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CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

PAPER 56-9

GEOLOGICAL RECONNAISSANCE OF THE NORTH COAST OF ELLESMERE ISLAND DISTRICT OF FRANKLIN NORTHWEST TERRITORIES

(Report and Map 16-1956)

By

R. L. Christie

OTTAWA
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Price, 50 cents

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GEOLOGICAL RECONNAISSANCE OF THE NORTH COAST OF ELLESMERE ISLAND, DISTRICT OF FRANKLIN NORTHWEST TERRITORIES (1954)

INTRODUCTION

Location

Ellesmere Island is the largest and most northerly of the Queen Elizabeth Islands, District of Franklin, Northwest Territories. This report describes the north coast of the island from Cape Columbia to Lands Lokk, or between about longitudes 72° and 92° west.

Present Investigation and Acknowledgments

A geological reconnaissance of a part of the north coast of Ellesmere Island was made by the author for the Geological Survey of Canada as a member of the joint Canada-United States Northern Ellesmere Island Ice Shelf Expedition of 1954.

Previous to the 1954 expedition, no geological studies had been made of this extensive part of the northern coast of Ellesmere Island, although some speculative conclusions had been drawn from rock specimens brought back by early explorers. The field work in 1954 extends westward the reconnaissance survey from Cape Sheridan to Cape Columbia made by R. G. Blackadar (1954)[1] of the Geological Survey of Canada in 1953.

The personnel of the expedition comprised Geoffrey Hattersley-Smith, of the Defence Research Board of Canada, leader; A. P. Crary, of the United States Air Force Cambridge Research Center, geophysicist; E. W. Marshall, of the Snow, Ice, and Permafrost Establishment of the U.S. Army, glaciologist; the author, of the Geological Survey of Canada, geologist; and Imina and Karkutiak, Eskimos from Thule, Greenland. The expedition, with two dog teams and supplies for five months, was flown by the U.S. Air Force from Thule Air Base to Ward Hunt Island. After freeze-up in the fall, the scientists, specimens, and gear were flown back to Thule Air Base.

Radio contact was maintained with Alert Weather station on northern Ellesmere Island during the five-month field season. The station personnel gave friendly cooperation in listening for and transmitting messages and in caring for the dogs and members of the expedition on occasion.

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[1] Dates in parentheses are those of references cited at the end of this report.

The author is indebted to the other members of the expedition for much assistance in collecting geological data, and information generously made available by them is contained in the notes on weather, ice phenomena, water depths, and wildlife.

Fossil identifications were made by W.L. Fry, Peter Harker, G.W. Sinclair, and F.J.E. Wagner of the Geological Survey of Canada. The sponge material from around Ward Hunt Island was studied by E.L. Bousfield, National Museum of Canada, and by M.W. deLaubenfels of Oregon State College, Corvallis, Oregon. Plant identifications were made by H.J. Scoggan of the National Museum of Canada.

History of Discovery

The first Europeans to travel the north coast of Ellesmere Island were members of the British Arctic Naval Expedition of 1875-76 under the command of Captain Sir George Nares. A crew led by Lieutenant Pelham Aldrich man-hauled a sledge westward to Alert Point. A map and notes left by this party were found at Cape Fanshawe Martin (Plate I).

Lands Lokk[1], westernmost Ellesmere Island, was visited and named in 1902 by Captain Otto Sverdrup, leader, and Per Schei, geologist, of the "Second Norwegian polar expedition in the 'Fram'"; this was their farthest north point reached on an extended dog-sledge trip from southern Ellesmere Island.

In 1906 Commander R.E. Peary travelled the entire length of the northern coast of Ellesmere Island and crossed the strait to Axel Heiberg Island. A note left by Peary was found north of Cape Colgate (Plate II). Also recovered were a cache and note left on Ward Hunt Island in 1909 by D.B. McMillan in support of Peary's expedition to the pole (Plate III).

In 1920, Commander Goodred Hansen, of the Royal Danish Navy, visited Cape Aldrich to leave a cache in support of Roald Amundsen and the North Polar Drift of the 'Mand'.

In 1930, an ill-fated party of three explorers, led by Prof. H.K.E. Kruger, travelled north a few miles along the coast of Ellesmere Island from Lands Lokk before turning southwest

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[1] Geographical names used in this report are subject to revision by the Canadian Board on Geographical Names.

towards Axel Heiberg Island. A note left by Kruger in an old Peary cairn was recovered (Plate IV).

In 1950 Colonel J. Fletcher of the U.S. Air Force landed an aircraft at Cape Aldrich, and visited the cairns and signposts there. In 1953, Geoffrey Hattersley-Smith and R.G. Blackadar made a reconnaissance survey of the northern coast of Ellesmere Island between Cape Sheridan and Cape Nares.

In recent years the Royal Canadian Air Force has flown photographic flights over northern Ellesmere Island, and fairly reliable maps have been compiled from airphotos. Ice reconnaissance flights by the R.C.A.F. and the United States Air Force have contributed to the knowledge of ice phenomena in this remote region.

Accessibility and Method of Travel

The region is accessible only by air or by dog team over the ice from more southerly points. Ships have reached Alert Weather Station about 100 miles southeast of Cape Columbia.

Travel during the spring and fall was by dog team and komatik; extensive areas of old sea ice and shelf ice provide good travel conditions for dog teams.

Soft snow up to 3 feet deep, an unusual phenomenon in the Arctic, is found in late winter and spring in the long, protected fiords of the northern Ellesmere Island coast. The fan-type dog hitch and broad, heavy komatik used in Greenland are not suited to this snow condition, and no headway can be made using them in the deeper snow.

In late June or early July the melt season begins, and melting progresses very quickly. Inland, 10 or 20 miles away from the ice shelf, the melt begins a week or more earlier than at the coast and on the shelf. During the period of melt, the land surface becomes almost free of snow, the sea ice becomes covered with water, and the troughs of the shelf ice fill with water. Travel on the ice, except along the ridges of the shelf ice, is difficult and uncomfortable in the summer.

Travel conditions on land are variable; walking is generally easy because of the sparseness of the Arctic vegetation, but over large areas ankle-deep mud resulting from thawing ground makes travel on foot tedious.

Because the spring and fall cold seasons are the best in which to travel great distances over shelf ice, sea ice, or fiord ice, most geological reconnaissance is done in those seasons. However, the five or six weeks of summer melt season are most rewarding for geological observations; blanketing and brilliance due to snow are absent, and the colours of the rocks are more easily discerned.

Topography

The northern coast of Ellesmere Island is a rugged, fiord-dissected, mountain region of moderate relief. The coastal mountains, which flank the high, ice-covered United States Range, attain elevations of about 3,500 feet. At the heads of the fiords, at the edge of the United States Range, elevations of 5,000 feet occur.

The trunk or larger valleys are deep, straight-walled glacial valleys, the lower parts of which have been drowned to form fiords. Glacial ice from the United States Range flows in the upper parts of the valleys and in many cases extends, floating, several miles along the fiords.

Submarine channels or trenches, which may be continuations of the drowned trunk valleys, are indicated off the coast by seismic and line sounding data. A compilation of data obtained in 1954 and of soundings by Ross G. Marvin of the Peary expedition in 1906 shows a series of linear deeps or trenches parallel to the coast-line and connecting with the relatively deep fiords (from map by A.P. Crary, personal communication). The deeps lie just off the outermost shoreline, and are about 1,200 feet in depth. The banks lying to the seaward side of the deeps, about 6 to 12 miles from shore, are at depths of about 250 to 600 feet.

A deep channel was found west of Ward Hunt Island, and was traced westerly to a point off Cape Discovery; the total extent is not known. The maximum depth recorded is about 2,800 feet, compared to depths in the order of 250 to 600 feet along the outer edge of the ice shelf. The channel may be a continuation of Disraeli Bay fiord.

The submarine topography probably is due to various causes; morainal ridges, erosion along unconformities or faults, and fault scarps may be suggested.

Many of the smaller, tributary valleys in the coastal mountains have been but slightly affected by glacial action. Some may have contained flowing ice, but have been modified by streams so that they are now V-shaped in cross-section. Other small valleys appear to have been excavated by normal stream erosion only.

The volume of water in all streams is extremely variable because the source is mainly melt-water from the snow and glaciers. The streams below the larger glaciers are commonly braided. In the cold seasons, of course, streams do not exist.

The region contains a few small lakes. The ice on the lakes broke up in 1954, but it is apparent from airphotos taken in other summers that ice may remain on the lakes from year to year. That the ice in the fiords has not broken up for many years is inferred from its measured thickness of 9 to 14 feet and from a study of airphotos taken in summer. However, open water develops along the shores each year as discontinuous 'moats'.

Unusual, thick, extensive floating rafts of ice occur along the coast and in some fiords. These occurrences, known collectively as 'the ice shelf', possess a striking ridge and trough topography and a relief of about 3 to 24 feet. The phenomenon is described further under the heading, 'Pleistocene, including recent time'.

Climate

The climate in the Arctic Archipelago of Canada is of two types. During the winter, a continental climate prevails, characterized by very low average temperatures during the cold months (January and February) and by consistently high barometric pressures. During the summer, a maritime influence is present, and cool temperatures and low barometric pressures prevail.

The annual mean temperature at Eureka and Alert, the northernmost Canadian weather stations, is about 0° F., compared to 10° to 20° in northern continental Canada; the winter cold month (January or February) mean temperature is about -30° compared to -15° to -20°, and the warm month (July) mean temperature is about 40° compared to 50° to 60°. The minimum temperatures recorded are no lower in the Arctic than to the south but the maximum summer temperatures are not so high, (from a table in Fort Simpson report, Experimental Farms Service 1954).

The precipitation recorded in the northern part of the Arctic Archipelago is very low - in the order of 2 to 5 inches a year - but from the experience of the expedition at Ward Hunt Island in the season from April to September of 1954, the precipitation along the northern coast of Ellesmere Island would be considerably greater. Over 7 inches of rain fell during the melt season of 1954, and soft snow 20 to 30 inches deep in the fiords indicates a snowfall unusually great for the Arctic.

On the ice shelf, minimum temperatures of -10°F. and -3°F. were recorded in early May and late September respectively, and a maximum of 42°F. occurred in late July. A few miles inland, temperatures as high as 52°F. were recorded.

The typical Fahrenheit temperatures experienced during the season were: April and May, below 0° to 20°; late May and June, 20° to 30°; early July (July 2), melt began; July and August 30° to 40°; September, 30° to 0°.

The winds were remarkably constant in direction, almost all being either easterly or westerly along the coast, all heavy storms coming from the west. Winds up to 35 knots were experienced, but the average wind speed was about 4.5 knots. Periods of calm were frequent.

During the cold period, drifting snow or ice crystals frequently obscured the visibility. During the warmer season, in the vicinity of the shelf ice or the polar pack ice, low cloud and fog were frequent. Inland, away from the ice, the visibility was usually somewhat superior.

Vegetation and Game

The vegetation is sparse, as might be expected from the shortness of the period of melt, the shallow depth to which thawing advances, and the generally poor drainage resulting from these phenomena.

Several species of grass, grass-like sedge and rush, chickweed, sandwort, and sorrel were collected, as well as various other species of small flowering plants. Saxifrage, moss campion, and poppy are found in great abundance. Species of fern and of heather were also collected. Willow is the only substantial plant found; it grows usually to heights of 3 or 4 inches with branches the thickness of a finger.

Although the plants are small, they are widespread, and the tiny, brilliant flowers, blooming during almost the entire snow-free season, provide a colourful carpet on the rounded hills.

Probably because of the slight vegetative cover, there are few land animals on this northern coast. Five musk-oxen and two caribou were seen, and wolf and fox tracks were observed. Several weasels were seen on land and on the shelf ice, and many lemming tracks and several dead lemmings were found. Insects, including flies, a type of daddy-long-legs, caterpillars, moths, and butterflies were found, often alive but in a stupor, on the snow and ice surfaces of the ice shelf.

Four seals were seen at the edges of the ice shelf.

Birds, especially snow buntings and gulls, are in fair abundance. Also seen were ptarmigan, an owl, knots, jaegers, and ducks.

GENERAL GEOLOGY

Formations of several ages and various lithological types are found on the northern coast of Ellesmere Island. The most extensive formation is a gneiss and schist terrain of unknown age. The metamorphic terrain has been intruded by coarse-grained igneous rocks, and is presumed to be overlain by less metamorphosed but highly folded volcanic and volcanic-sedimentary rocks and by moderately folded slate, sandstone, and limestone containing fossils of Ordovician age. A thick, late Palaeozoic, moderately folded limestone-sandstone formation of great areal extent overlies with an angular unconformity the older formations. A small amount of poorly consolidated mudstone and sandstone rests at one locality upon the eroded schist formation.

Dykes of medium- and fine-grained rocks are widespread, but have not been found in the poorly consolidated formation.

Inland, stratified rocks of great thickness and extent have been observed, but have not been correlated with certainty with the formations at the coast.

Glacial ice is widespread. The ice does not appear to be retreating at present, and may be in a state of advance that has not been exceeded in at least several hundreds of years. However, widespread glacial debris indicates that glaciation formerly was more extensive.

Marine beaches up to 200 feet above sea-level indicate a recent emergence of the land. Frozen ground phenomena are abundant and widespread.

Table of Formations

Period or epoch	Group or formation	Deposits Lithology
		Stream deposits, talus, soil
		Firn ice Sea ice?
		Fluvioglacial deposits; gravel, sand
Pleistocene and Recent		Firn ice, alpine glacier ice, till
Disconformity ?		
Mesozoic or Cenozoic	Eureka Sound group	Sandstone, mudstone, weakly consolidated shale
		Weakly consolidated volcanic conglomerate
Relations not known		
		Sills and dykes of felsite andesite, dacite, diabase and gabbro
Intrusive contacts		
Upper Carboniferous and Lower Permian		Limestone, sandstone; minor conglomerate
Angular unconformity		
Pre-Upper Carboniferous	Imina group	Subgreywacke, shale, slate; may be equivalent to M'Clintock group, in part
Relations not known		
	Bourne group	Volcanic flows, dykes, and sills of intermediate type; hybrid intrusive rocks; minor interbedded slates, greywacke or tuff; may be equivalent to M'Clintock group, in part

Relations not known

Middle and Upper Ordovician	Challenger group	Limestone, impure red sandstone, conglomerate, slate; minor basic volcanic rock
	Angular unconformity ?	
Probably Middle Ordovician or earlier	M'Clintock group	Andesitic and basaltic flow-rocks, breccias, tuffs, greywacke, arkosic sandstone, slate; minor crystalline limestone, quartzite; may be equivalent to Imina and Bourne groups
	Relations not known	
	Mount Disraeli group	Phyllite, crystalline limestone
	Relations not known	
Age unknown, possibly more than one		Granite, norite, peridotite, syenite
	Intrusive contacts	

The granite, norite, peridotite, and syenite have been found intruding only the Cape Columbia group

Pre-Middle Ordovician	Cape Columbia group	Biotite-feldspar, hornblende-biotite-feldspar, garnet-biotite-feldspar, and feldspar-augen gneiss; chlorite-feldspar schist, quartzite, crystalline limestone; gneissic granite or granite gneiss, probable meta-intrusive rock

The above table contains many groups of rocks, the relations and ages of which are unknown. They are arranged approximately in order of decreasing metamorphism (reading up). Sedimentary formations, the relations of which are known to a limited extent are shown in the highest possible position; intrusive rocks in the lowest.

Pre-Middle Ordovician

Cape Columbia Group

The term, Cape Columbia group, was first applied by R. G. Blackadar (1954, p. 8) to an unusual assemblage of metamorphic rocks on Capes Columbia and Aldrich. In this report the term includes all rocks of advanced metamorphic grade.

The metamorphic rocks of the Cape Columbia group (1)* were noted by the early expeditions, and were the basis for Schuchert's inference (1923, p. 192) that an ancient borderland, which he called 'Pearya', existed along, or north of, the northern coast-line of Ellesmere Island.

The Cape Columbia group is one of the most extensive rock-units so far mapped on this northern coast. Rocks of the unit occur between Cape Aldrich and Cape Albert Edward, on Ward Hunt Island, at the head of M'Clintock Fiord, and between Ayles Bay and Phillips Fiord. A terrain extending about 160 miles along the coast is represented by these outcrops.

The Cape Columbia group includes biotite-feldspar gneiss, hornblende-biotite-feldspar gneiss and schist, garnet-biotite-feldspar gneiss, mica schists, quartzite, micaceous quartzite, marble, and a variety of granitic gneisses. Amphibole-gneisses are generally present in the vicinity of Cape Nares and Ward Hunt Island. In the gneiss terrain between Ayles Bay and Phillips Bay, quartz-mica schists and quartzite predominate, and carbonate beds occur.

Persistent banding due to variation in composition is generally present; this, with the presence of distinct beds of carbonate and quartzite, indicate a sedimentary origin for most of the gneissic and schistose rocks.

Part of the group, however, appears to be crushed and metamorphosed plutonic rock. Such rocks are the gneissic syenite on Ward Hunt Island, and the gneissic granite of Capes Bicknor and Evans. Angular debris of augen-gneiss, possibly of plutonic origin, occurs on floating shelf ice in Yelverton Bay. This ice may have come from Yelverton Fiord, but from a study of bedrock structures evident in airphotos, the writer believes the debris on the ice more probably is derived from the mountains of Cape Evans.

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* Numbers in brackets following rock-group names refer to the number of the map-unit.

The structural relations within the group are undoubtedly very complex. There appears to be no persistent trend of the bedded or banded rocks, and, as already stated, part of the group appears to be crushed and metamorphosed plutonic rock.

The Cape Columbia group is assumed to be older than the other rock units of the region because of its higher metamorphic grade. Permo-Carboniferous strata overlie the Cape Columbia rocks with angular unconformity at the head of M'Clintock Fiord, on Ward Hunt Island, in a valley east of Cape Albert Edward, and on the east face of Cape Nares.

A conglomerate on the east shore of Disraeli Bay contains pebbles of crystalline limestone and quartzite that may be derived from the Cape Columbia group. The conglomerate appears to be part of the M'Clintock volcanic-sedimentary group, which may be overlain unconformably by the Challenger sedimentary group (4) of Middle and Upper Ordovician age. The M'Clintock group and the Challenger group have undergone only slight metamorphism. Thus a major orogeny resulting in metamorphism of the Cape Columbia group may have occurred in the early Palaeozoic. The complexity of the group, however, suggests that it has a long tectonic history and may be, at least in part, Precambrian.

Middle Ordovician or Earlier

Mount Disraeli Group

The Mount Disraeli group (2) of slightly metamorphosed sedimentary rocks occurs between Markham Fiord and Clements Markham Inlet, as described and named by R.G. Blackadar (1954, p. 10). Flat-lying crystalline limestone was found on Wood Point, and moderately dipping, brown-weathering grey phyllite occurs on the east shore of Markham Fiord. No further data on this group has been obtained.

The group is described as "Precambrian or Palaeozoic" by Blackadar. The present author tentatively considers the age to be pre-Middle Ordovician, because the rocks appear more metamorphosed than those of the Challenger group. However, it is possible that the metamorphic grade varies from one place to another, and that the two groups are of about the same age.

M'Clintock Group

The M'Clintock group (3) is named for its spectacular cliff exposures at the mouth of M'Clintock Fiord. The group comprises volcanic flows, breccias and tuff, associated tuffaceous greywacke, slate, sandstone, chert, and limestone. An unknown thickness of these rocks occurs in the vicinity of M'Clintock and Disraeli Fiords.

Greenish grey, fine- to medium-grained tuffs and tuffaceous rocks predominate, and are interbedded with abundant andesitic to basaltic flows and breccias. Black slates, greenish and black cherty rocks, and thin limestone beds make up perhaps one-fifth of the group. A small gypsum deposit occurs on the east wall of M'Clintock Fiord. A conglomerate on the east shore of Disraeli Bay may be near the base of the M'Clintock group. This conglomerate contains pebbles of rocks, such as crystalline limestone and quartzite, that are found in the Cape Columbia group.

In thin section, greenish grey fine- to coarse-grained rocks are seen to consist of crystals and fragments of feldspar in a chlorite-epidote-feldspar matrix. Quartz fragments occur in negligible amount. These rocks may be called tuffaceous greywacke.

The rocks are well indurated, the more mafic-rich varieties being commonly chloritic and schistose. Epidote-quartz and carbonate mineralization have occurred along fractures.

The strata are closely folded; dips of 40 degrees to 60 degrees are typical, and nearly vertical bedding is not uncommon. Graded bedding is common and indicates the strata to be facing upwards.

The structures trend approximately east, the strike of the bedding varying from northeast to southeast. Bedding is generally apparent, but it has not been possible to interpret the internal structure of the group. The thickness is probably greater than 10,000 feet.

The M'Clintock group is considerably less metamorphosed than is the Cape Columbia group (1), and is overlain unconformably by Permo-Carboniferous limestone (7).

The M'Clintock group is considered to be older than Middle Ordovician for the following reasons: the degree of induration and the severity of folding of the M'Clintock rocks are at least as great as in the adjacent Challenger group (4) of Middle and Upper Ordovician age; pebbles of volcanic rocks similar to those of the M'Clintock group occur in a conglomerate of the Challenger group; and the Challenger group may overlie the M'Clintock group with angular unconformity on M'Clintock Fiord.

Middle and Upper Ordovician

Challenger Group

The Challenger sedimentary group (4) of Middle and Late Ordovician age, and possibly including rocks of earlier or later ages, occurs on upper M'Clintock Fiord, outcropping in the foothill mountains that flank the United States Range. The group is named after the man-hauled sledge, 'H.M. Sledge Challenger', and the crew that travelled with such heroic persistence along this northern coast in 1876.

The rocks of the Challenger group are dominantly grey limestone and reddish impure sandstone. Minor conglomerate and conglomeratic sandstone occur and, for several miles along the fiord, altered basic volcanic rocks form about 10 per cent of the strata. In many places the rock contains hematite, which, on weathering out, colours the hills and canyons brilliant red. Reddish limestone, red argillaceous mudstone, and red feldspathic sandstone form about 15 per cent of the formation.

Thin sections of an impure sandstone, a coarse hematite-sandstone, and the green-grey matrix from a conglomerate showed these rocks to be calcareous sandstones with a subgreywacke aspect. The rocks contain mainly angular quartz and chert grains. Plagioclase, perthite, and muscovite fragments are in minor amounts, and carbonate occurs both as clastic grains and as matrix with clay-minerals and hematite.

The sandstones appear to have formed at shallow depths (say, in the order of 100 to 400 feet) on an unstable shelf bordering a fairly mature terrain of metamorphic and plutonic rocks. The mineral particles are moderately sorted and but little abraided. Subsidence and accumulation apparently occurred fairly rapidly in contrast to an environment that would have produced, for example, quartz sandstones and limestone.

Because the structure and sequence have not been determined, the thickness of the Challenger group is not known. However, it is certainly more than 5,000 feet thick (the topographic relief of the region) and may be two or three times this thickness.

The strata have been moderately to tightly folded, with dips generally about 30 to 60 degrees. The fold axes generally trend easterly. A complex drag-fold or overthrust fold occurs at the fossil locality on the west wall of M'Clintock Fiord, which indicates overturned folding with an upriding thrust from the south.

The Challenger group probably overlies the M'Clintock group for a fossiliferous conglomerate of Upper Ordovician age on a headland on M'Clintock Bay contains pebbles of volcanic flow or tuffaceous rocks probably derived from the latter. Altered granitic pebbles are also present in the conglomerate, which suggests that the Challenger group is younger than at least some of the plutonites that intrude the Cape Columbia group. From the attitude of bedding seen at outcrops and from a distance, the Challenger group appears to overlie the M'Clintock group with great angular unconformity. At the contact between the Challenger group and the M'Clintock group on M'Clintock Fiord, however, the dip of limestone strata of the Challenger group changes from moderate to steep in approximate conformity to beds of the underlying M'Clintock group. A creek has cut a deep canyon along this contact, which may be a fault.

The Challenger group is more severely folded than Permo-Carboniferous limestone and sandstone. The contact between these groups has not been found.

Fossils collected from the Challenger group have been identified by G. Winston Sinclair of the Geological Survey of Canada as follows: From a headland east of Cape Richards:

Crinoid fragments
Anthozoa, genus indeterminate
Sowerbyella sp.
Liospira sp.
Illaenus sp.
Gonioceras sp.
Richardsonoceras sp.

These fossils are of Middle Ordovician age.

From the west wall of upper M'Clintock Fiord, the following have been provisionally determined:

Plasmopora lambei Schuchert
Columnaria n. sp. aff. *C. halysitoides* Troedsson
Paleofavosites sp.
Calapoecia canadensis Billings
Halysites sp. aff. *H. feildeni* Etheridge
Syringopora n. sp.
Batestoma n. sp.
Rhinidictya sp.
Cyclospira cf. *vokesi* Roy
Hormotoma gracilis (Hall)

Lophospira spp.
Umbospira sp.
Holopea sp.
Trilobite fragments
Leperditia sp.
Aparchites sp.
Welleria sp.
Rayella sp.
Conchoprimites sp.
Scolecodonts

The age of these fossils is Upper Ordovician.

From faunal evidence, the Challenger strata are comparable to the Gonioceras Bay limestone of Middle Ordovician age, and the upper part of the Cape Calhoun limestone of Upper Ordovician age, of northwest Greenland, as described by Koch, Troedsson, and Troelsen (Troelsen, 1950, p. 53). The Challenger group is only slightly dissimilar in lithology from the Gonioceras Bay and Cape Calhoun limestones, but contains and is associated with slightly more arenaceous beds than is the Ordovician limestone of Cape Calhoun. However, the arkoses and mudstones of M'Clintock Fiord may be strata of slightly different age from the fossiliferous rocks so far collected, and earlier or later periods may be present in this thick series of arenites and calcarenites.

Pre-Upper Carboniferous

Bourne Group

The Bourne group (5) is named for its occurrence on Cape Bourne, a prominent landmark on the northwesternmost coast of Ellesmere Island. The group outcrops between Cape Bourne and Lands Lokk, and consists of an unknown thickness of volcanic flows, minor interbedded sedimentary rocks, and associated intrusive rocks.

Although Peary (1907, p. 213) refers to volcanic-appearing rocks in the vicinity of Lands Lokk, he describes them as being "like pumice and slag", which the Bourne group rocks are not. Peary may have been describing the limestone of Lands Lokk, which weathers with a very porous, nodular surface not unlike slag. Per Schei (1904, p. 461) describes rocks on the islands at Lands Lokk as greenish and porphyritic, with phenocrysts of feldspar, olivine, and augite, and resembling somewhat the lavas that appear at Sorte Vaeg on Axel Heiberg Island. Schei refers to them as "probably intrusives".

Typical rocks are dark, green-grey, medium- and fine-grained andesites and diabases. The grain size and texture vary greatly, and as much as one-half of the rock may occur as diabasic dykes and sills, and as irregular gabbroic intrusive bodies. It is difficult to determine which rocks are extrusive and which are intrusive in origin. Because the intrusive rocks are so widespread, and so intimately mixed with the flow-rocks, it seems probable that all are nearly contemporaneous.

In thin section, extrusive and intrusive rocks alike are found to be slightly altered plagioclase-pyroxene and plagioclase-hornblende rocks of sub-ophitic texture.

The Bourne group also includes green-grey to black slate, tuff, and bedded phyllite, which may make up one-fifth of the formation.

Feldspathic vein-networks occur, and epidote is widespread.

Some obscure layering was observed which indicates a north to east trend of folding. Dips of 45 degrees and 55 degrees were recorded.

At Lands Lokk, a fossiliferous limestone tentatively referred to the Upper Carboniferous and included in the Permo-Carboniferous group (7) apparently overlies the steep-dipping Bourne group volcanic rocks, but the contact has not been observed directly. The relationships with other formations are not known. The Bourne group can therefore be dated only tentatively as late Carboniferous or older.

The volcanic-sedimentary nature of the Bourne group invites a comparison with the M'Clintock group (3). The two groups may be of the same age and origin, though the Bourne group contains relatively more crystalline igneous rock. It may be that Cape Bourne is closer to an ancient locus of volcanic activity than is M'Clintock Bay.

Imina Group

The name Imina group is applied to a series of sedimentary rocks of unknown thickness occurring between Phillips Bay and Cape Bourne. Imina was one of the Greenland Eskimos who accompanied the 1954 expedition as a dog driver, and the name used for the group in the absence of any suitable geographic name (6).

The Imina group (6) is a uniform series of subgreywacke, greywacke, and argillaceous greywacke beds. The rocks are blue-grey to black, fine to medium grained, and limy. Graded bedding occurs.

In thin section, a medium-grained subgreywacke contains about 50 per cent angular quartz fragments, 10 per cent altered feldspar fragments, some undetermined rock fragments, and 40 per cent carbonate-chlorite-sericite-clay mineral matrix. The carbonate apparently occurs both as a primary mineral and as a replacement mineral.

Mounds of graphitic debris containing a few plant impressions were found on ice a few miles northeast of Cape Bourne. The origin of the debris is not known, but it may have been pushed up from the sea bottom onto the ice by breaking and movement of the ice.

Although no carbonaceous rocks have been found in outcrop in the Imina group, the coaly debris is tentatively included in the group because of the close association and the comparable degrees of metamorphism.

The dust and the rock fragments of the coaly material were analyzed separately by W.J. Montgomery of the Mines Branch and the results are:

	"Fines"		Rock fragments	
	Capacity Moisture	Dry	Capacity Moisture	Dry
Proximate analysis				
Moisture ....%	6.7	0.0	8.0	0.0
Ash ....%	10.7	11.5	66.8	72.7
Volatile matter ....%	12.5	13.4	14.8	16.1
Fixed carbon % (by difference)	70.1	75.1	10.4	11.2
Ultimate analysis				
Sulphur ...%	0.5	0.5	0.4	0.4
Calorific value B.T.U./lb. gross	12,510	13,430	2,100	2,290

A.S.T.M. classification of the "fines", based on the dry fixed carbon: Medium volatile bituminous.

The Imina group is moderately to tightly folded, and a slaty cleavage has been developed. From the few attitudes that have been mapped, little of the interval structure can be determined.

An outlier or extension of the Permo-Carboniferous limestone (7) of Lands Lokk apparently overlies the Imina group. A fossiliferous conglomerate at the base of the limestone is tentatively referred to the Upper Carboniferous, and contains pebbles of green-grey volcanic and sedimentary rocks similar to Bourne and Imina group rocks.

No contact between the Imina (6) and Bourne (5) groups has been found. However, the Imina group subgreywacke rocks appear to have undergone less intrusion, induration, and metamorphism than the Bourne group volcanic-sedimentary rocks. The Imina group is, on this evidence, tentatively considered to be younger than the Bourne group.

The Imina and Bourne groups together are lithologically similar to the M'Clintock group (3) to the northeast, and may be equivalents of it.

Carboniferous and Permian

A group (7) of slightly folded, Permo-Carboniferous limestone and sandstone is widespread on northern Ellesmere Island. It was discovered by Feilden and De Rance (1878, p. 559) on Feilden Peninsula, and called "Carboniferous Limestone".

The Permo-Carboniferous group includes buff-weathering grey limestone, conglomerate, cherty limestone, and sandstone. The most conspicuous member is a thick sequence of buff-weathering grey limestone beds. These strata form notable cliffs on Markham Fiord, Cape Albert Edward, Ward Hunt Island, and on a fiord east of Cape Bourne. The limestone also underlies Lands Lokk, and occurs to the south of Lands Lokk, as described by Schei. Extensive, gentle-dipping, well-bedded strata at the head of Yelverton Fiord may belong to the Permo-Carboniferous group.

The basal beds of the group are exposed at Cape Nares, in a creek valley east of Cape Albert Edward, in creek canyons on 'Camp Creek', at Lands Lokk, and on a fiord east of Cape Bourne. The basal beds east of Cape Albert Edward consist of 50 feet of arkosic conglomerate containing a large proportion of pebbles and fragments of the Cape Columbia gneisses which occur below the unconformity, and about 100 feet of red-weathering arkose and arkosic conglomerate. At Cape Nares, the basal beds are a few tens of feet thick.

The basal beds east of Cape Albert Edward are similar to the Guide Hill group on Parry Peninsula and Guide Hill, about 40 miles to the east. The Guide Hill group is described by Blackadar (1954, p. 14) as "chocolate-red sandstone and conglomerate, brick-red sandstone, black and purple shale, and grey limestone. The conglomerate carries fragments of quartz, jasper, limestone, quartzite, red and black shale, and granitic rocks". From the distribution of these rocks shown on the map (Blackadar, 1954), and from the lithology, it may be suggested that the group represents the basal beds of the Permo-Carboniferous rocks.

Overlying the basal detrital beds is a great thickness of thick-bedded, buff-weathering, fossiliferous grey limestone. The thickness of such rocks exposed in the valley east of Cape Albert Edward, where the strata and the surface of unconformity with the Cape Columbia gneisses (1) are tilted at angles of 60 to 90 degrees, is at least 2,500 feet. The limestone is characterized by the presence of irregular chert nodules and 'tubers' about 1 inch to 4 inches thick.

Fossils collected from the talus of Permo-Carboniferous limestone beds on Ward Hunt Island were identified by P. Harker of the Geological Survey of Canada as follows:

Echinoconchus sp. cf. E. punctatus (Martin)
Echinoconchus sp. cf. E. longispinus (Sowerby)
Productus irginae Stuckenberg (sensu lato)
Productus sp. possibly P. orientalis Tschern.
Productus cora-planus Milorad
'Productus cora' large flat form cf. Tschern 1902 Pl. LIV fig. 5.
Productus uralicus Tschern.
Martinia sp. cf. M. subradiata McCoy
Spiriferina cristata? Schloth.
Choristites fritschi Schellwien
Spiriferella saranae arctica (Haughton)
Euomphalus sp.
Dictyoclostus sp. ex gp. semireticulatus
Chaetetes sp.
Fenestellid Bryozoa
'Cyathophyllum' sp.
Syringopora sp.
Colonial corals.

This collection contains fossils of both Upper Carboniferous and Lower Permian age.

Cape Nares:

Streptorhynchus ? sp. small form

Productus lineatus ? Waagen
Dictyoclostus sp. ex gp. semireticulatus
Aulopora sp.
Solitary coral fragments.

Lands Lokk:

Dictyoclostus sp. ex gp. semireticulatus

East of Cape Bourne:

Linoproductus sp. cf. L. cora planus ?
Spirifer ? small species.

The above three collections are tentatively dated as Upper Carboniferous in age.

Syringopora sp.
Rugose coral fragments
'Cyathophyllum' sp. large species.
Eumphalus sp.

This collection is late Palaeozoic in age.

A uniform sequence of grey, green, and red sandstone beds at least 2,000 feet thick occurs in the mountains at the head of M'Clintock Fiord. At the base, an arkosic conglomerate rests unconformably on calcareous and quartzose mica schists, and contains pebbles of quartz, mica schist, and quartzite. The arenaceous strata are very well indurated and most of the rock is quartzite with shale partings. A few poorly preserved plant impressions are present.

In thin section the arenaceous rocks are found to consist of angular to subangular fragments of quartz and chert. The matrix is authigenic quartz and chert. Red impure sandstone contains abundant hematite. The quartzitic nature of the sandstones is due to the tough cement of chert.

The stratigraphic relation of the sandstone beds to the fossiliferous limestone beds is not known. It may be noted that a very great thickness of well-bedded, moderately folded sedimentary rock occurs in the mountains at the head of M'Clintock Fiord and a complete sequence of the Permo-Carboniferous group may eventually be found there.

Associated with the thick buff-weathering limestone beds on Markham Fiord are chert, limy shale, and limestone strata containing the following fossils:

Linoproductus sp. cf. *L. svalbardensis* Frebold.
Michelinia sp.
Large rugose coral

Neospirifer cameratus ? Morton
Linoproductus svalbardensis Frebold
Spirifer indet.

of Lower Permian age. The thickness and structure of these beds is not known.

The Permo-Carboniferous group is widespread, and overlies, with great angular unconformity, rocks of all previously described units. The unconformity is well exposed at Cape Nares, in the valley east of Cape Albert Edward, and at the head of M'Clintock Fiord; in these localities, the basement rocks are the Cape Columbia group gneisses and schist. The Permo-Carboniferous group overlies the Cape Columbia group on Ward Hunt Island, although the unconformity there is hidden by debris. It seems probable that a submarine channel west of Ward Hunt Island (found in 1954 by geophysical means) is a topographic expression of the surface of unconformity below the limestone, which dips north and strikes west through Cape Nares and Ward Hunt Island.

Inland a few miles and west of Disraeli Fiord, an outlier of moderately dipping Permo-Carboniferous limestone rests upon steeply dipping volcanic-sedimentary rocks of the M'Clintock group (3).

An outlier or extension of gentle-dipping Permo-Carboniferous limestone overlies moderately dipping subgreywacke of the Imina group (6) east of Cape Bourne. At Lands Lokk, Permo-Carboniferous limestone appears to dip gently to the south, overlying steep-dipping Bourne volcanic group (5). The Permo-Carboniferous strata are generally gently to moderately folded, though some very steep dips occur, as east of Cape Albert Edward where the basal strata are vertical. Also, some complex overfolds of drag-folds are evident east of Cape Bourne and at the head of M'Clintock Fiord. Dips of 30 to 45 degrees are typical everywhere.

Faunal evidence indicates that the Permo-Carboniferous group includes strata of both Upper Carboniferous and Lower Permian age group and it is consequently equivalent to the Lower Marine series and Upper Marine series of northeast Greenland. The buff-weathering limestone and the sandstone beds with plant remains are lithologically similar to the Lower Marine series of northeast Greenland as described by Grønwall.

There is a marked similarity in lithology and structure between some of the Permo-Carboniferous rocks described in this report and the Feilden limestone described by Blackadar (1954, p. 15). Fossils from the Feilden group have been identified as Permian (since the publication of Blackadar's report); thus the Feilden group may be restricted to the Permian, and only a general correlation with the Permo-Carboniferous rocks to the west can be made.

The Permo-Carboniferous formation is a shelf-type deposit. The thick limestone beds, the rounding of the quartz and chert grains, and the early-formed silica cement in the sandstones indicate relatively stable conditions and a moderate rate of accumulation compared, say, to the conditions that would produce a thick sequence of greywacke.

Mesozoic or Cenozoic

Young Volcanic Rock

A single occurrence of soft basalt conglomerate (8) was found on the east shore of Yelverton Bay. This rock consists of dark blue-grey rounded and subangular pebbles of equigranular and porphyritic volcanic rock in a soft, greenish black, amygdular basalt matrix. Little layered structure is evident, but there is some indication that stratification could be horizontal. The rock has a fresh appearance and is tentatively dated as Mesozoic or Cenozoic age.

Eureka Sound Group?

Poorly consolidated sediments (9) of apparently only a few miles extent occur on the east side of Alert Point. The deposits include mudstone, sandstone, and shale; conglomerate; and concretionary, limy mudstone. The conglomerate contains rounded and subangular boulders up to 8 inches in diameter of marble, quartzite, schist, granite gneiss, medium-grained gabbroic intrusive rocks, and fine-grained volcanic or dyke-rocks. The matrix is a fresh-appearing arkose.

Fragments of dark grey petrified wood and carbonaceous plant remains were collected from creek debris from the formation, but no precise stratigraphic information could be obtained from them.

The deposits, where examined, are well-stratified and the strata are extremely contorted into irregular, overthrust, crumpled folds about 50 feet across. In the airphotos however, flat-lying bedding is evident and the contorted structure may be of local extent.

Contacts with other formations have not been discovered. However, the weak lithification of the muds and sands and the fresh appearance of the coarser detritus suggest a youthful age for the deposits. The extreme contortion of the bedding is unusual in young formations, but in this case may be due to slumping or to pressures from active glacial ice.

The formation is similar to lignite and plant-bearing sandstones and shales occurring locally in many places on Ellesmere, Axel Heiberg, and Amund Ringnes Islands, and named "Eureka Sound group" by Troelsen (1950, p. 78). Various coaliferous deposits have been described and assigned to ages including Eocene and Miocene. The age is most commonly assumed to be Cenozoic. Troelsen concluded, from the examination of calcified wood, that the Eureka Sound group may be of either Cretaceous or Cenozoic age.

The nearest deposits similar to those on Alert Point are on the north shore of Greely fiord, and in the region north of Conybeare Fiord. These deposits have been referred to the Miocene by Schei (1904, p. 461), and to either Cretaceous or Cenozoic by Troelsen. Coal-bearing sand, silt, and boulder beds about 40 miles southwest of Alert contain plant remains that are suggested to be not older than Miocene age (Blackadar, 1954, p. 19).

Intrusive Rocks

Intrusive rocks on northern Ellesmere Island are divided, for purposes of description, into three classes:

1. Older (?) plutonic rocks, now metamorphosed to gneisses. (B)
2. Massive plutonic rocks. (A)
3. Dyke-rocks. (Not shown on the map)

These rocks probably range greatly in age, and the age of none is known definitely.

The older plutonic rocks consist of gneissic brown syenite (Bb) on Ward Hunt Island and gneissic granite (Ba) on Cape Bicknor. In thin section, both plutonites are found to be microcline-rich rocks. The Ward Hunt syenite possesses a crush-texture. The Cape Bicknor granite appears to be a recrystallized rock.

The foliated intrusive rocks (B) are of Palaeozoic or Precambrian age. They have suffered tectonic alteration together with the sedimentary rocks of the Cape Columbia group (1), which they appear to intrude.

Massive plutonic rocks (A) occur on the east shore at the mouth of Phillips Fiord (7) and on Cape Richards. These intrusive rocks appear to be stocks in the order of 10 miles across.

The plutonite of Phillips Fiord (Aa) is very fresh-appearing light grey granite (adamellite of Johannsen's classification), varying from equigranular to porphyritic in texture. The granite intrudes the oldest rocks of the region; so beyond that its age is not known but its fresh appearance suggests a relatively youthful age - probably late Palaeozoic or later.

The plutonite of Cape Richards is a complex association of grey granite (monzogranite of Johannsen), and dark grey norite and brown-weathering peridotite (Ab). The norite grades into peridotite, and the peridotite into magnetite-dunite. Float of serpentinized magnetite-olivine rock was found. The granite (Aa), variations of which are aplite, cuts the peridotitic rocks. On the northern part of Cape Richards, foliated granite occurs, the relationship of which to the other intrusive rocks is not known.

The Cape Richards intrusive rocks cut steep-dipping quartzites of the Cape Columbia group.

Dykes and sills, and other relatively small intrusive bodies, occur in fair abundance along the coast between Cape Columbia and Lands Lokk. They were found to cut all formations except the muds and sandstones on Alert Point, although further search may reveal the presence even there of intrusions. Several ages of igneous activity are represented.

The oldest of the dyke-rocks may be represented by some of those found cutting the Cape Columbia group. On Cape Evans, schistose, gabbroic sills lie parallel to the gneissosity in the granite gneiss. Most of the intrusive bodies in the Cape Columbia terrain are however of fresh, andesitic or diabasic rock.

Sills and dykes occur in the M'Clintock (3) and Bourne (5) volcanic-sedimentary formations. The amount of intrusive rock in these formations is difficult to assess because much of it is of a grain size and texture similar to that of the extrusive, country rock. The intrusive bodies are variously andesitic, dacitic, diabasic, or gabbroic rocks. Both volcanic groups contain some larger dykes, one or two hundred feet across, of coarse-grained gabbro and pyroxene gabbro. The Bourne group contains a particularly high proportion of intrusive rock, much of which is pyroxene gabbro that varies considerably in texture and composition. Between Cape Bourne and Cape Colgate, the group is a complex of flow-rocks, hybrid gabbroic to granodioritic intrusive rocks, and feldspathic dykes and veins. Younger, fine-grained volcanic sills and dykes occur also.

The abundant, thin but extensive, fresh-appearing sills and dykes that cut all the rocks except the Alert Point muds and sandstones are probably the youngest intrusive rocks of the region. The composition and texture vary considerably to include felsite, andesite, dacite, diorite, diabase, and gabbro. Some of the intrusive rocks are feldspar porphyries. The dykes follow various trends and no favoured direction was observed.

Pleistocene, including Recent Time

Unconsolidated deposits mantle the valleys and hills of the northern coast except where slopes are very steep. The superficial deposits vary in thickness and nature; in places, particularly in the valleys, the debris is clayey, and contains rounded glacial erratics. Generally, however, frost action has disintegrated the underlying bedrock and has admixed angular debris soil into the glacial debris. Where slopes are moderate or steep, solifluction has removed all the older deposits and the surface debris is entirely frost-heaved bedrock. Talus slopes are numerous, as is characteristic of mountainous regions. Small 'rock glaciers' occur, and much evidence of 'rock glacier' action, or solifluction in talus, exists along the coast-line.

The abundance and wide distribution of glacial debris indicate that glaciation formerly has been much more advanced. In the coastal hills, rounded transported debris and glacial grooving have been found at elevations of about 2,500 feet.

Outcrops on the valley bottoms and sides are striated parallel to the valley so that it is evident that ice streams followed the present drainage system. Other glacial features are rock 'thresholds', one of which causes a waterfall at the mouth of 'Camp Creek' valley, and the hanging nature of many of the small- and medium-sized valleys. The discordance between the floors of tributary and trunk valleys is especially notable along the fiords, which are greatly overdeepened. Disraeli Fiord is deeper than 1,000 feet (the length of the sounding line used in 1954) southwest of the larger island, and the tributary valleys enter about 200 feet above sea-level, so that the discordance there is at least 1,200 feet. Discordances of 300 or 400 feet exist on land, but mostly have been obscured by normal stream erosion at the mouths of the tributary valleys.

The major valleys contain benches of fluvioglacial sand and gravel, into which streams are cutting canyons. The fluvial deposits are particularly conspicuous near sea-level, where the debris has been built up into delta-like banks and benches. On the mainland opposite Ward Hunt Island, gravel benches lie at elevations of 300, 250, and 200 feet. Three miles inland on 'Camp Creek', gravel benches are about 260 feet above sea-level. At 'Terrace Bay' mid-way up M'Clintock Fiord on the west shore, extensive, striking terraces lie at various elevations; the highest is in the order of 500 feet.

Glacier ice (10), at present covers about half the land area of northern Ellesmere Island. The ice exists, for the greater part, as a great ice-dome and snowfield on the United States Range of mountains. The snowfields lie between elevations 3,000 and 8,000 feet, generally, but rise as high as 9,500 feet. The ice of the snowfields flows as great valley glaciers into the fiords to the north and south of the range. Some fiords, such as Yelverton Fiord are filled at their head with floating glacier ice.

The glaciers of this region are characterized by several phenomena generally not found in more southerly latitudes. Subglacial drainage tunnels do not exist; instead, melt-water drains from the ice in surface channels. The lower termini of the glaciers, on land, are generally vertical or overhanging cliffs. Dirty bands near the base cause increased ablation in some, and calving of vertical columns occurs in some others.

Relatively small ice-caps exist on the mountains and hills flanking the United States Range, and particularly on the peninsulas or capes that project into the polar sea. Ice deposits of such small size and limited nourishment that they apparently do not flow, occur in very large numbers. These small ice deposits or 'drift glaciers' occur in various shapes and sizes down to mere patches of ice two or three hundred feet across and 50 feet thick. The 'drift glaciers' overlie the normal glacial, fluvioglacial, rock-disintegration debris, and beach-deposits, and the ice contains only wind-blown material. It appears that these ice deposits have grown in place since the last major retreat of glaciation.

The snowfields, alpine glaciers, not broken by ice-falls and much crevassing, and the 'drift glaciers' contain uniform banding a few millimetres broad. The 'drift glaciers', in most cases, are banded horizontally, or nearly so. The banding in the alpine glaciers or ice-streams is generally contorted, but is no more conspicuously developed in the ice-streams than in apparently immobile ice deposits. The banding is uniformly developed in all parts of the ice-stream, and is persistant as continuous bands over great distances. The laminae are apparently depositional layers.

The present surfaces of the non-mobile ice patches are not conformable to the banding or layering in the ice. It is evident, therefore, that the ice is not accumulating at present.

On the west wall of M'Clintock Fiord, the snout of a small, active glacier lies about 100 feet from, and higher than, raised beach-deposits 230 feet or more above sea-level. Undisturbed bivalve shells lie near the surface in the beach debris, which is wave-reworked glacial till. If the glacier advanced more than 100 feet from its present position the beach would be destroyed. It is apparent that this glacier is now at a position of advance which has not been much exceeded since the formation of the beach - perhaps for thousands of years.

It may be suggested that the region has, in recent hundreds of years, experienced an increase in glacial activity but that ice is not at present accumulating and that the glaciers are nearly at their most recent position of maximum advance, or will advance little farther.

The present ice-free land surface has been exposed for a considerable time since the last major retreat of glacial ice. For the purpose of discussing superficial phenomena in this restricted region, this time may be referred to as 'post-glacial', though glacial activity may still be either increasing or decreasing.

Since the last major retreat of glacier ice, the land has been exposed to weathering and frost action, and the shores to wave action. Streams have been eroding channels in the gravels and bedrock in the existing valleys since the valleys were uncovered by ice. The streams, redepositing fluvioglacial debris, have maintained broad floodplains below glaciers and built small deltas at the mouths of creeks. Talus slopes have been and are still active. Frost contraction cracks have developed in poorly drained, gently or moderately sloping ground (up to about 20 degree slope) to form large, irregular polygons in the order of 100 feet across. Many frost crack systems appear to be very old, as though they are relicts of conditions more favourable to the formation of cracks than is the present climate. Ground patterns of a smaller scale are abundant. Weakly to moderately distinct stone polygons and stripes, both sorted and non-sorted, are common on slopes up to 10 degrees, and occur occasionally on slopes of 15 degrees. Solifluction terraces or benches have developed on the steeper slopes.

Thawing in the ground was found, in 1954, to proceed to depths of 12 to 16 inches on the level, and to depths of 20 or 30 inches on slopes in which drainage was effective. Ground frost was found to lie almost at the surface in talus slopes, particularly in those facing north.

Well developed, raised, wave-constructed beaches lie at various elevations on shore slopes and in creek valleys. Locally distinct beach-terraces lie at elevations 10, 20, 30, 50, 60, and 70 feet, and many others are present but less distinct or extensive. Very well developed beach-terraces lie at elevations about 120 and 150 feet. Less distinct beach levels are at 170 feet and about 200 feet. The highest shell deposits were found 230 feet above sea-level. The tops of delta-type deposits at the mouths of creeks occur at about 250, 280, and at about 500 or 600 feet elevation.

Shell collections from the beach deposits and from debris on ice in 'shoal water' near Cape Bourne were examined by Frances J.E. Wagner, Geological Survey of Canada, who identified the following species:

Foraminifera

- _Cassidulina laevigata_ d'Orbigny
- _Cassidulina norcrossi_ Cushman
- ?_Cassidulina_ sp.
- _Quinqueloculina_ sp. cf. _Q. seminula_ (Linné)
- _Lagena sulcata_ (Walker and Jacob)
- _Globulina glacialis_ Cushman and Ozawa
- _Astrononion stelligerum_ (d'Orbigny)
- _Elphidium frigidum_ Cushman
- ?_Fissurina laevigata_ Reuss
- _Lamarckina haliotidea_ (Heron-Allen and Earland)
- _Eponides frigidus_ Cushman
- ?_Eponides_ sp.

Pelecyoda

- _Nuculana tenuisulcata_ Couthouy
- _Astarte borealis_ Schumacher
- _Astarte banksii_ Leach
- _Astarte_ sp.
- _Astarte_ sp. cf. _A. fabula_ Reeve
- _Astarte whiteavesii_ Dall
- _Hiatella arctica_ (Linné)
- _Bathyarca glacialis_ (Gray)
- _Mya truncata_ var. _uddevalensis_ Forbes
- _Pseudamussium_ sp. cf. _P. andersoni_ Dall
- _Limatula subauriculata_ Montagu
- _Yoldia arctica_ (Gray)

Gastropoda

- _Scissurella_ sp. cf. _S. crispata_ Fleming

Acmaea sp.
cf. Gyraulus arcticus (Beck) Möller; freshwater

Annelida

?*Serpula* sp.

Ostracoda

1 unidentified species

Raised beaches have been reported from many parts of Ellesmere and adjacent islands (as summarized by Troelsen, 1950, p. 15), but it does not seem possible, at present, to correlate them. The elevations on northern Ellesmere Island are of the same order as those found elsewhere.

The beaches have formed since the last major ice retreat as undisturbed shells have been found a few hundred feet from the snout of a small glacier. Shells collected below elevation 230 feet were examined by Dr. Wagner, who remarks: "The species are all ones that are known to be living in the Arctic at present, and although a number of them have been recorded also from Pleistocene deposits, many of them are apparently known only in Recent seas. The mode of occurrence of the assemblage also suggests that these shells post-date the last Pleistocene ice retreat in the area."

An age of about 7,200 years[1] has been obtained from carbon-14 data for shells from a beach 125 feet above sea-level on Ward Hunt Island.

Very thick, floating, tabular deposits of ice, or 'shelf' ice, are characteristic of the northern coast of Ellesmere Island. Shelf ice occurs as a partial cover in the fiords, as discontinuous fenders and patches along the coast, and as slowly drifting islands along the 240 miles of coast between Cape Colan and Cape Bourne. The widest shelf is at Ward Hunt Island, where shelf ice extends about 12 miles from the mainland. The deposit is about 160 feet thick, though thinner near the outer edges.

Shelf ice is characterized by its great thickness, and by a striking, wave-like ridge and trough topography. The ridges are about 500 to 800 feet from crest to crest, with a relief of from

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[1]Age determination by J. Lawrence Kulp from the U.S. Air Force Cambridge Research Center, obtained from A.P. Crary by personal communication.

3 to 24 feet above the trough bottoms. The average wavelength is 760 feet; the average relief 7 feet. The ridges and troughs appear remarkably uniform and a single ridge may be followed for miles. The troughs are occupied by long lakes and streams during the melt season.

Debris of various types is found on the shelf ice. Much is apparently windblown, it being very fine, uniform in size, and more abundant near land. Some debris is angular rock fragments, which may have been swept onto the ice by streams from shore. Some, near fiord walls, includes very coarse boulders of local rock, and appears to be talus. However, the origin of some angular, coarse debris that lies a great distance from land is not readily explained and opinions on the origin differ.

Organic debris in some abundance occurs on the shelf ice east of Ward Hunt Island. Sponges, marine shells, mud, and fine angular rock debris are found on the ice surface. Sponge collections, obtained as far as 3 miles east of the island, have been studied by M. W. deLaubenfels of Oregon State College, Corvallis, Oregon, who states that they compare most closely with "*Geodia spherastrella* Topsent .... This genus is common from low tide down to several hundred fathoms, in all oceans, from Arctic to Antarctic, including the warmest tropical seas". Dr. deLaubenfels further describes the genus as having great tolerance for crowded habitats, or conditions where there is a cover of inanimate debris. The origin and history of this debris is not clear. The fauna appear to have grown almost in place and there may have existed in the lee of Ward Hunt Island a great supra-ice pond, with a mud-covered bottom supporting animal and plant growth. An age of 4,000 years[1] has been determined for the sponge material using carbon-14 data.

The thick ice-sheets appear to be remnant patches of a formerly continuous, more extensive sheet of shelf ice. The history of the deposit appears to be complex, and the origin is not fully agreed upon. It appears to be at least in part a sedimentary deposit of ice derived from snow, and may be a relatively recent phenomenon. It probably post-dates the formation of the raised, wave-built beaches and the greater part of the period of rise in land level.

It seems very probable that the ice islands (such as described by Rodahl, 1954) in the polar sea are derived from the

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[1] Age determination by J. Lawrence Kulp from the U.S. Air Force Cambridge Research Center, obtained from A. P. Crary by personal communication.

north coast of Ellesmere Island. The islands are similar in appearance, thickness, and structure, and the superficial rock debris on T-3 ice island appears to be similar to gneisses found in Yelverton Bay and vicinity.

There are several indications that the region has had a considerably more temperate climate in recent geological times. The marine fauna in raised beach-deposits includes Limatula subauriculata Montagu, a form occurring in north Greenland and described by Laursen (1954, p. 22) as being not a high arctic form, indicating a rise in temperature "..........during post-Glacial time". Several fragments of driftwood from trees of large diameter were found at sea-level near 'Camp Creek', opposite Ward Hunt Island. These occurrences indicate an open polar sea and an absence of any barrier of ice along the coast during some period since the last major retreat of glacial ice. Age determinations using carbon-14 yield ages of about 3,000 to 6,000 years. Unless driftwood is found at greater elevations, and assuming the land is still rising, it may be suggested that the present barrier of shelf ice is a relatively recent phenomenon. It is certain that northern Ellesmere Island has undergone a post-glacial temperature maximum and a later minimum. At present, the minimum temperature period may be past, but relatively active glaciation still persists.

STRUCTURAL GEOLOGY

The structures on the north coast of Ellesmere Island have undoubtedly developed during several periods of orogeny. All formations are more or less folded, and there were probably at least three periods of igneous intrusion. The trend of folding varies considerably from rock unit to rock unit, and often varies within the unit.

Strata of the Cape Columbia group, M'Clintock group, Challenger group, Bourne group, and Imina group are moderately to tightly folded. The limestones and sandstones of the Permo-Carboniferous group lie in open folds on a very extensive eroded surface of the older, more folded formations. Faulting has probably occurred on a major scale.

The Cape Columbia strata generally dip steeply and vary widely in trend, and the group is isoclinally folded and distorted into a very complex structure.

The dips of the strata in the Bourne and Imina groups are moderate, but general trends are not evident.

The Challenger group of Ordovician age is moderately to tightly folded into east-trending structures.

The Permo-Carboniferous strata are flat-lying to gently folded. A very great thickness of this Permo-Carboniferous strata may occur at the heads of M'Clintock and Yelverton Fiords, and may form the greater part of the rugged United States Range. The group lies on an eroded surface that truncates all the other groups. This unconformity is of great extent; it is exposed at intervals from Feilden Peninsula to Lands Lokk, a distance of about 270 miles. The unconformity represents a long and wide-spread period of uplift and erosion that followed a period of orogeny in which pre-Carboniferous deposits were deformed.

The ages of the orogenies on Ellesmere Island have long been disagreed upon. Suggested ages have included Silurian, pre-Pennsylvanian, late Pennsylvanian or later, and Late Mesozoic. It is certain that more than one period of orogeny has occurred.

On CanyonFiord, in west-central Ellesmere Island, Troelsen (1952) found evidence of gently folded Middle Carboniferous sandstone and limestone unconformably overlying intensely folded late Silurian strata, indicating a latest Silurian or early Carboniferous age for the major orogeny. On Feilden Peninsula in northern Ellesmere Island, Blackadar (1954, p. 22) found that a formation of "Late Carboniferous or Early Permian (limestone) is closely folded, whereas the Feilden group, also of Late Carboniferous or Early Permian age,* has been only gently folded ...." indicating a latest Carboniferous or earliest Permian folding. Also, folding is suspected in pre-Middle Silurian times.

West of Cape Aldrich, on the northern coast of Ellesmere Island, the gentle folding of the Permo-Carboniferous limestone and sandstone group contrasts with the relatively tight folding of the Middle and Upper Ordovician Challenger limestone and sandstone group. Also, the relatively unmetamorphosed sedimentary and volcanic formations, including the Challenger group, contrast with the metamorphic rocks of Cape Columbia group. From this data, three major stages of orogeny may be proposed; pre-Middle Ordovician, in which the Cape Columbia group was folded and metamorphosed; post-Upper Ordovician - pre-Upper Carboniferous, in which the Mount Disraeli, M'Clintock, Challenger, Bourne, and Imina groups were folded and slightly metamorphosed; and post-Lower Permian, in which the Permo-Carboniferous group was gently folded.

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*Since the publication of Blackadar's report the fossils in both formations have been determined to be Permian in age.

Little direct evidence of faulting on a large scale and no data on the ages of faulting were found. However, from a study of the topography, drainage, and geology, it is almost certain that a considerable amount of faulting has occurred. Topographic features due probably to faulting are evident in the airphotos, and faulting is suspected on the west shore of Disraeli Fiord and is evident in the dragging of bedding in the M'Clintock Bay group on M'Clintock Fiord.

The fiords and trunk glacial valleys present a jointed pattern which suggests that erosion has followed major lines of weakness, such as would mark widespread faulting. Some valleys follow the trend of the bedrock formations, but this is not general west of Cape Aldrich. The following generalizations can be made: 1. A roughly convergent pattern of fractures may exist normal to the huge arc of the coast-line. Tangential trends are not apparent. 2. A pattern of fractures lying at about 60 degrees in either direction from the radial pattern may be present. 3. In north-eastern Ellesmere Island, a strong northeast trend of topography parallels the trend of folding in the bedrock formations.

A major orogenic belt along the northern coast of Ellesmere Island is indicated by the existence of plutonic intrusions of several ages and including ultrabasic rocks, by the extent of old metamorphosed rocks, and by several ages of folding. The axis of the belt, from a study of the present distribution of land, the geological information, and the trend of possible fractures, appears to be a great arc approximately following the coast-line. The orogenic belt, which is more or less coincident with the inferred old borderland, 'Pearya', has been named the Northern Ellesmere Fold Belt, and is part of the Innuitian Orogenic System (Fortier, McNair, Thorsteinsson, 1954, p. 2087), which includes also the Eureka Sound and the Ellesmere-Greenland Fold Belts to the southeast.

Fortier, McNair, and Thorsteinsson tentatively suggested that the Northern Ellesmere Fold Belt is the eugeo-syncline, and the Ellesmere-Greenland Fold Belt is the miogeo-syncline of an early orogenic system, and that the Eureka Sound Fold Belt is a later, superimposed geosyncline. The information obtained during the 1954 expedition on the northern coast supports the hypothesis. Along the coastal zone eugeosyncline-type deposits of Precambrian or Palaeozoic age, including greywacke and volcanic flows, have been intruded by granite, gabbro, and peridotite. Miogeosyncline-type deposits of early Palaeozoic age occur in the Ellesmere-Greenland Fold Belt to the southeast (as described by many explorers, and summarized by Fortier, McNair, and Thorsteinsson, 1954, p. 2093). The shelf-type sedimentary rocks, including limestone and cherty sandstone of the Permo-Carboniferous group belong to the Eureka Sound geosyncline of late Palaeozoic and Mesozoic age.

The historical geology may be summarized as follows. Sedimentary deposition took place in Precambrian time, followed by at least one major orogeny by earliest Palaeozoic time to form the Cape Columbia group; eugeosynclinal deposits formed in a northern Ellesmere Island geosyncline during early Palaeozoic time, and were tightly folded by a Caledonian orogeny; Permo-Carboniferous limestones and sandstones were deposited on an extensive 'stable shelf' in the region of the United States Range, and have been gently folded by a Mesozoic or later orogeny; Cretaceous or Cenozoic (probably Cenozoic) terrestrial sediments have been deposited on an erosion surface developed during early Cenozoic time; the land is at present undergoing widespread erosion and elevation, both in a large part connected with the Pleistocene glacial epoch; glaciation is still active.

MINERAL DEPOSITS

One fragment of malachite-coated rock was found on the mountain east of the pass between 'Camp Creek' and 'Ben Creek'.

A deposit of gypsum of apparently limited extent occurs on the east shore of M'Clintock Fiord, about 12 miles from the mouth. The gypsum may be a lens-shaped bed that pinches out against a coarse limestone conglomerate. The deposit is about 400 feet thick and extends about 1,000 feet along the steep hillside. Extensions of the bed occur a few thousand feet away along the fiord wall, but these are small, and faulting or folding has distorted the structure. The rocks adjacent to the gypsum deposit are fine-grained andesitic volcanic flows and breccias of the M'Clintock group, some of which are altered to chlorite-rocks.

Float of banded, serpentinized magnetite-olivine rock occurs along the beach in the vicinity of Aldrich's cairn on Cape Richards. This rock is undoubtedly related to the peridotite bedrock found nearby. A polished surface of the magnetite-rock indicates that about 10 per cent of the rock is magnetite as individual crystals, thin streaks of disseminated grains, and veins. Magnetite bands as thick as 4 mm. occur.

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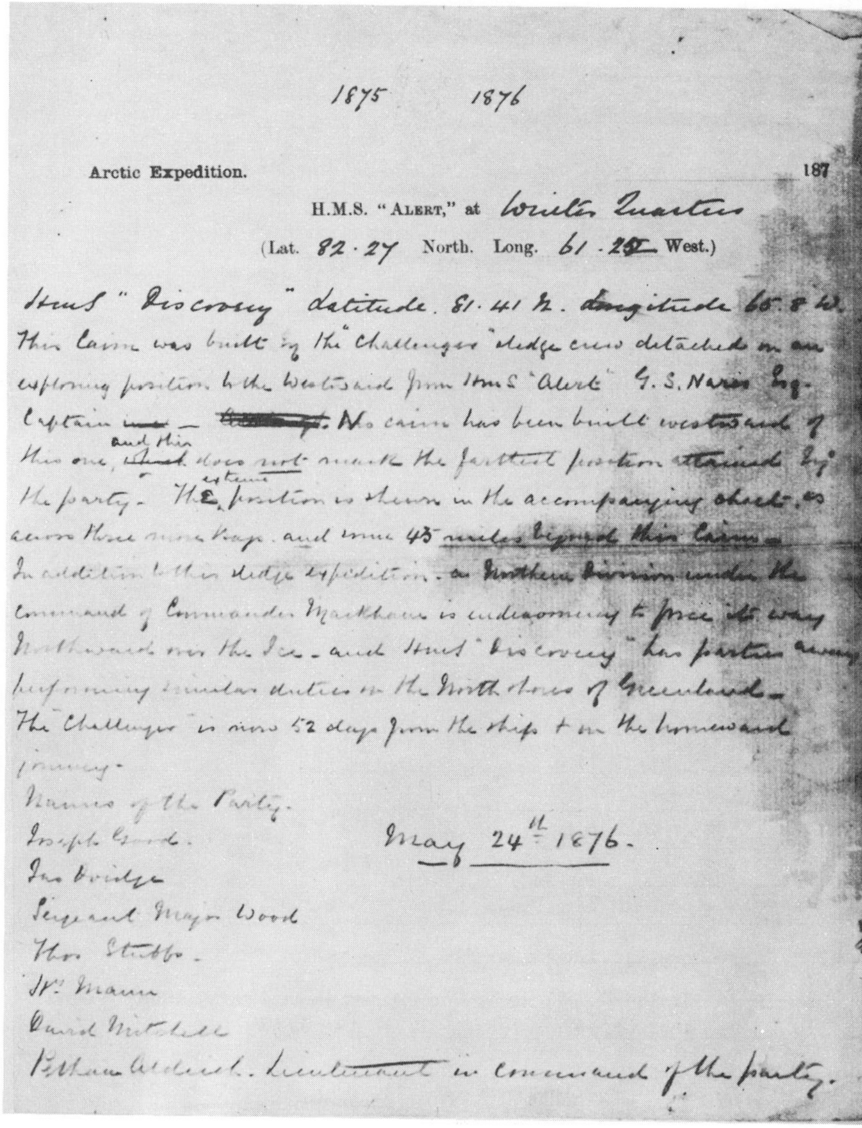


1875 1876

Arctic Expedition. 187

H.M.S. "ALERT," at Winter Quarters

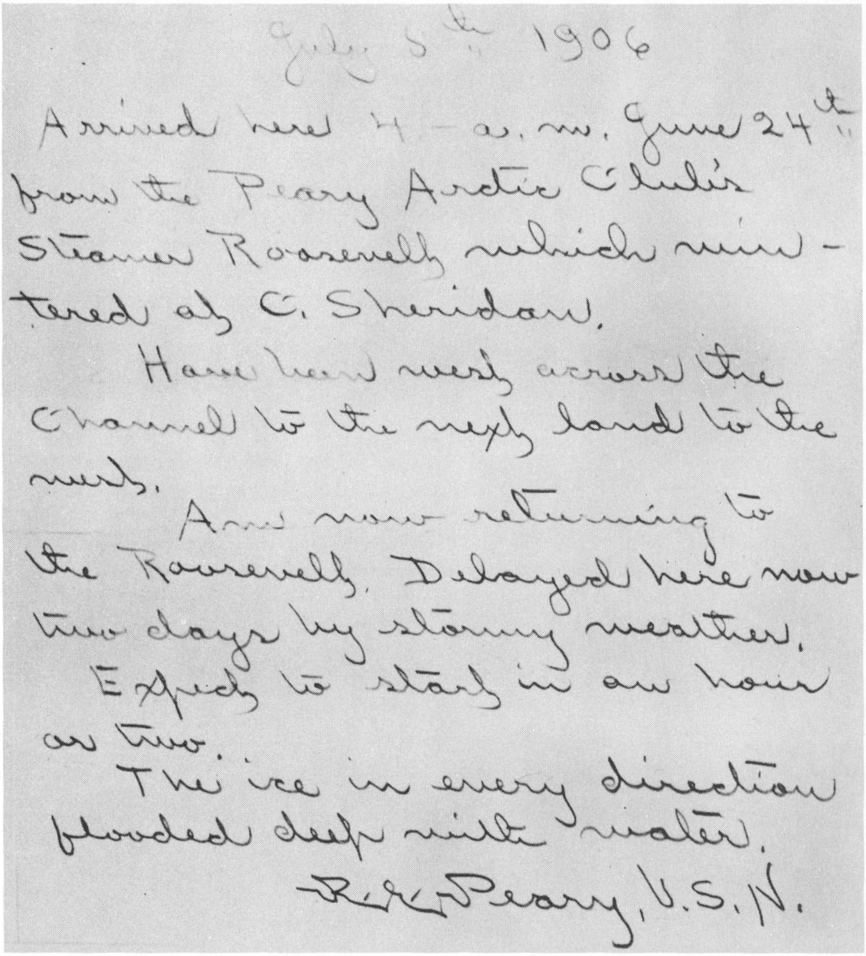
(Lat. 82·27 North. Long. 61·~~25~~ West.)

HMS "Discovery" Latitude 81·41 N. Longitude 65·8 W.
This Cairn was built by the "Challenger" sledge crew detached on an exploring position to the Westward from HMS "Alert" G. S. Nares Esq. Captain ~~[illegible]~~ – ~~[illegible]~~. No cairn has been built westward of this one, ~~which~~ and this does not mark the farthest position attained by the party – The extreme position is shewn in the accompanying sheet, as across three more bays. and some 45 miles beyond this Cairn –
In addition to this sledge expedition. a Northern Division under the command of Commander Markham is endeavouring to force its way Northward over the Ice – and HMS "Discovery" has parties away performing similar duties on the North shore of Greenland –
The "Challenger" is now 52 days from the ships & on the homeward journey.

Names of the Party.
Joseph Good.
Jas Doidge
Sergeant Major Wood
Thos Stubbs.
Wm Mann
David Mitchell
Pelham Aldrich. Lieutenant in Command of the party.

May 24th 1876.

Plate I. Facsimile of note by Lieutenant Pelham Aldrick, 1876. Found at Cape Fanshawe Martin (82° 52' N, 81° 48' W).



July 5th 1906

Arrived here 4 – a.m. June 24th
from the Peary Arctic Club's
Steamer Roosevelt which win-
tered at C. Sheridan.

Have been west across the
Channel to the next land to the
west.

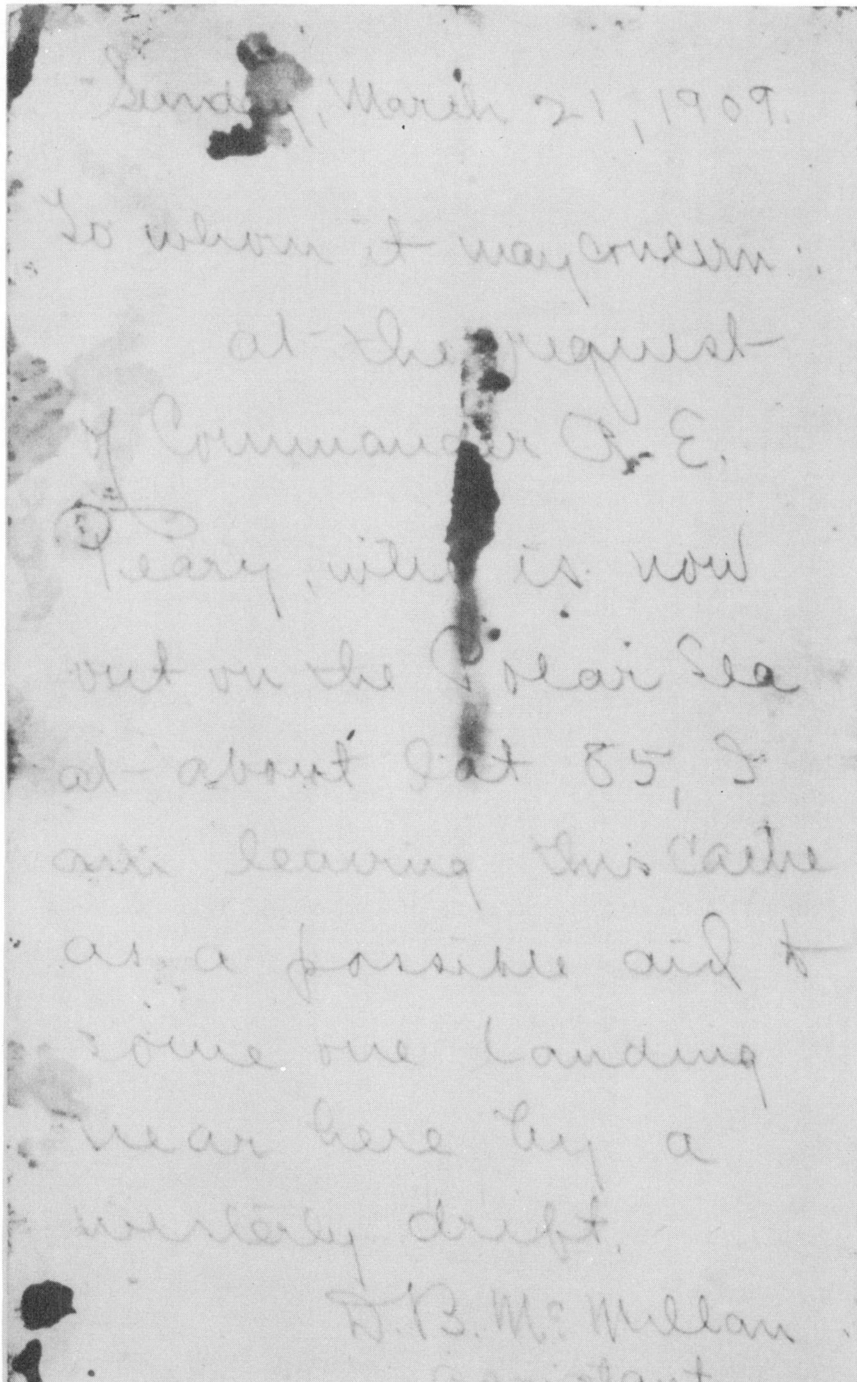
Am now returning to
the Roosevelt. Delayed here now
two days by stormy weather.

Expect to start in an hour
or two.

The ice in every direction
flooded deep with water.

R. E. Peary, U.S.N.

Plate II. **Facsimile of note by Commander R. E. Peary, 1906. Found near Cape Colgate (81° 37' N, 91° 58' W).**

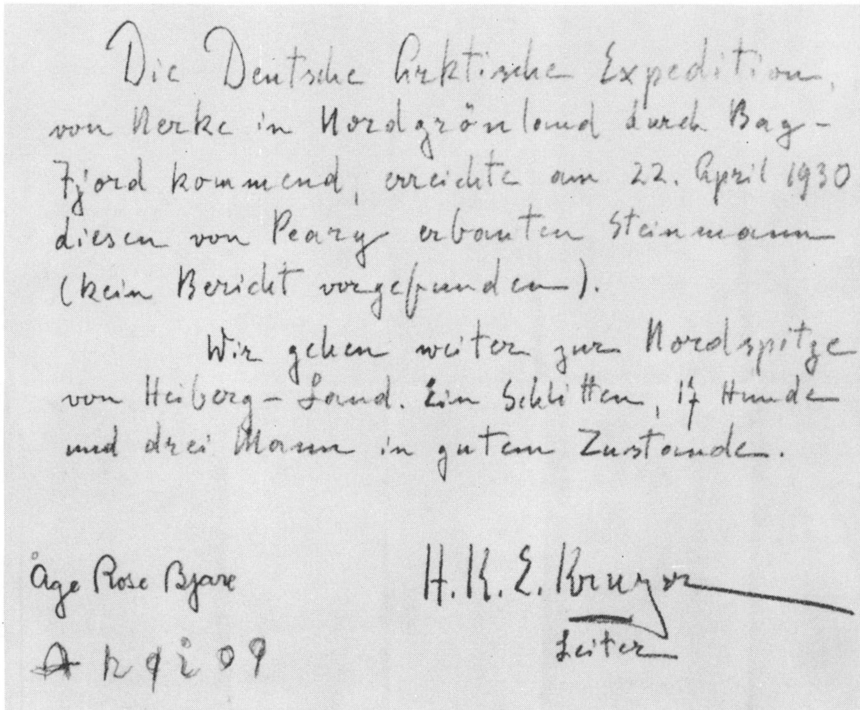


Sunday, March 21, 1909.

To whom it may concern:
At the request of Commander R. E. Peary, who is now out on the Polar Sea at about lat 85, I am leaving this cache as a possible aid to some one landing near here by a westerly drift.

D. B. McMillan
assistant.

Plate III. Facsimile of note by D. B. McMillian, 1909. Found on North side, Ward Hunt Island (83^{o} 06' N, 75^{o} 24' W).



Die Deutsche Arktische Expedition,
von Nerke in Nordgrönland durch Bay-
Fjord kommend, erreichte am 22. April 1930
diesen von Peary erbauten Steinmann
(kein Bericht vorgefunden).

Wir gehen weiter zur Nordspitze
von Heiberg-Land. Ein Schlitten, 17 Hunde
und drei Mann in gutem Zustande.

Åge Rose Bjare

H. K. E. Kruger
Leiter

Plate IV. Facsimile of note by Dr. H. K. E. Kruger, 1930. Found near Cape Colgate (81° 26' N, 92° 39' W).