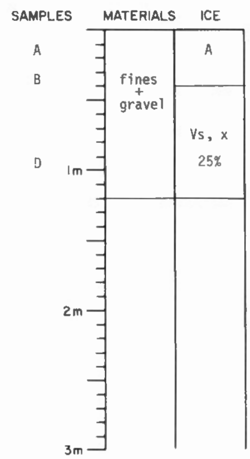
Comments:

Unit: 9/5h
Station: 77: 11/7-103
Grid Ref: NB 610 952



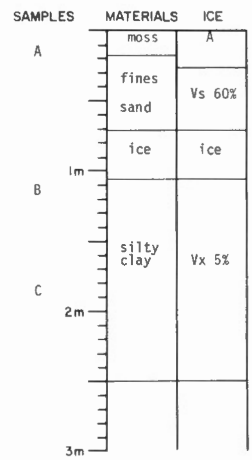
Comments:

Unit: 9/5h
Station: 77: 13/7-2
Grid Ref: NB 623 958



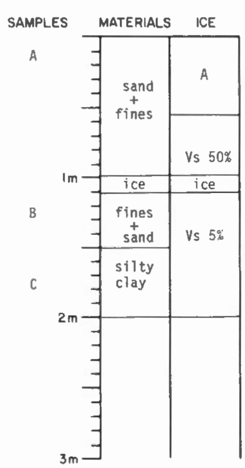
Comments:

Unit: 9/5n
Station: 77: 16/7-2
Grid Ref: NB 564 540



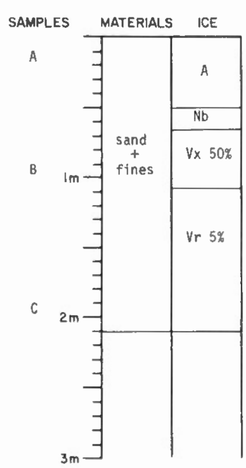
Comments: Centre of palsa, 30 cm high, 3 m diam., in wet site

Unit: 9/5n
Station: 77: 16/7-3
Grid Ref: NB 567 540



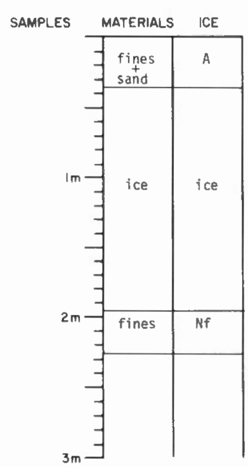
Comments: Dry site 25 m from 16/7-2

Unit: 10/5n
Station: 77: 2/8-1
Grid Ref: NB 546 510



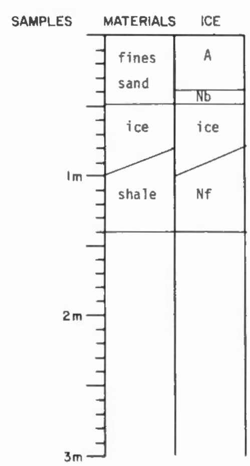
Comments:

Unit: 10/5n
Station: 77: 2/8-2
Grid Ref: NB 546 510



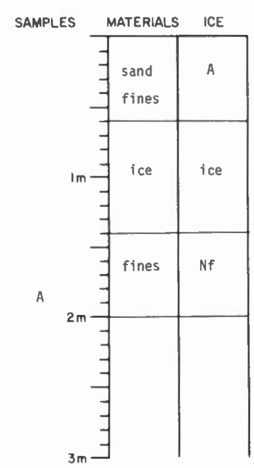
Comments: Frost fissure trough

Unit: 10/5n
Station: 77: 2/8-3
Grid Ref: NB 546 510

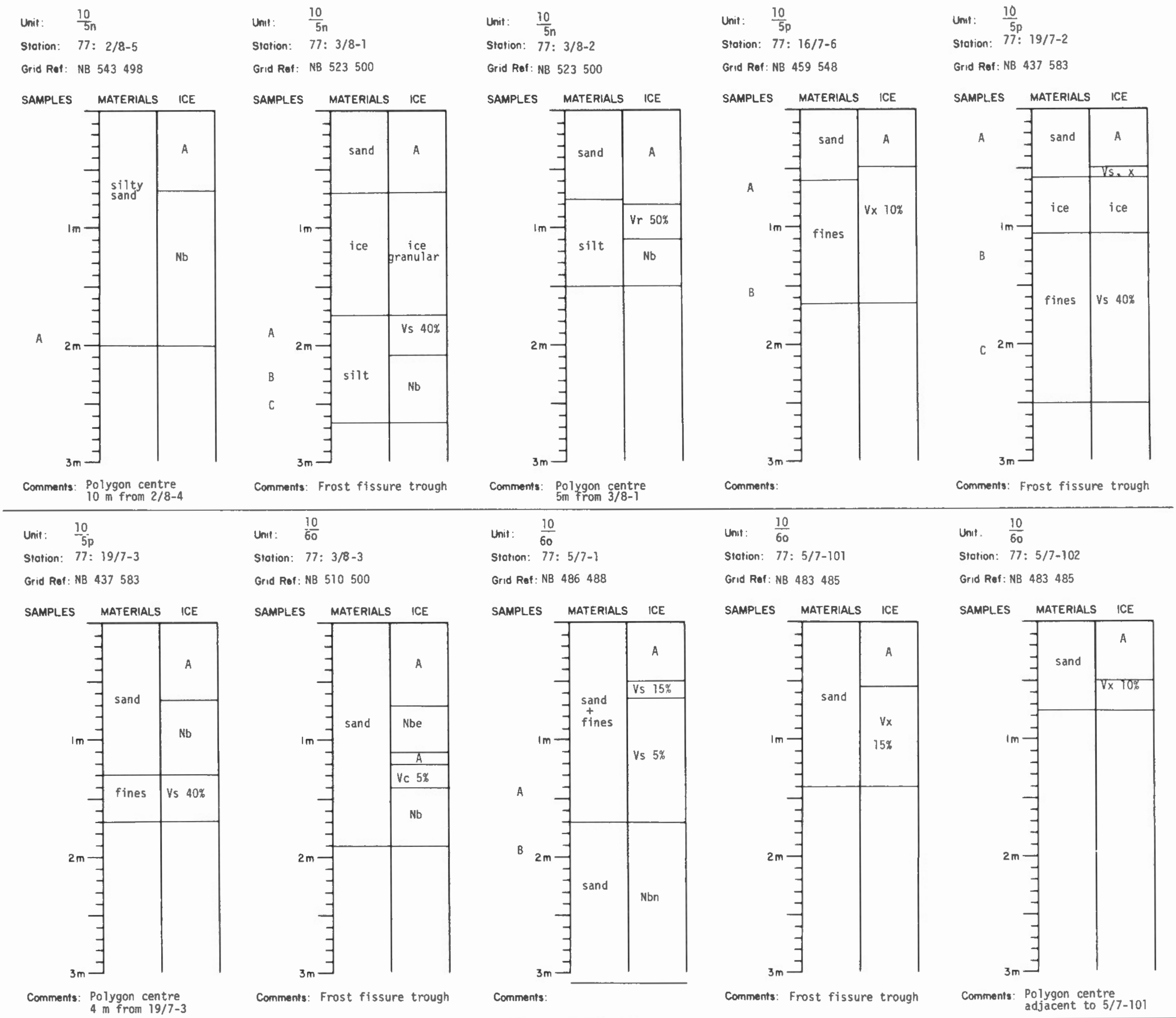


Comments: Edge of frost fissure trough 2/8-2

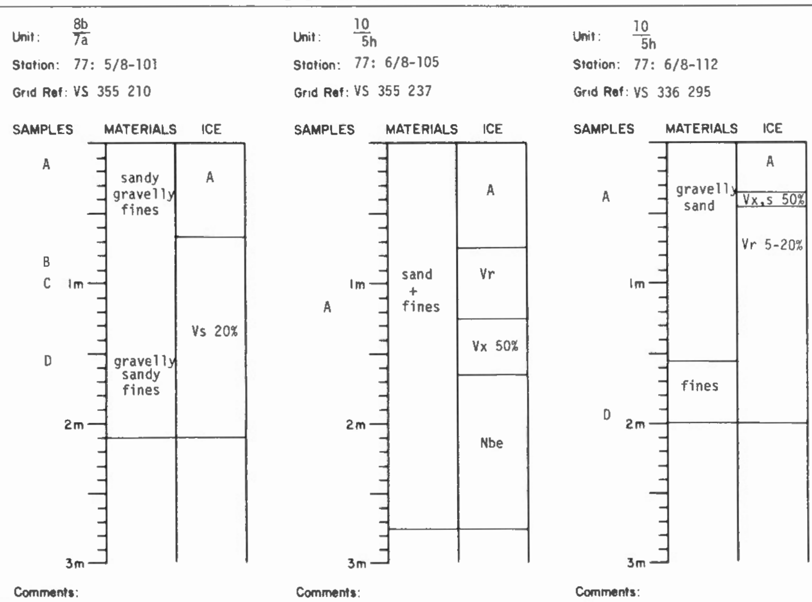
Unit: 10/5n
Station: 77: 2/8-4
Grid Ref: NB 543 498



Comments: Frost fissure trough

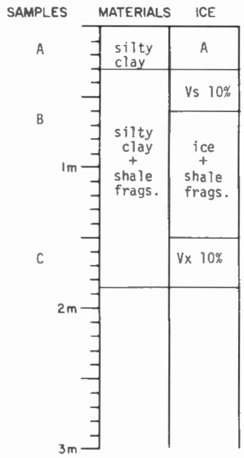


CORNWALL ISLAND



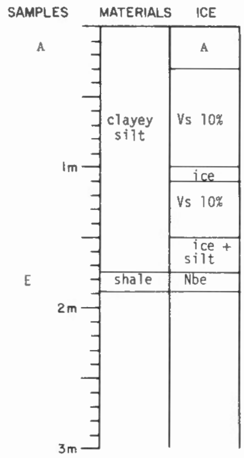
ELLEF RINGNES ISLAND

Unit: 2n
Station: 76: 30/7-2
Grid Ref: MB 714 782



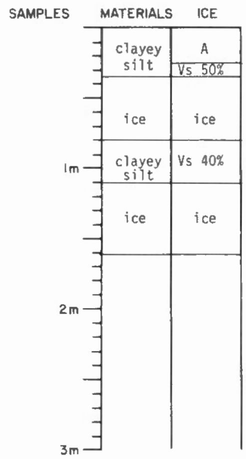
Comments: 1 m from back of earthflow

Unit: 2n
Station: 76: 13/8-4
Grid Ref: ES 569 979



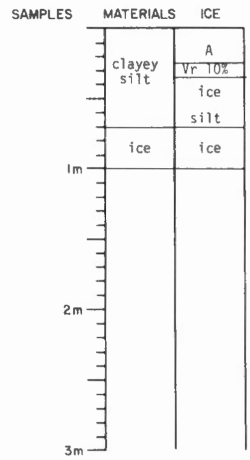
Comments:

Unit: 2p
Station: 76: 28/7-3
Grid Ref: MB 670 781



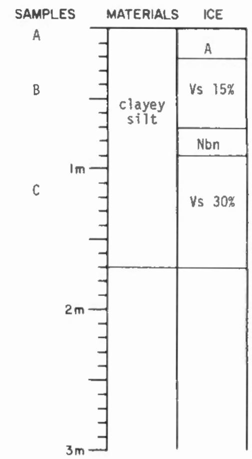
Comments: Frost fissure trough

Unit: 2p
Station: 76:28/7-4
Grid Ref: MB 670 781



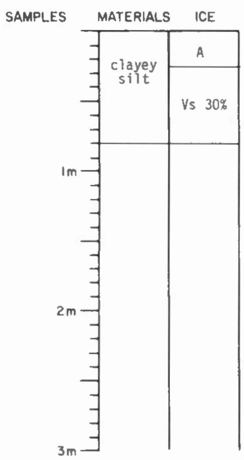
Comments: Polygon centre 10 m from 28/7-3

Unit: 2p
Station: 76:28/7-5
Grid Ref: MB 671 781



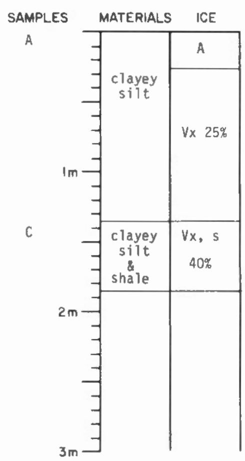
Comments:

Unit: 2p
Station: 76: 28/7-7
Grid Ref: MB 672 801



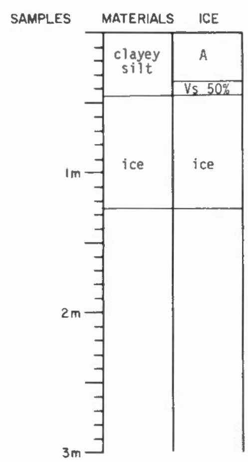
Comments:

Unit: 2p
Station: 76:29/7-1
Grid Ref: MB 679 796



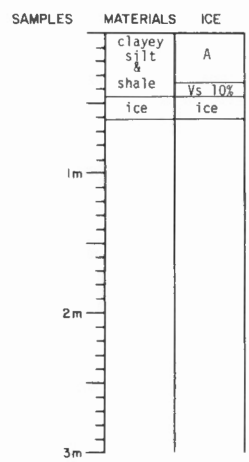
Comments:

Unit: 2p
Station: 76:29/7-2
Grid Ref: MB 686 795



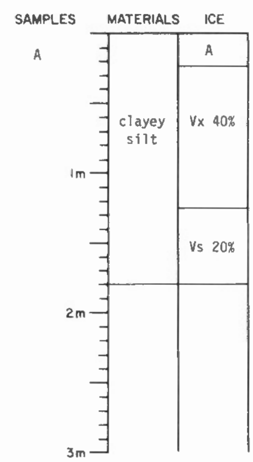
Comments: Frost fissure?

Unit: 2p
Station: 76:29/7-3
Grid Ref: MB 686 795



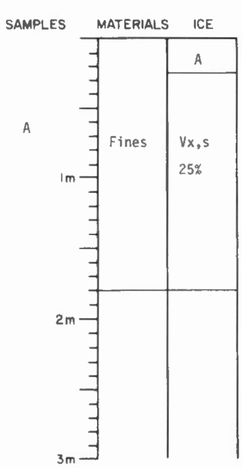
Comments:

Unit: 5p
Station: 76:28/7-1
Grid Ref: MB 666 783



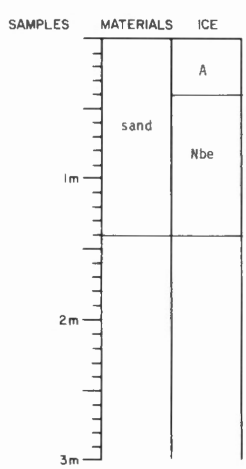
Comments:

Unit: 5p
Station: 76:28/7-2
Grid Ref: MB 666 783



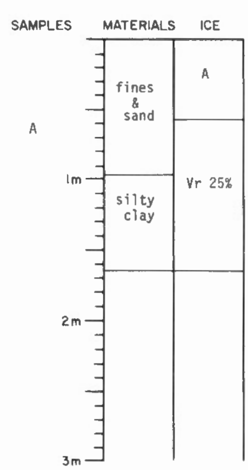
Comments:

Unit: 6m
Station: 76:14/8-3
Grid Ref: ES 528 955



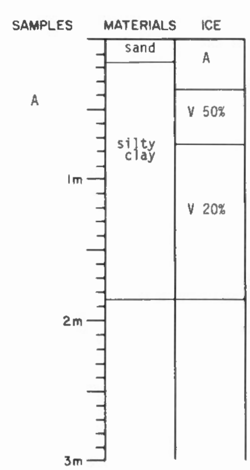
Comments:

Unit: 9
Station: 76:14/8-5
Grid Ref: ET 551 017



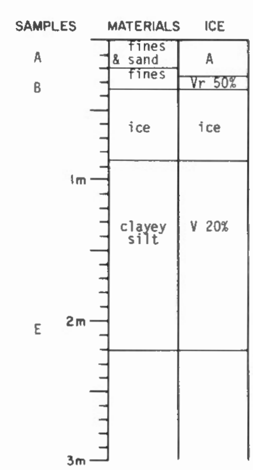
Comments:

Unit: 9/5n
Station: 76:13/8-1
Grid Ref: ES 536 995



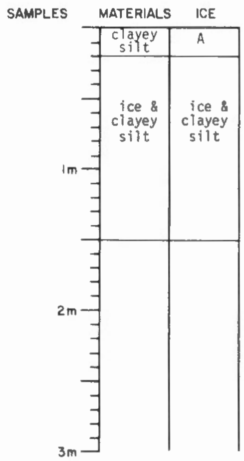
Comments:

Unit: 9/5n
Station: 76:13/8-2
Grid Ref: ES 544 988



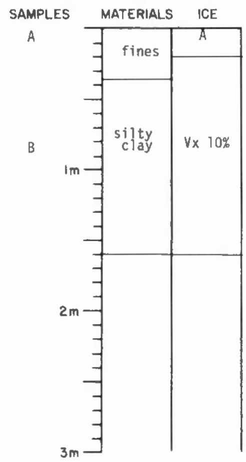
Comments:

Unit: $\frac{9}{5n}$
Station: 76:13/8-3
Grid Ref: ES 558 980



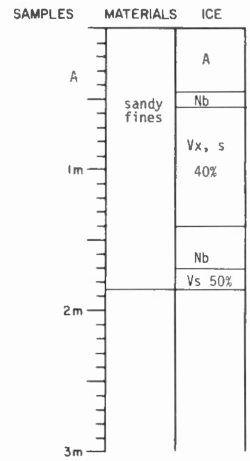
Comments:

Unit: $\frac{9}{5n}$
Station: 76:14/8-1
Grid Ref: ES 539 988



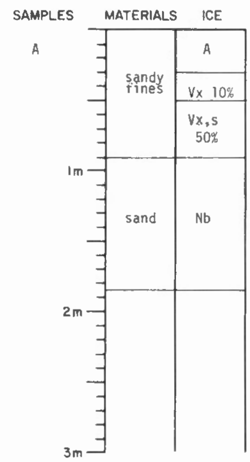
Comments: 1 m from back of earthflow

Unit: $\frac{9}{6r}$
Station: 76:24/7-2
Grid Ref: MB 647 780



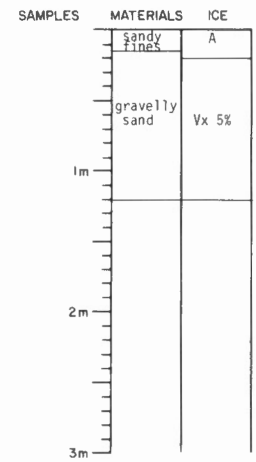
Comments:

Unit: $\frac{9}{6r}$
Station: 76:24/7-3
Grid Ref: MB 631 770



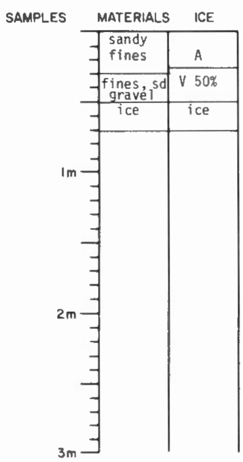
Comments:

Unit: $\frac{9}{6r}$
Station: 76:24/7-4
Grid Ref: MB 631 770



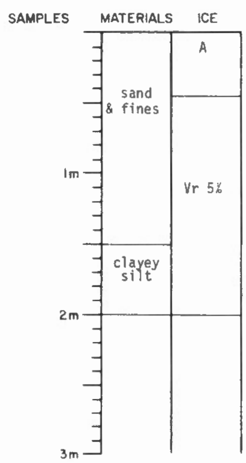
Comments: Edge of frost fissure trough adjacent to 24/7-3

Unit: $\frac{9}{6r}$
Station: 76:24/7-5
Grid Ref: MB 613 770



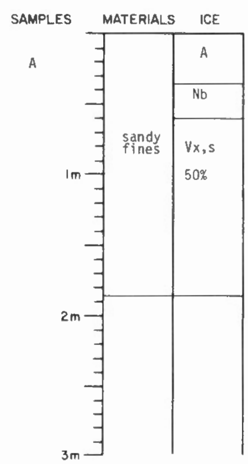
Comments: Centre of frost fissure trough adjacent to 24/7-2 1 m from 24/7-3

Unit: $\frac{10}{5n}$
Station: 76:14/8-2
Grid Ref: ES 511 974



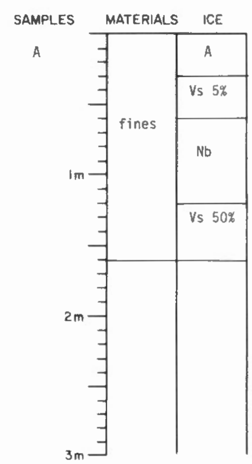
Comments:

Unit: $\frac{10}{5q}$, 6r
Station: 76:24/7-1
Grid Ref: MB 651 722



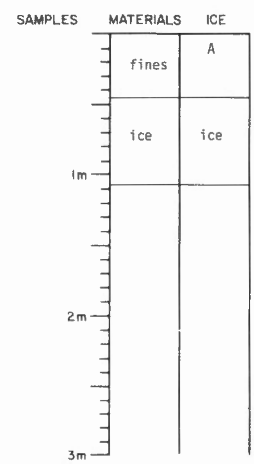
Comments:

Unit: $\frac{11}{2n}$, $\frac{11}{3o}$
Station: 76:29/7-5
Grid Ref: MB 708 793



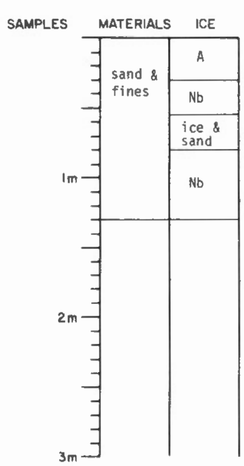
Comments:

Unit: 12
Station: 76:24/7-6
Grid Ref: MB 615 755



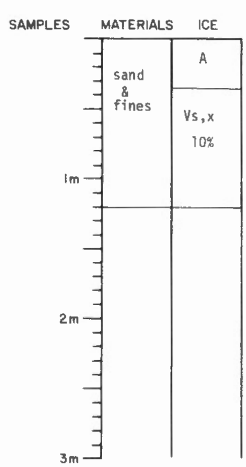
Comments: Possible frost fissure trough

Unit: 12
Station: 76:24/7-7
Grid Ref: MB 615 755



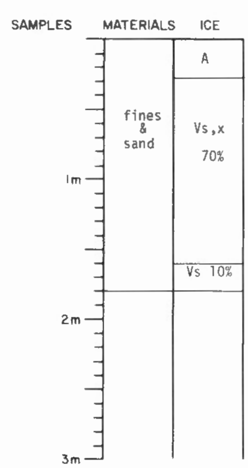
Comments:

Unit: 12
Station: 76:24/7-8
Grid Ref: MB 615 755



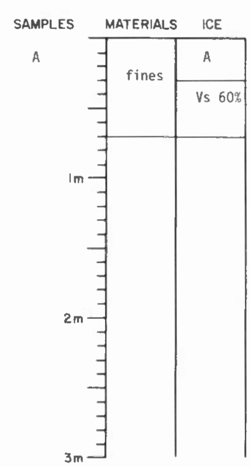
Comments:

Unit: 12
Station: 76:25/7-101
Grid Ref: MB 587 765



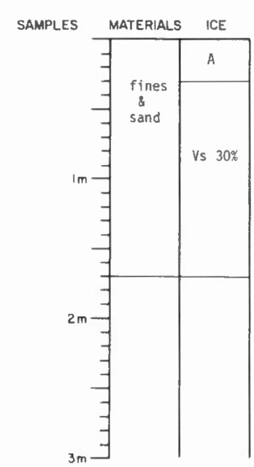
Comments: Polygon centre

Unit: 12
Station: 76:25/7-102
Grid Ref: MB 587 765



Comments: Polygon centre

Unit: 12
Station: 76:26/7-101
Grid Ref: MB 587 765



Comments:

Unit: 12
Station: 76:27/7-1
Grid Ref: MB 567 765
SAMPLES: A
MATERIALS: sand & fines
ICE: A; Nb; Vs 10%; Nb; Vs 20%
Comments:

Unit: 12
Station: 76:27/7-2
Grid Ref: MB 553 762
SAMPLES:
MATERIALS: fines & sand; sand & fines
ICE: A; Vs 25%; Vs 50%; ice & fines; Nb
Comments:

Unit: 12
Station: 76:27/7-3
Grid Ref: MB 543 761
SAMPLES:
MATERIALS: gravelly sand
ICE: A; Nb; Vs 10%
Comments:

Unit: 12, 10?
Station: 76:27/7-4
Grid Ref: MB 540 761
SAMPLES:
MATERIALS: sand; clayey silt
ICE: A; Nb
Comments: 0.5 m above sea level

Unit: 12
Station: 76:14/8-4
Grid Ref: ET 550 008
SAMPLES:
MATERIALS: sand
ICE: A; V 10%; ice; V 10%
Comments:

KING CHRISTIAN ISLAND

Unit: 2n
Station: 76:17/7-101
Grid Ref: MB 434 365
SAMPLES: A; B
MATERIALS: silty clay; sandy shale
ICE: A; Vs 30%; ice & shale; Nb
Comments:

Unit: 2n
Station: 76:17/7-102
Grid Ref: MB 430 364
SAMPLES: A; B
MATERIALS: clay; sandy shale
ICE: A; Vs 50%; Nb
Comments:

Unit: 2n
Station: 76:17/7-103
Grid Ref: MB 407 370
SAMPLES: B
MATERIALS: silty clay; ice; clay; ice
ICE: A; Vs 30%; ice; Vs 50%; ice
Comments: Frost fissure?

Unit: 2n
Station: 76:18/7-103
Grid Ref: MB 378 362
SAMPLES: A; B
MATERIALS: fines
ICE: A; Vs 25%; ice; Vs 25%; ice; Vs 25%; ice; Vs 25%
Comments: Polygon centre

Unit: 2n
Station: 76:18/7-104
Grid Ref: MB 378 362
SAMPLES:
MATERIALS: fines; ice
ICE: A; Vs 40%; ice
Comments: Frost fissure trough adjacent to 18/7-103

Unit: 3o
Station: 76:18/7-105
Grid Ref: MB 324 368
SAMPLES:
MATERIALS: sand
ICE: A; Vs 10%
Comments:

Unit: 5k
Station: 76:9/7-102
Grid Ref: MB 493 340
SAMPLES: A; C
MATERIALS: clayey silt
ICE: A; Vs 25%
Comments:

Unit: 5k
Station: 76:9/7-101
Grid Ref: MB 493 340
SAMPLES:
MATERIALS: silty sand
ICE: A; Vs 15%
Comments: Close to contact with unit 6m

Unit: 6m
Station: 76:10/7-4
Grid Ref: MB 487 341
SAMPLES: A
MATERIALS: sand
ICE: A; Nb; Vs 30%; Nb
Comments:

Unit: 6m
Station: 76:10/7-5
Grid Ref: MB 487 341
SAMPLES:
MATERIALS: sand
ICE: A; Nb; ice & sand; Nb
Comments: Frost fissure trough adjacent to 10/7-4

Unit: 7a
Station: 76:18/7-101
Grid Ref: MB 403 344

SAMPLES	MATERIALS	ICE
A	gravelly fines	A
		Vs 25%

1m, 2m, 3m

Comments:

Unit: 7b
Station: 77:13/8-1
Grid Ref: MB 520 318

SAMPLES	MATERIALS	ICE
A	gravelly sand	A
	sand	ice & sand
		Nb

1m, 2m, 3m

Comments: Frost fissure trough

Unit: 9
Station: 76:18/7-10
Grid Ref: ES 680 280

SAMPLES	MATERIALS	ICE
A	fines	A
B		Nb
		Vs 40%
		Vs 5%

1m, 2m, 3m

Comments:

Unit: 9
Station: 76:19/7-101
Grid Ref: MB 405 296

SAMPLES	MATERIALS	ICE
A	silty clay	A
B		Vs 30%
		ice & clay
	gravel	Vx 20%
	clay	ice & clay

1m, 2m, 3m

Comments.

Unit: 9
Station: 76:19/7-102
Grid Ref: MB 405 295

SAMPLES	MATERIALS	ICE
A	silty clay	A
		Vs 25%
	ice	ice
	silty clay minor gravel	Vs,x 30%

1m, 2m, 3m

Comments.

Unit: 9
Station: 76:19/7-3
Grid Ref: MB 405 295

SAMPLES	MATERIALS	ICE
	silt & clay	A
		Nb
A		Vs 40%
		Vs 10%

1m, 2m, 3m

Comments:

Unit: 9
Station: 76:19/7-103
Grid Ref: MB 402 303

SAMPLES	MATERIALS	ICE
A	silty clay	A
		Vs 30%
		ice & clay
	ice	ice
	shale	Nb

1m, 2m, 3m

Comments:

Unit: 9/5k
Station: 76:2/7-1
Grid Ref: MB 520 336

SAMPLES	MATERIALS	ICE
	sand & fines	A
		Vs 5%

1m, 2m, 3m

Comments:

Unit: 9/5k
Station: 76:5/7-2
Grid Ref: MB 519 332

SAMPLES	MATERIALS	ICE
A	silty sand	A
	fines	Nb
		Vs 10%

1m, 2m, 3m

Comments. Graded airstrip

Unit: 9/5k
Station: 76:5/7-3
Grid Ref: MB 518 323

SAMPLES	MATERIALS	ICE
	silty sand	A
		Vs 5%
		Vs 40%
		Vs 5%

1m, 2m, 3m

Comments:

Unit: 9/5k
Station: 76:10/7-101
Grid Ref: MB 405 296

SAMPLES	MATERIALS	ICE
A	fines	A
		Vs 25%
	clayey silt	?

1m, 2m, 3m

Comments:

Unit: 9/5k
Station: 76:19/7-105
Grid Ref: MB 506 354

SAMPLES	MATERIALS	ICE
A	silt & clay	A
		Vs 50%
D		Nb

1m, 2m, 3m

Comments:

Unit: 9/5k
Station: 77:9/8-1
Grid Ref: MB 520 336

SAMPLES	MATERIALS	ICE
A	sandy fines	A
B		Nb
C		ice & fines
D		Vs 5%
E		ice & fines
F	silty clay	Vs 10%
		ice & fines

1m, 2m, 3m

Comments:

Unit: 9/5k
Station: 77:13/8-2
Grid Ref: MB 509 331

SAMPLES	MATERIALS	ICE
A	sandy fines	A
B		Vs 15%
C	clayey silt	Nbn
D	shale?	

1m, 2m, 3m

Comments:

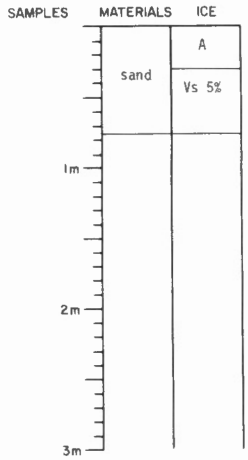
Unit: 10
Station: 76:6/7-1
Grid Ref: MB 537 334

SAMPLES	MATERIALS	ICE
	sand	A
		Nb
		ice & sand
		A & Nb

1m, 2m, 3m

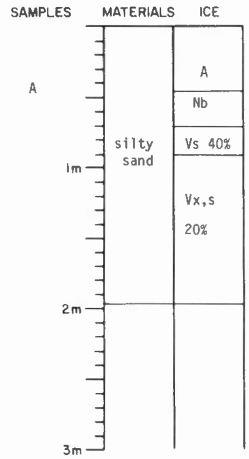
Comments: Frost fissure trough. Pond upslope

Unit: 10
Station: 76:7/7-101
Grid Ref: MB 537 334



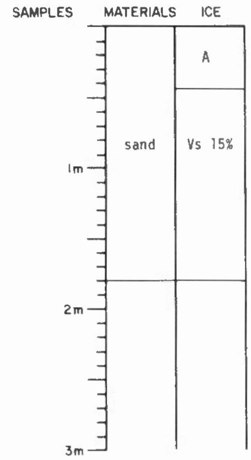
Comments:

Unit: 10
Station: 76:7/7-102
Grid Ref: MB 537 334



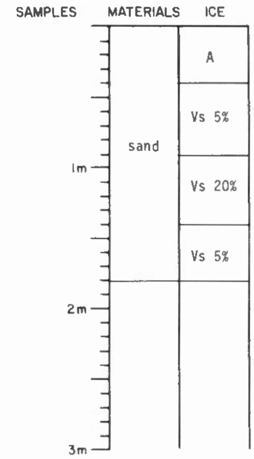
Comments: Frost fissure trough

Unit: 10
Station: 76:7/7-103
Grid Ref: MB 541 334



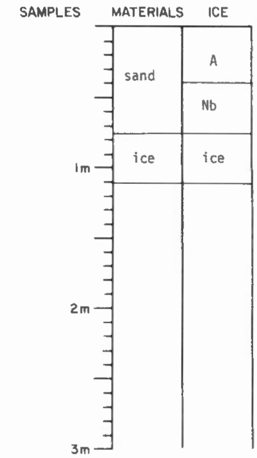
Comments:

Unit: $\frac{10}{6\text{m}}$
Station: 76:9/7-1
Grid Ref: MB 514 312



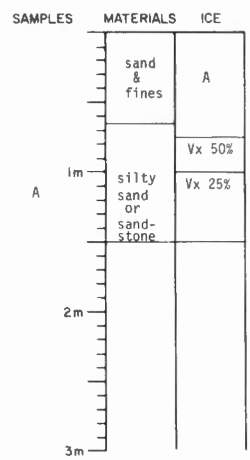
Comments:

Unit: $\frac{10}{6\text{m}}$
Station: 76:19/7-104
Grid Ref: MB 483 298



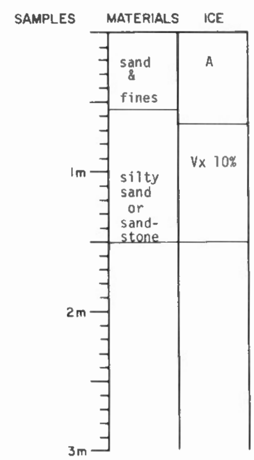
Comments: Frost fissure trough

Unit: $\frac{10}{6\text{m}}$
Station: 77:12/8-1
Grid Ref: MB 524 340



Comments:

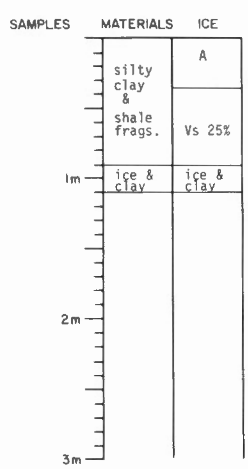
Unit: $\frac{10}{6\text{m}}$
Station: 77:12/8-2
Grid Ref: MB 531 343



Comments:

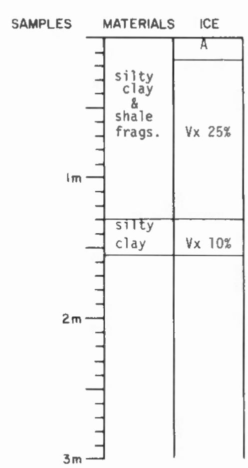
GRAHAM ISLAND

Unit: 2p
Station: 74:2/8-1
Grid Ref: WR 607 840



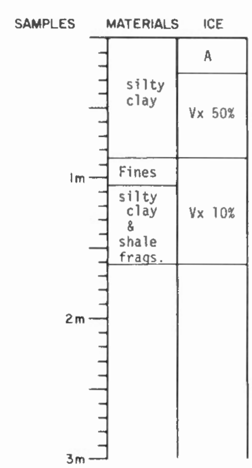
Comments:

Unit: 9
Station: 74:3/8-101
Grid Ref: WR 595 808



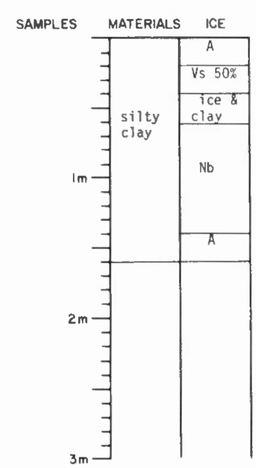
Comments

Unit: 9
Station: 74:3/8-102
Grid Ref: WR 583 803



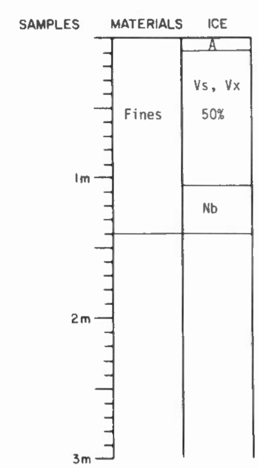
Comments:

Unit: 9
Station: 74:3/8-103
Grid Ref: WR 576 815



Comments:

Unit: 9
Station: 74:3/8-104
Grid Ref: WR 582 810



Comments: Moss surface cover