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CARBONIFEROUS AND PERMIAN STRATIGRAPHY OF AXEL HEIBERG ISLAND AND WESTERN ELLESMERE ISLAND, CANADIAN ARCTIC ARCHIPELAGO

(Accompanied by 19 geologic maps by J.Wm. Kerr, R. Thorsteinsson, E.T. Tozer and H.P. Trettin)

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Abstract

This bulletin is primarily a study of the stratigraphy of Carboniferous and Permian rocks in Axel Heiberg Island, and western and northwestern regions of Ellesmere Island. It is accompanied by eighteen geologic maps (scale 1:250,000) of Axel Heiberg Island, and a considerably larger area of Ellesmere Island than is included by the bulletin; and a detailed geologic map (scale 1:50,000) of the environs of the Eureka weather station on the west coast of Ellesmere Island. Eureka represents the only settlement within the report area.

Axel Heiberg and Ellesmere Islands represent the most northerly islands in the Canadian Arctic Archipelago. They are characterized by some of the boldest alpine scenery in this region. Their principal topographic features include mountain ranges, fiords, lowlands and extensive ice-caps.

Carboniferous strata constitute basal deposits of the Sverdrup Basin, a major geological province within the archipelago, that contains an essentially concordant succession of formations ranging in age from Early Carboniferous to about mid-Cenozoic. The Sverdrup Basin lies with angular unconformity on folded and faulted, lower Paleozoic rocks of the Franklinian Geosyncline. Rocks of the Sverdrup Basin are themselves folded and faulted into northerly and northeasterly trending structures by the Eurekan orogeny of about mid-Cenozoic inception.

Carboniferous and Permian rocks are mainly of marine origin. The predominant rock types are carbonate, quartzose clastics and anhydrite. Nonmarine quartzose clastics and volcanic rocks are present locally. These rocks range in age from Early Carboniferous to Late Permian, and include the stages, Visean, Namurian,

Bashkirian, Moscovian, Zhigulevian, Orenburgian, Asselian, Sakmarian, Artinskian and Guadalupian. Rocks of earliest Carboniferous (Tournasian) and latest Permian (Djhulfian) are apparently absent. Much of the quartzose clastic sediments appears to have a southeasterly provenance.

Carboniferous and Permian rocks constitute a natural grouping of structurally conformably formations. The base of the Carboniferous is everywhere an angular unconformity. Sedimentation was continuous across the Carboniferous-Permian boundary (This is also the case with the Mississippian-Pennsylvanian boundary of continental North America). The upper surface of the Permian is marked by a widespread disconformity, and Permian rocks are generally overlain by sediments of Early Triassic age.

Four widely distributed disconformities within Carboniferous and Permian rocks, subdivide these systems into five sequences, that are described below in order upwards.

1. <u>Lower Carboniferous (Viséan) nonmarine sequence</u>, represented by the Emma Fiord Formation (new name) that crops out locally in northern Axel Heiberg and northern Ellesmere. The formation consists of quartzose clastic sediments and ranges in thickness from zero to 1,140 feet.

2. <u>Upper Carboniferous (Namurian) to lower Permian (Artinskian) marine sequence</u>. Of the five sequences, this is by far the thickest and includes the greatest span of time. The Borup Fiord (new name) is the oldest formation of this sequence, and is Namurian in age. It consists mainly of red beds that vary in thickness from 330 feet to about 1,300 feet. It is distributed widely over northern Axel Heiberg Island and northwestern Ellesmere Island, and constitues basal deposits of the Sverdrup Basin where Emma Fiord rocks are absent.

Younger formations in this sequence are characterized by complex facies relationships, and are segregated into five northeasterly trending facies belts. From northwest to southeast these belts and the formations that typify them are as follows: (a) The northwestern carbonate belt which occupies large areas of northern Axel Heiberg and northwestern Ellesmere, is represented by a single formation, the Nansen (new name), consisting largely of relatively pure, light coloured limestone, varying from about 4,000 feet to almost 8,000 feet in thickness, and ranging from Bashkirian to early Artinskian in age. The Nansen is the most widely distributed formation in the Carboniferous-Permian succession of these islands. A somewhat different facies of the Nansen is developed in yet another facies belt - the southeastern carbonate belt - to be discussed later. (b) The evaporitic and clastic belt extends through central regions of Axel Heiberg Island into northwestern Ellesmere Island, where this belt is terminated by the union of the northwestern carbonate belt and southeastern carbonate belt. The oldest formation in the evaporitic and clastic belt is the Otto Fiord (new name), that is made up of anhydrite and minor amounts of limestone, attains thickness in excess of 1,000 feet, and is Bashkirian in age. The Hare Fiord Formation (new name) overlies the Otto Fiord, consist largely of siltstone, shale and limestone, varies from 1,000 to about 4,100 feet in thickness, and ranges from early Moscovian to early Artinskian in age. Towards the northwest, and southeast the Otto Fiord and Hare Fiord grade into the Nansen. In the vicinity of this facies change limestone reefs are developed in the Hare Fiord. (c) The southeastern carbonate belt occupies a strip of territory along the west coast of Ellesmere Island and probably includes parts of eastern Axel Heiberg Island; it is represented by the Nansen Formation. Although the Nansen here consists mainly of limestone, it also contains conspicuous amounts of sandstone and siltstone interbeds that reflect proximity to the southeastern margin of the Sverdrup Basin. (d) The marginal clastic and carbonate belt is situated along the southeast side of the southeastern carbonate belt. Along the border of these belts the Nansen gives way to combinations of either two or four formations. Extensively developed throughout the greater length of the marginal clastic and carbonate belt is the combination, Canyon Fiord Formation and overlying Belcher Channel Formation. The Canyon Fiord constitutes basal deposits of the Sverdrup Basin in this belt. It consist mainly of red quartzose sandstone and lesser amounts of limestone and conglomerate, and ranges from zero to about 5,500 feet in thickness. The Canyon Fiord is Moscovian in age throughout much of its areal extent in the marginal clastic and carbonate belt, but in limited area north of Cañon Fiord, the formation includes beds of Bashkirian age. The Belcher Channel is mainly interbedded limestone with lesser amounts of quartzose clastic rocks. It varies in thickness from 480 to 1,910 feet, and ranges in age from Zhigulevian to early Artinskian. The four-fold combination of formations includes in order upwards, Canyon Fiord, Antoinette, Mount Bayley and Tanquary. The three last named formations are new, and collectively they equate with the Belcher Channel. All three formations occupy a narrow strip of territory in western Ellesmere Island that extends from south of Cañon Fiord to the mouth of Tanquary Fiord. The Antoinette is mainly limestone, varies in thickness from 1,500 to over 2,650 feet, and ranges in age from Zhigulevian to Asselian. In a limited area north of Cañon Fiord, the Antoinette includes rocks as old as Moscovian in age. The Mount Bayley is made up largely of anhydrite, varies in thickness from zero to in excess of 800 feet, and is Asselian in age. The Tanquary consists of quartzose clastics and limestone, varies in thickness from 700 to 2,740 feet, and ranges in age from Asselian to early Artinskian. (e) The marginal clastic belt is a relatively narrow and short belt that extends north and south of Cañon Fiord. It includes one formation -

the Canyon Fiord, which ranges from Bashkirian to Sakmarian and possibly into the early Artinskian, and attains a thickness of about 5,500 feet. The type section of the Canyon Fiord is included in this belt.

Two and possibly three volcanic formations occur within the Carboniferous-Permian succession. The Audhild Formation (new name) is intercalated between the Borup Fiord and Nansen near the northwestern extremity of Ellesmere Island, where it is composed of basalt and spilitic flows and lesser amounts of pyroclastic sediments, and attains a maximum thickness of 1,840 feet. The Esayoo Formation (new name) crops out sporadically in northern Axel Heiberg Island and northern Ellesmere Island. It overlies the Nansen and is overlain by various formations, the oldest of which is van Hauen. It consists of basalt flows and agglomerate, and varies in thickness from zero to 975 feet. Basalt flows and pyroclastic sediments are exposed over a large part of the unnamed peninsula formed by Emma and Audhild Fiord in northwestern Ellesmere Island. The volcanic rocks conformably overlie a relatively thin representative of the Nansen. No younger formation is known to overlie the volcanic rock the precise age of which is therefore uncertain.

3. Lower Permian (Artinskian) nonmarine sequence, is represented by the Sabine Bay Formation, consisting of light coloured, quartzose sandstone, and varying from zero to 635 feet in thickness. The formation crops out locally in the territory north and south of Cañon Fiord in western Ellesmere Island. It appears to have been deposited along the margin of the Sverdrup Basin and to have no equivalents elsewhere in the basin.

4. Lower Permian (Artinskian) marine sequence, includes the Assistance Formation, a near-shore deposit, and the correlative van Hauen Formation (new name), a basinal facies. The Assistance crops out in a narrow, northeasterly trending belt in western Ellesmere Island. It consists mainly of grey quartzose sandstone and ranges from zero to 1,330 feet in thickness. The van Hauen is exposed sporadically over a large area including southwestern and northwestern Ellesmere Island, and eastern and northern Axel Heiberg Island. It is made up largely of dark coloured shale, siltstone and chert, and varies from zero to 2,240 feet in thickness.

5. Upper Permian (Guadalupian) marine sequence, comprises the Trold Fiord Formation (new name), and the correlative Degerböls Formation (new name). The Trold Fiord is a near-shore deposit that consists mainly of green quartzose sandstone, and ranges from zero to more than 900 feet in thickness. It crops out in a narrow, northeasterly trending belt in western Ellesmere Island. The Degerböls is a shelf-type carbonate. Typically, it is made up of light coloured limestone and minor chert, and ranges from zero to 1,270 feet in thickness. It is distributed sporadically over large areas of northern Axel Heiberg Island, and southwestern and northwestern Ellesmere Island.

Diapirs consisting of cores of highly deformed anhydrite and its alteration product gypsum, constitute some of the most interesting topographic and structural features in the Sverdrup Basin. The diapirs vary in size from bodies a few square feet in area to major topographic features several miles in diameter, towering above the surrounding country. About ninety-eight diapirs in Axel Heiberg and Ellesmere Island are of sufficient size to be shown on the geologic maps that accompany this report. Three principal classes of diapirs are recognized on the basis of their regional setting: 1) Diapiric domes; large diapirs, oval to rounded in plan that intrude little deformed sediments in western regions of the Sverdrup Basin including western Axel Heiberg Island. 2) Diapiric anticlines; generally small, elongate diapirs aligned along the axes of anticlines. 3) Fault diapirs; small and large, elongate diapirs aligned along gravity and thrust faults. The anhydrite that forms the mobile rock in the diapirs is not cap rock but of primary sedimentary origin. The Otto Fiord Formation has provided the source rock in all diapirs in Axel Heiberg and Ellesmere Islands, and probably also for all diapirs in the Sverdrup Basin. Halite is not present in the Otto Fiord where the formation is observed in normal stratigraphic succession, and there is good evidence that halite is not present in the diapirs of Axel Heiberg and Ellesmere Islands. A diapir in Axel Heiberg Island and another in Ellesmere Island are continuous with the Otto Fiord Formation normal stratigraphic position. The geological setting of these two diapirs in particular, suggests that: 1) halite was not essential to diapirism in the Sverdrup Basin, 2) under suitable stress conditions, the principal cause of diapirism was differences in plasticity between source rocks and overburden, and not bouyancy of light material beneath an overburden of higher density.

The majority, and probably all diapirs in Axel Heiberg and Ellesmere Islands were induced by the mid-Cenozoic Eurekan Orogeny.

Besdies the Otto Fiord Formation, three other anhydrite formations occur on Ellesmere Island. They are the Baumann Fiord Formation (Ordovician), Bay Fiord (Ordovician), and Mount Bayley (Formation). These formations are comparable to the Otto Fiord in thickness and gross lithology, and, like the Otto Fiord, occur in folded and thrust-faulted terrane. All three formations are overlain by relatively thick, competent carbonate formations, and none give rise to diapirs. It is therefore, concluded that the Otto Fiord produced diapirs because it was overlain by relatively incompetent siltstone and shale of the Hare Fiord Formation. As a corollary it seems reasonable to suggest that the Otto Fiord and Hare Fiord Formations are distributed coextensively in the subsurface throughout parts of the Sverdrup Basin southwest of Axel Heiberg Island, in which occur diapirs but in which Carboniferous and Permian strata are hidden beneath younger sediments.

CARBONIFEROUS AND PERMIAN STRATIGRAPHY OF AXEL HEIBERG ISLAND AND WESTERN ELLESMERE ISLAND, CANADIAN ARCTIC ARCHIPELAGO

INTRODUCTION

SCOPE OF STUDY AND LOCATION

This bulletin is a study of the stratigraphy of Carboniferous and Permian rocks of Axel Heiberg and Ellesmere Islands which constitute the most northerly islands of the Canadian Arctic Archipelago. It is based primarily on thirty-five critically chosen sections that were studied in considerable detail and measured by means of a five-foot rule equipped with a clinometer. The measured sections are widely distributed over an area estimated roughly as about 30,000 square miles. The report area includes all exposures of Carboniferous and Permian rocks on Axel Heiberg Island, and western and northwestern regions of Ellesmere Island (see Text-fig. 1), but it does not include rocks of these systems that are exposed in northeastern regions of Ellesmere Island which have been studied in 1964 by Nassichuk and Christie (1970), and by members of Operation Grant Land directed by R.L. Christie in 1965 and 1966. The thirty-five stratigraphic sections are illustrated graphically on figures 1, 2, 3 and 4 in the accompanying box. Besides these sections numerous other exposures of Carboniferous and Permian rocks were examined within the report area.

Carboniferous and Permian rocks have been known to occur in the Canadian Arctic Archipelago for more than a century, and have been studied and reported on by many geologists. Most studies have dealt with marginal facies of these systems that crop out in a narrow belt along the southern (Melville Island, Bathurst Island group and Grinnell Peninsula; see Fig. 6) and southeastern margins (western Ellesmere Island) of the Sverdrup Basin, with the result that the stratigraphy of these deposits is moderately well known. Nevertheless, the Carboniferous and Permian have remained the least known of Phanerozoic systems in the archipelago. There are two principal reasons for this circumstance: (1) By far the greater volume of Carboniferous and Permain rocks in the Sverdrup Basin is represented by shelf and basinal facies which are situated to the north and northwest of the marginal deposits. Rocks of the shelf and basinal facies are exposed, for the most part, only in northern and eastern Axel Heiberg Island, and north-western Ellesmere Island, regions which until recently have constituted some of the more inaccessible parts of the archipelago. These rocks have therefore received little attention and are poorly understood. (2) The shelf and basinal facies, like the marginal facies, are notable for abrupt changes from one rock type to another within short distances, and stratigraphic relationships that are further complicated by disconformities and transgressive units. Mainly because of these complexities the limited studies made at isolated localities in these regions prior to the present investigations, failed to elucidate the regional relationships of Carboniferous and Permian rocks.

The principal aim of the present study is to establish the classification, age and correlation of Carboniferous and Permian rocks across the various facies belts on Axel Heiberg and Ellesmere Islands.

Ellesmere and Axel Heiberg Islands comprise areas of about 82,000 and 16,000 square miles respectively. The only permanent settlement within the report area is the Eureka weather station on the west coast of Ellesmere Island at latitude 79°59'N, and longitude 85°57'W. This station was established in 1947 by airlift from Thule, Greenland, and is jointly operated by the Canadian Department of Transport and the United States Weather Bureau. It is resupplied each year by icebreaker, and has an airstrip that is normally serviceable all year.

FIELD WORK

This bulletin is one of sveral reports resulting from reconnaissance mapping and stratigraphic studies carried out over a period of five field seasons, during which the Eureka weather station served as base camp. In 1956, E.T. Tozer and the writer investigated parts of eastern Axel Heiberg Island, and and northwestern western Ellesmere Island by means of dog teams and canoe (Thorsteinsson and Tozer, 1958). In 1957, the writer, using the same methods of travel worked in the same general regions of these islands, including a trip to the west coast of Axel Heiberg Island and Meighen Island (Thorsteinsson, 1961). In 1961 and 1962, a Geological Survey project known as Operation Eureka, mapped and studied the geology of previously unstudied parts of Axel Heiberg Island, and and northwestern western Ellesmere Island (see Text-fig. 1). This project was directed by the writer, and included staff geologists, J.Wm. Kerr, E.T. Tozer and H.P. Trettin. J.G. Fyles was a member of the project in 1961 when he studied the Pleistocene geology of the region. Field transportation in 1961 was provided by three Piper Super Cub aircraft that were supplied by Bradley Air Services Limited of Carp, Ontario. The aircraft were equipped with large, low-pressure tires for landing on unprepared terrain. Two aircraft were used in 1962: a G2A Bell helicopter contracted from Atlantic Helicopters Limited of Montreal; and a Piper Super Cub aircraft supplied by Bradley Air Services. Non-contract service on Operation Eureka in 1961 included a DC-4 flight from Churchill to Eureka at the start of the field season and a DC-6 flight from Eureka to Montreal at the close of the season. In 1962 the party moved from Yellowknife to Eureka, and returned by means of a Bristol Freighter aircraft. The writer, accompanied by P. Harker devoted the field season of 1963 to further stratigraphic studies and mapping on Axel Heiberg Island and Ellesmere Island. Field transportation was by Super Cub aircraft once again contracted from Bradley Air Services.

Much of the early work carried out by Tozer and the writer using dog teams and canoe consisted of journeys of three to eight weeks duration made from Eureka. Both methods of travel limited geological investigations to coastal areas, and much time was devoted to studying excellent exposures that commonly characterize the sides of fiords on these islands. Even under winter conditions which persist until about June in these latitudes, the steeper fiord walls are commonly free of snow by early April, owing partly to strong winds but mainly to the insolating effect of the sun[1]. Temperatures in the Eureka district in April are generally about 40 below zero, and during this time the field parties lived mainly in igloos. With the progressively moderating temperatures of May and June, double-walled tents were found to provide more practical living quarters than snow houses. Ring seal, abundant in the fiords of these islands were shot to provide food for the dogs. Although July is generally the best month of the year for field work on Axel Heiberg and Ellesmere Islands, sledging is impractical because of widening shore leads, and the development of long cracks in the sea ice, up to about 40 feet in width, that trend across the fiords. Moreover, the disappearance of the snow from the surface of the fiord ice which generally occurs in late June, produces a condition that cuts the feet of dogs. Consequently, July was spent in traversing on foot and conducting detailed geological studies in the environs of Eureka. It was such circumstances that provided the opportunity for Tozer and the writer to make a detailed geologic map of the Slidre Fiord area (see Map 000A). By early August the ice in the fiords is generally sufficiently broken up to permit the use of a canoe. This method of travel comes to an end in late August with the onset of winter and freezing conditions.

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The sun remains above the horizon at the latitude of Eureka from March 25 to August 22. Insolation is especially effective in the case of dark coloured rocks. For instance on May 29, 1956 the author observed running water and live flies on dark grey rocks of the Triassic Blaa Mountain Formation about 1,000 feet above sea-level in Hare Fiord. At the same time the temperature on the surface of the fiord was 5 degrees fahrenheit below zero.

In most years at Eureka, the period during which the land is free of snow, and conditions are therefore optimum for geologic investigations, lasts from about mid-June until August 25. In this connection extreme conditions prevailed during the two years of Operation Eureka. In 1961 the snow-free period lasted from about July 1 to August 25; in 1962 from June 1 to August 26.

The main base of operation during the field seasons of 1961, 1962 and 1963, was established in tent quarters about a quarter of a mile west of Eureka. Throughout each field season this camp was occupied by a cook, radio operator, and varying numbers of staff geologists and geological assistants. The average number of hours flown by each contract aircraft in the field during the three field seasons was about 225 hours. The aircraft served three main functions: (1) They were used in setting out small parties of one or two geologists in subsidiary base camps where these men remained for periods generally varying from two days to a week before being flown back to Eureka or to another locality. (2) Aircraft were used also in day long traverses out of the main base camp for purposes of mapping and stratigraphic studies. The average day traverse entailed about eight landings. (3) At various times flights were made to set out caches of aviation gasoline, both as a safety measure, and in order to extend the range of aircraft into more distant parts of the area of study.

GEOLOGIC MAPS, RESPONSIBILITIES AND REPORTS

This bulletin is accompanied by 19 geological maps, 18 of which are published on a scale of 1:250,000. The NTS numbers and names of these maps are as follows: 49C Baumann Fiord; 59F Haig-Thomas Island; 59E Glacier Fiord; 49F Eureka Sound South; 49E Strathcona Fiord; 59G Middle Fiord; 59H Strand Fiord; 49G Eureka Sound North; 49H Cañon Fiord; 39G Sawyer Bay; 39H Dobbin Bay; 560A Bukken Fiord; 340B

Greely Fiord West; 340A Greely Fiord East; 120B Kennedy Channel; 560D Cape Stallworthy; 340C Otto Fiord; and 340D Tanquary Fiord. Slidre Fiord is a detailed geologic map of the environs of the Eureka weather station on a scale of 1:50,000.

The greater part of the area represented by the above geologic maps resulted from work carried out on Operation Eureka when field responsibilities were divided as follows: Kerr was responsible principally for studying and mapping early Paleozoic miogeosynclinal rocks; Trettin the early Paleozoic eugeosynclinal rocks; Tozer was responsible for the stratigraphy of Mesozoic and Cenozoic rocks in the Sverdrup Basin; and the author the late Paleozoic rocks of the Sverdrup Basin. Tozer and the writer were jointly responsible for mapping rocks of the Sverdrup Basin.

A list of selected reports which are particularly useful to a fuller understanding of the geologic maps accompany the present report is as follows:

Christie, R.L.
1967: Bache Peninsula, Ellesmere Island, Arctic Archipelago; Geol. Surv. Canada, Mem. 347.

Frebold, Hans
1964: The Jurassic faunas of the Canadian Arctic, Cadoceratinae; Geol. Surv. Canada, Bull. 119.

Fricker, P.E. and Trettin, H.P.
1962: Pre-Mississippian succession of northernmost Axel Heiberg Island, District of Franklin; Axel Heiberg Island Research Reports, McGill University, Montreal Geology, No. 3.

Kerr, J.Wm.
1967: New nomenclature for Ordovician rock units of the eastern and southern Queen Elizabeth Islands, Arctic Canada; Bull. Can. Petrol. Geol., vol. 15, No. 1, pp. 91-113.

1967: Vendom Fiord Formation - a new red-bed unit of probable early Middle Devonian (Eifelian) age, Ellesmere Island, Arctic Canada; Geol. Surv. Canada, Paper 67-43.

1967: Stratigraphy of central and eastern Ellesmere Island, Arctic Canada. Part I, Proterozoic and Cambrian; Geol. Surv. Canada, Paper 67-27.

Kerr, J. Wm.
1967: Devonian of Franklinian miogeosyncline and adjacent Central Stable Region, Arctic Canada; in D.H. Oswald, ed. International Symposium on the Devonian System, vol. 1, pp. 677-692, Alta. Soc. Petrol. Geol., Calgary, Alberta

1968: Stratigraphy of central and eastern Ellesmere Island, Arctic Canada. Part II, Ordovician; Geol. Surv. Canada, Paper 67-27.

Thorsteinsson, R. and Tozer, E.T.
1970: Arctic Lowlands, Franklinian System, Sverdrup Basin, and Arctic Coastal Plain; in R.J.W. Douglas, ed. Geology and Economic Minerals of Canada; Econ. Geol. Series No. 1, Geol. Surv. Canada.

Tozer, E.T.
1961: Triassic stratigraphy and faunas, Queen Elizabeth Islands, Arctic Archipelago; Geol. Surv. Canada, Mem. 316.

1963: Mesozoic and Tertiary stratigraphy, Western Ellesmere Island and Axel Heiberg Island, District of Franklin; Geol. Surv. Canada (Prel. Acct.), Paper 63-30.

1965: Latest Lower Triassic ammonoids from Ellesmere Island and northeastern British Columbia; Geol. Surv. Canada, Bull. 123.

1967: A standard for Triassic time; Geol. Surv. Canada, Bull. 156.

Trettin, H.P.
1963: Caledonian movements in the Canadian Arctic Archipelago; Bull. Can. Petrol. Geol., vol. 11, pp. 107-115.

1967: Devonian of the Franklinian eugeosyncline; in D.H. Oswald, ed. International Symposium on the Devonian System, vol. 1, pp. 693-670, Alta. Soc. Petrol. Geol., Calgary, Alberta

1969a: Pre-Mississippian geology of northern Axel Heiberg and northwestern Ellesmere Islands, Arctic Archipelago; Geol. Surv. Canada, Bull. 171.

1969b: Geology of Ordovician to Pennsylvanian rocks, M'Clintock Inlet, North coast of Ellesmere Island, Canadian Arctic Archipelago; Geol. Surv. Canada, Bull. 183.

1970: Ordovician-Silurian flysch sedimentation in the axial trough of the Franklinian geosyncline, northeastern Ellesmere Island, Arctic Canada in Flysch sedimentology in North America, in J. Lajoie, ed. Geol. Assoc. Can., Spec. Paper 7, pp. 13-35.

Trettin, H.P.

1971a: Stratigraphy and sedimentology of lower Paleozoic clastic units, Tanquary and Cañon Fiord regions, Ellesmere Island; in Report of Activities, Part A: April to October, 1970, Geol. Surv. Canada, Paper 71-1, pp. 236-241.

1971b: Geology of lower Paleozoic formations, Hazen Plateau and southern Grant Land Mountains, Ellesmere Island, Arctic Archipelago: Geol. Surv. Canada, Bull. 000.

PHYSIOGRAPHY

The diverse physiographic regions making up Axel Heiberg and Ellesmere Islands include high mountain belts, valley and ridge systems and dissected plateaus, all impressive alike for magnitude and ruggedness; as well as lesser regions of lowlands. Moreover, all systems of Phanerozoic time including rocks of the Canadian Shield occur in one place or another in these islands, and the variety and number of rock formations are accordingly great. Each of these formations has impressed its own specific characteristics on the landscape. Indeed, for variety and interest of topographic forms, no part of the Canadian Arctic Archipelago offers more attractions than Axel Heiberg and Ellesmere Islands.

Lare areas of Axel Heiberg and Ellesmere Islands are presently ice-capped, and certain ice caps are of sufficient size to constitute in themselves, distinctive physiographic regions. All parts of both islands appear to have been glaciated, and many topographic features relate to the time of more extensive ice cover, and to submergence during and following deglaciation. The most notable of such features are knife-edge crests, cirques, u-shaped valleys, and fiords that cut deep into the islands forming numerous and characteristic peninsulas. A system of interconnecting fiords is undoubtedly responsible for the separate existence of Axel Heiberg and Ellesmere Islands. Ice tongues occupy many valleys, and in places these and the ice caps reach tidewater.

The most extensive mountain belts are: the United States Range that overlooks the Arctic Ocean in northern Ellesmere; the Victoria and Albert Mountains between Greely Fiord and the east coast of Ellesmere Island; and the Princess Margaret Range that occupies much of central Axel Heiberg Island. Each of these mountain belts carries an extensive ice cap. Barbeau Peak, a nunatak in the United States Range with an elevation of 8,760 feet and situated some 19 miles northeast of the head of Tanquary Fiord (Tanquary Fiord), represents the highest mountain in North America east of the Rocky Mountains (Hattersley-Smith, 1970). The highest point on Axel Heiberg Island, also a nunatak, is 6,720 feet; it is situated in the northeastern portion of the Middle Fiord map-area.

To explain fully the present physiography of Axel Heiberg and Ellesmere Islands it would be necessary to consider the long succession of stratigraphic and structural events that are responsible for the character and distribution of the various formations, as well as the processes of subaerial erosion, particularly glaciation, that have in the recent geologic past shaped the landscape. Such a study is beyond the scope of the present report. For a detailed and well-illustrated description of the topography of Axel Heiberg and Ellesmere Islands, based mainly on the study of aerial photographs, the reader is referred to Dunbar and Greenaway (1956).

GEOLOGIC SETTING

Carboniferous and Permian rocks constitute a small, albeit important part of the unusually extensive and inclusive geological record of Axel Heiberg and Ellesmere Islands. It seems desirable therefore, to present here a brief summary of the structural and stratigraphic history of these islands as a background against which the record of Carboniferous and Permian times may be seen in perspective.

Two structural provinces are included in the combined areas of these islands. They are the Central Stable Region and the Innuitian Orogen (see Fig. 5). These provinces are each divisible into two major geologic regions: Central Stable Region including the Canadian Shield and Arctic Platform; and Innuitian Orogen comprising the Franklinian Geosyncline and Sverdrup Basin.

Canadian Shield. The Precambrian rocks of the Canadian Shield constitute basement in the Central Stable Region and are exposed in southeastern Ellesmere Island where they occupy an area a little less than one quarter of the island. The shield is here composed mainly of gneissic and granitoid rocks, including small areas of Proterozoic-type sediments (Christie, 1962a, 1962b, 1967).

Arctic Platform. The Arctic Platform forms the outer part of the Central Stable Region, and consists of a narrow belt of relatively thin sediments that range in age from Early Cambrian to Early Devonian (Christie, 1967; Kerr, 1967, 1968). To the north and northwest, rocks of the Arctic Platform are continuous with, and thicken into, rocks of the Franklinian Geosyncline. The contact of platform and geosynclinal deposits is arbitrarily shown in figure 5 at the outer limit of folded and faulted geosynclinal rocks. Rocks of the platform are broken by numerous normal faults, most of which cannot be more closely dated than post early Paleozoic. However, a few faults displace the early Cenozoic, Eureka Sound Formation, preserved as outliers lying disconformably on early Paleozoic rocks, and it is possible that the majority of faults in Arctic Platform are related to widespread, Mid-Cenozoic crustal movements in the archipelago, discussed later.

Rocks of proved Late Cambrian age have not been found in the Arctic Platform, or for that matter in the entire archipelago. Nevertheless, it is difficult to believe that rocks of this age were never deposited in this region, and it seems likely that they will ultimately be found, probably in some of the, as yet, unexplored part of the Franklinian Geosyncline.

Franklinian Miogeosyncline. Rocks of the Franklinian Geosyncline adjacent to the Arctic Platform are miogeosynclinal in character, and record nearly continuous and heavy sedimentation from late Precambrian to Late Devonian. The miogeosyncline, like the Arctic Platform, is confined to Ellesmere Island, and is sigmoidal in plan. It trends southwestward in southwestern parts of the island, north-south in central parts, and then northeastward to Kennedy Channel on the east coast. Miogeosynclinal rocks consist mainly of carbonates and quartzose sandstone, with lesser amounts of siltstone, shale and anhydrite (Kerr, 1967a, 1967b, 1967c, 1968). The greatest thickness of formations at any one locality is about 45,000 feet. The two youngest formations in the conformable succession of the miogeosyncline constitute a thick clastic wedge of late Middle to Late Devonian age and are clearly related to the climactic orogeny (Acadian) of the eugeosyncline. They are the Bird Fiord Formation of Givetian age that attains a thickness of about 3,000 feet, and the Okse Bay Formation of Fasnian and Fammenian age that reaches a thickness of at least 10,000 feet (McLaren, 1963). The clastic wedge provides the lower age limit of the main orogeny that deformed the miogeosyncline - the Ellesmerian orogeny of latest Devonian or Early Carboniferous inception. The upper age limit is obtained from the Early Carboniferous age (Visean) of the oldest rocks in the Sverdrup Basin, that unconformably overlies rocks of the Franklinian Geosyncline.

Rocks of the miogeosynclinal belt have been folded and faulted along trends aligned with the sinuous course of the belt itself. Northeasterly parts of the miogeosyncline in the environs of Kennedy Channel on the east coast of Ellesmere Island are characterized by long, nearly parallel, northeasterly trending folds that are generally asymmetrical towards the southeast. A few high-angle faults are thrust in the same direction. In central parts of the miogeosyncline, meridionally-trending folds and faults are common (see for example Cañon Fiord). Faults are the dominant structural features here, and they include both normal and high-angle thrusts, the latter displaced relatively eastward. The outstanding structures in southwestern parts of the miogeosyncline are a series of widely spaced, strike-slip faults arranged diagonally across the miogeosynclinal belt (Baumann Fiord). Many thrust and normal faults are demonstrably related to the mid-Cenozoic Eurekan orogeny, in that they displace outliers of the early Cenozoic Eureka Sound Formation. While the relative affects of the two orogenies cannot be fully assessed on the basis of available evidence, it seems probable that simple folds were the principal structures of Ellesmerian orogeny, (as is the case in the Franklinian miogeosynclinal belt on Bathurst and Melville Islands) and that faulting was effected mainly during Eurekan orogeny.

Franklinian Eugeosyncline. Northwestern Ellesmere Island, and a relatively small area in northern Axel Heiberg Island are characterized by rocks of eugeosynclinal aspect. Much of this region is rugged and ice-covered. It is difficult of access, and large areas have not been investigated in detail. Although the eugeosyncline is less well understood than the miogeosyncline, the broader outlines of its sedimentary and structural history are beginning to emerge, mainly through the work of H.P. Trettin (1967, 1968, 1969a, 1969b, 1970, 1971a, 1971b).

The boundary between the miogeosyncline and eugeosyncline is shown in figure 5 as a northeasterly trending line that joins the heads of Greely Fiord and Archer Fiord in northern Ellesmere Island. It marks approximately the northwestern limit of significant volumes of miogeosynclinal carbonate rocks, and in particular it represents the approximate line of facies change along which Lower and Middle Ordovician carbonates grade northwesterly into predominantly clastic rocks of the eugeosyncline. There is moreover evidence that this boundary coincides also with the northwesterly transition of Lower and Middle Cambrian carbonates to clastics. Nevertheless the boundary is admittedly arbitrary as the eugeosynclinal environment, of various times, advanced southeastward over miogeosynclinal sediments. A noteworthy example is represented by Upper Ordovician to Lower Devonian graptolitic shale and siltstone that grades southeasterly into carbonate rocks along a northeasterly trending facies zone situated some 60 miles southeast of the miogeosyncline-eugeosyncline boundary as shown in figure 5.

Typical eugeosynclinal terrane is confined to northern Axel Heiberg Island and northwestern parts of Ellesmere Island that are characterized by acidic and basic plutons, low to high rank metamorphic rocks, and sedimentary rocks dominated by rapidly deposited sandstone and siltstone, and associated shale, greywacke, arkose and chert. In some place, notably in the environs of M'Clintock Inlet (Trettin, 1969), thick carbonate units occur, but they appear to be mostly of local extent. Ordovician and Silurian volcanic rocks are common in Ellesmere Island, and Silurian and Devonian volcanic rocks occur in Axel Heiberg Island. The volcanic flows are commonly keratophyric in composition. The aggregate thickness of layered rocks is known to be in the order of several thousands of feet, but thicknesses are generally difficult to estimate because of structural complexity and alteration.

While it is probable that sedimentary rocks of the eugeosyncline range from late Precambrian to about Early Devonian, it should be noted that the presence of Ordovician, Silurian and Lower Devonian rocks only, is substantiated by paleontological evidence. Moreover, Lower Devonian sediments are known only in northern Axel Heiberg Island, although in northwestern Ellesmere Island, a unit of apparently unfossiliferous clastic rocks that lie conformably on Upper Silurian carbonate rocks (Marvin Formation; Trettin, 1969b), may be in part at least Early Devonian. That late Precambrian and Cambrian sediments are present seems likely in view of the occurrence of thick deposits of these ages in the miogeosyncline (Kerr, 1967c). Furthermore, a thick, widespread clastic unit that lies stratigraphically below rocks of Early Ordovician age in northwestern Ellesmere Island may well include rocks of Cambrian age (Grant Land Formation; Trettin, 1971b). Trettin has tentatively assigned this unit to the Early Ordovician and/or Cambrian.

The presence in northwestern Ellesmere Island of clastic units that were presumably derived from tectonic lands beyond the present day coast of the Arctic Ocean, indicates that eugeosynclinal terrane probably underlies a considerable area of the continental shelf and slope.

A remarkable succession of deep water, clastic sediments ranging from Early Ordovician to about Middle Silurian and probably into Early Devonian was deposited in linear, northeasterly trending trough in southeastern regions of the eugeosyncline. The trough has been named the Hazen Trough (Trettin, 1971a; see also 1970, 1971b). Rocks of the Hazen Trough are characterized by a sedimentary and structural history that set them apart from contemporaneous deposits in the adjoining miogeosyncline, as well as from remaining parts of the eugeosyncline. The Hazen Trough lies conformably on clastic rocks of the Grant Land Formation of Early Ordovician and/or Cambrian age. Incipient deposits in the trough are represented by the Hazen Formation, a unit of graptolitic shale, chert, redeposited carbonate, and minor amounts of breccia. It is about 1,300 feet thick, and ranges from Early to early Middle Ordovician. Conformably overlying the graptolitic rocks is uniform succession of flysch deposits, about 3,600 feet in thickness and consisting of calcareous greywacke, calcareous siltstone, calcareous shale, and minor amounts of conglomerate and breccia. These deposits are assigned to the Imina Formation. The Imina is the youngest formation preserved in the Hazen Trough as shown in figure 5, and in this region the formation ranges from late Middle Ordovician to late Early or Middle Silurian.

On the basis of extensive studies of directional features, Trettin (op. cit) has demonstrated that the great bulk of flysch deposits entered the trough, probably as turbid flows, from the northwest and were deflected to the southwest along the axis of the trough. He has also shown that the flysch deposits were flanked to the northwest and southeast by correlative graptolitic shales, and that range from late Middle Ordovician to Middle Silurian; moreover, that the flysch deposits advanced both to northwest and southeast as the Hazen Trough widened progressively. The most southeasterly exposures of the flysch deposits occur in the environs of Cañon Fiord, deep within areas previously characterized by miogeosynclinal sediments, and some 40 miles southeast of the generalized boundary of the trough depicted in figure 5. In Cañon Fiord the flysch deposits have been dated as Late Silurian to Early Devonian. Thus the Imina Formation in the Hazen Trough may be reasonably considered to range from late Middle Ordovician to about Early Devonian.

Although the Hazen Trough includes neither volcanic or plutonic rocks, and is therefore neither genuinely eugeosynclinal or miogeosynclinal, the predominantly clastic nature of its sediments, and the absence of shelf-type carbonate rocks suggests relationship with the eugeosyncline rather than the miogeosyncline. Presumably the Hazen Trough is what it seems to be - a region of transitional deposits between typical miogeosynclinal and typical eugeosynclinal deposits.

Significant differences in degree of deformation characterize different regions of the Franklinian eugeosyncline, which is thereby divisible into three parts. 1. The dominant structural pattern of rocks in the Hazen Trough is a uniform series of relatively short, tightly compressed folds with well-developed axial plane cleavage. The folds are commonly asymmetric to overturned, with northwesterly dipping axial planes. Faulting appears to have played a minor role in this part of the eugeosyncline. 2. A crystalline area made up largely of gneissic and schistose rocks, and plutonic bodies occupies a narrow strip of coastal territory along the northwest coast of Ellesmere Island between Phillips Inlet and Cape Columbia. Both basic and acidic plutons are represented, the latter including diorite, quartz diorite, quartz monzonite and related rocks. The known rank of metamorphic rocks range from chlorite to staurolite facies. 3. The main part of the eugeosynclinal belt lies between the crystalline area and the Hazen Trough, and includes northern Axel Heiberg Island and the greater part of northwestern Ellesmere Island. This region is strongly deformed into dominantly northeasterly striking folds and faults, although marked deviations from the regional trend characterizes northern Axel Heiberg Island where structures generally strike somewhat west of north, and an area west of M'Clintock Inlet in northwestern Ellesmere Island, in which northerly trending folds and faults are conspicuously developed. As in the case of the Hazen Trough many of the folds are represented as similar folds with well-developed axial plane cleavage. Both high- and low-angle faults are common. Scattered along northwestern parts of this region are small acidic and basic plutons.

In general metamorphic rank decreases markedly southeastward from the crystalline belt into the sedimentary and volcanic terrane of the eugeosyncline, where rank above greenschist facies is rare.

The exact age of the matamorphic rocks in the crystalline area and their relationship to rocks of known Lower Ordovician to Lower Devonian age in other parts of the eugeosyncline are uncertain. However, in the environs of M'Clintock Inlet, an angular unconformity separates weakly altered Middle Ordovician rocks from older quartz-muscovite-chlorite schist rocks that may be correlative with the metamorphic rocks in the crystalline area (Trettin, 1969).

The eugeosyncline has been studied in detail at widely separated localities only, and large intervening areas have not been studied except for interpretations from aerial photographs. Consequenctly, on the tectonic map (Fig. 5), most folds and faults in the eugeosynclinal belt are indicated by trend lines.

The eugeosyncline was a region of considerably greater crustal mobility than the miogeosyncline. Various considerations including the sedimentary record, angular unconformities of various levels, and radiometric dates indicate the occurrences of five pulses of orogeny in the eugeosyncline (Trettin, 1969). 1. Cambrian or earlier orogeny indicated by the widely distributed Grant Land Formation, consisting mainly of fine- to coarse-grained sandstone, and dated as Early Ordovician and/or Cambrian. According to Trettin (1971) the Grant Land Formation was derived from the north, presumably from the metamorphic terranes around Cape Columbia. 2. Middle Ordovician or earlier orogeny based on an angular unconformity separating Middle Ordovician rocks from rocks of presumed Early or Middle Ordovician age (or even older) in the M'Clintock Inlet region in northwestern Ellesmere Island. 3. Caledonian orogeny based mainly on an angular unconformity between Middle Silurian and Lower Devonian rocks in northern Axel Heiberg Island, and partly on radiometric determinations that cluster about 390 million years for several plutons in northern regions of Ellesmere Island. The extent and magnitude of the Middle Ordovician or earlier orogeny, and the Caledonian orogeny is not clearly defined as these events have been masked by later events. 4. Acadian orogeny represented principally by an angular unconformity between rocks as young as Early Devonian in eugeosynclinal rocks of northern Axel Heiberg Island, and the Early Carboniferous (Viséan) age of basal deposits in the overlying Sverdrup Basin. While the limiting dates of this unconformity are admittedly too great to identify specifically

Acadian as the climatic orogeny of the eugeosyncline in northwestern Ellesmere Island where the youngest dated rocks beneath the unconformity are Late Silurian - particularly in view of Caledonian movements in northern Axel Heiberg Island - other lines of evidence all but confirm it. (a) The thick and widespread, clastic wedge of late Middle to Late Devonian age in the miogeosyncline indicates that an uplift of unprecedented magnitude and intensity occurred in the eugeosyncline at about late Middle or early Late Devonian time. (b) Sediments of Middle and Late Devonian ages are apparently absent throughout the eugeosyncline suggesting that northern Axel Heiberg Island and northwestern Ellesmere Island were above sea-level during this interval of time and being actively eroded. (c) Radiometric determinations of several plutons in northern Axel Heiberg Island and northwestern Ellesmere Island have given ages of about 360 million years. [With regards to Caledonian versus Acadian crustal movements in the eugeosyncline it seems reasonable to regard the long, northerly extension of of Blue Fiord Carbonates (Emsian and Givetian) in the miogeosyncline, as shown in figure 5, as indicating a period of quiescence between the two movements]. 5. Eurekan orogeny of mid-Cenozoic age. The effects of this orogeny are deferred to later discussion, but it is of interest to note at this time that whereas much, or all of the eugeosyncline was deformed by Eurekan deformation, the Hazen Trough was unaffected by this event.

The precise limits of regions affected by Acadian and Ellesmerian orogenies is not clearly defined. It is possible that deformation of the Hazen Trough was effected by one or the other orogeny,or by both.

<u>Sverdrup Basin</u>. The Sverdrup Basin lies with angular unconformity on rocks of the Franklinian Geosyncline. It includes a thick and little interrupted sequence of largely marine sediments that range from Early Carboniferous to mid-Cenozoic in age. Rocks of

the basin underlie nearly all of Axel Heiberg Island, with the exception of the small area of exposed eugeosyncline around the northern extremity of the island, and they form a belt of exposures that trend northeasterly through western and northwestern regions of Ellesmere Island. There are thus fairly well-defined southeastern and northwestern boundaries to Sverdrup Basin rocks on these islands (see Fig. 5). The axis of the basin, which is marked by the position of greatest subsidence and generally thickest deposits, extends northeasterly through central regions of Axel Heiberg Island, and across northwestern Ellesmere Island. The aggregate maximum thickness of formations in axial regions of the basin as inferred from isopach studies is over 50,000 feet, but it is likely that the maximum thickness of sediments to accumulate at any one point is nowhere greater than about 40,000 feet. Towards the southeastern boundary of the Sverdrup Basin the sedimentary section thins markedly owing mainly to disconformities, thinning and pinch-outs of individual rock units, and overstepping relations. It is therefore apparent that the present day boundary corresponds more or less to the original depositional margin of the basin[1] (see Text-fig. 2; and Thorsteinsson and Tozer, 1970). While there is evidence of thinning of certain rock units of the basin in the direction of the northwestern boundary, it is obvious that the northwestern depositional margin, or threshold with the Arctic Ocean was situated farther to the northwest, probably along the continental shelf, and that Sverdrup Basin rocks have been stripped back to their present day northwestern boundary.

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1 It is of some interest to note that the southeastern margin of the Sverdrup Basin in Ellesmere Island was sufficiently fixed through time to suggest a hinge line of deep-seated structural origin; moreover that this hinge line strikes diagonally across the Franklinian miogeosynclinal and eugeosynclinal belts which must have also reflected deep-seated structural trends.

The Sverdrup Basin lies mainly on rocks of the Franklinian eugeosyncline, and to a lesser extent on adjacent parts of the miogeosyncline. Presumably a considerable area of the miogeosyncline was exposed to erosion during the growth of the basin, and contributed to deposits laid down in the basin.

The Sverdrup Basin was deformed by the Eurekan orogeny, the main pulse of which was about mid-Cenozoic. The age of this deformation is bracketed by two widely distributed, nonmarine, clastic units: the Eureka Sound Formation that occurs at the top of the conformable succession of Sverdrup Basin rocks, and is dated as Paleocene to about Miocene; and the Beaufort Formation that is Pliocene and/or early Pleistocene, and lies with angular unconformity on rocks of the Sverdrup Basin in islands of the archipelago situated to the southwest of Axel Heiberg Island (Thorsteinsson and Tozer, 1970). An early pulse of Eurekan Orogeny is indicated locally in eastern Axel Heiberg Island and neighbouring regions of northwestern Ellesmere Island by an angular unconformity between the Eureka Sound Formation, and various rock units as young as Early Cretaceous.

The Eureka Sound Formation is widely transgressive in regions of the archipelago beyond the limits of the Sverdrup Basin, and undoubtedly overspread much, if not all of Ellesmere Island. As noted in previous discussion, this formation is commonly preserved as widely separated outliers, lying either disconformably on rocks of the Arctic Platform; or with angular unconformity on the eroded edges of deformed rocks in the Franklinian Geosyncline (see for example Strathcona Fiord). In places, in the geosyncline, the Eureka Sound Formation is nearly flat-lying, but in others it is folded and thrust faulted. These outliers of Eureka Sound rocks are therefore of importance, not only in demonstrating that Eurekan deformation occured beyond the confines of the Sverdrup Basin, but also the extent of the region so affected.

Rocks of the Sverdrup Basin are folded and faulted along trends that are more or less aligned with those of underlying Ellesmerian or older structures. Eurekan deformation was not intense, and there is a marked contrast in the heavily deformed rocks of the Franklinian Geosyncline - particularly those of the eugeosyncline - and the much less deformed rocks of the basin. In so far as now known Eurekan orogeny was not accompanied by plutonism or metamorphism. Most folds in Sverdrup Basin rocks are symmetrical with gently dipping limbs; and overturning of beds is rare indeed.

Significant changes in the style of deformations characterize different parts of the Sverdrup Basin, as well as regions of the Franklinian Geosyncline that underwent Eurekan orogeny.

Large areas of the Sverdrup Basin including the northern half or more of Axel Heiberg Island adjacent regions of northwestern Ellesmere Island appear to have been only mildly flexed by compressive forces, but are disrupted by block faulting, or tilted and broken by normal faults, many of which have erratic trends (Bukken Fiord, Cape Stallworthy, Otto Fiord). In fact, normal faults represent the most common deformational features in regions affected by Eurekan orogeny. It is seemingly reasonable to attribute these faults to crustal distention that followed the main episode of Eurekan compression, and many normal faults are demonstrably postorogenic. Nevertheless, several normal faults in Sverdrup Basin rocks are known to be occupied by basic dykes, and available evidence suggests that most of these are Late Cretaceous in age (see p. 000). The problem is unresolved. Possibly some normal faults are related to the Late Cretaceous or early Cenozoic pulse of Eurekan orogeny, but it is also possible that certain dykes may have been emplaced following the climatic pulse of that orogeny in mid-Cenozoic time.

Folds and thrust faults increase in numbers and magnitude towards the southeastern margin of the Sverdrup Basin. Southern Axel Heiberg Island is of particular interest for a belt of well-displayed, long, subparallel folds of low amplitude and long wave lengths (Glacier Fiord). To the north in central parts of the island, these folds give place to a number of shorter and less regular, closely folded anticlines, and complementary, broader and open synclines (Strand Fiord). The latter folds are broken by numerous normal faults and characterized by the largest concentration of anhydrite diapirs in the Sverdrup Basin. It is probable that the folds in southern and central Axel Heiberg Island formed over a decollement at the level of the anhydritic, Otto Fiord Formation of Carboniferous age. It is probable also that the large, westerly dipping Stolz thrust (Eureka Sound North) that marks the eastern boundary of above described structures, soles in this decollement. If the northern trending structures of southern Axel Heiberg Island were in fact developed above a decollement, the underlying early Paleozoic rocks may have quite a different regional trend.

The majority of Eurekan thrusts are high-angle faults that dip to west or northwest, indicating that as in the case of earlier orogenies in these islands, the deformative forces were exerted from the oceanic side of the continent towards the Central Stable Region.

Although thrust faults are not expecially numerous in the Sverdrup Basin as a whole, it is noteworthy that much of the southeastern marginal region of the basin is marked by a series of generally high-angle thrust faults, commonly arranged en echelon (Eureka Sound South, Cañon Fiord, Greely Fiord West, Tanquary Fiord). Presumably the margin of the Sverdrup Basin acted as a buttress reflecting the hinge line that developed with the growth of the basin. However, it is of interest that the continuity of these thrusts is broken where the margin of the basin crosses the Hazen Trough.

The gross structural configuration of the Sverdrup Basin in Axel Heiberg and Ellesmere Islands is that of a southwesterly plunging synclinorium, the principal axis of which coincides approximately with the axis of maximum deposition, discussed earlier. It is this synclinorial character that causes all but the marginal belts of Carboniferous and Permian rocks to pass beneath the cover of Mesozoic and Cenozoic sediments in southwestern Axel Heiberg Island (see Text-fig. 3). Probably the synclinorium was largely effected by differential uplift during Eurekan orogeny, but differential isostatic adjustment post-dating the orogeny, and the possibility that a southwesterly plunge may have characterized the depositional Sverdrup Basin in these islands prior to orogeny, cannot be ruled out as contributing factors.

Finally it should be noted that no practical distinction can be made between Sverdrup Basin terrane and that of the Franklinian Geosyncline. The greater part of the combined areas of these diverse geologic provinces have undergone two or more tectonic adjustments that produced superimposed structures with similar regional trends. Consequently the various orogenic and epeirogenic events have merged through time to form a single orogenic region - the Innuitian Orogen.

Relations of Sverdrup Basin and Gulf Coast Basin. Several interesting comparisons are possible between the development of the Sverdrup Basin and that of the Gulf Coast Basin on the opposite side of the North American continent: (1) Both basins are successor basins superposed on ancient orogenic systems. An angular unconformity marks the surface of separation between the Sverdrup Basin and the underlying Franklinian system, while the Gulf Coast Basin overlies with angular unconformity on the Appalachian and Ouachita orogens of the United States, and their counterparts in Mexico and the Antilles. (2) Both basins developed as roughly oval-shaped depressions, the central and greater areas of which subsided more or less continuously with sedimentation and therefore include the thickest and most complete columns of rock. Along the margins of both basins the sediments are thinner and less complete. There also, the sequence of formations varies from place to place because of the wedging in and out of various units. (3) The sediments of both basins are genetically similar to, and belong with, miogeosynclinal and platform suites of rocks. (4) In neither basin is there a eugeosynclinal counterpart. Volcanic rocks of Carboniferous, Permian and Cretaceous ages occur in the Sverdrup Basin, while Cretaceous and Tertiary volcanic rocks occur in the Gulf Coast Basin. Nevertheless, these rocks constitute only an incidental portion of the total volume of rock in each basin; furthermore their distributions in these basins are not according to a eugeosynclinal plan . (5) Comparable maximum thicknesses of sediments - estimated as 40,000 to 50,000 feet - accumulated in both the Sverdrup and Gulf Coast Basins. (6) By far the greater portions of sediments in both basins are of clastic origin. Furthermore these sediments were derived from the continental side of each basin, in contrast to the respective underlying geosynclines in which the preponderance of clastic sediments was derived from offshore tectonic lands. (7) In both the Sverdrup and Gulf Coast Basins the aggregate thickness of formations as inferred from isopach studies is considerably greater than the thickness of the column of sediments present at any one locality, mainly because the axes of maximum deposition shifted in the directions of the bordering oceans with the passage of time. In the case of the Sverdrup basin, for example, the axis of greatest deposition in Carboniferous and Permian times appears to have been situated approximately parallel to the central west coast of Ellesmere Island. In the Triassic it extended northeasterly through eastern regions of Axel Heiberg Island, while in the Cretaceous it extended northeasterly through western Axel Heiberg Island. (8) Thick and widely distributed units of evaporites occur near the base of the sedimentary sequences in the Sverdrup Basin (Otto Fiord anhydrite) and the Gulf Coast Basin (Louann salt). These evaporitic sequences have been responsible for the numerous diapirs in their respective basins.

There are two principal differences in the development of these two basins: (1) The Sverdrup Basin contains an essentially conformable sequence of Carboniferous, Permian, Triassic, Jurassic, Cretaceous, and early Cenozoic (Paleocene to Miocene) rocks, whereas the Gulf Coast Basin comprises an essentially conformable sequence of Triassic, Jurassic, Cretaceous, Tertiary and Quaternary rocks. (2) The Sverdrup Basin has gone through the full cycle from sedimentary basin to deformed belt. In contrast the Gulf Coast Basin has not undergone orogeny but continues to receive sediments at present.

On the basis of the many similarities in the development of the Sverdrup and Gulf Coast Basins, it is probable that they are genetically similar geological provinces, and that neither difference in age nor structural history militates against this conclusion. Furthermore it would seem that neither basin in question represents a true geosyncline, at least not in the sense of an orthogeosyncline as defined by Stille (1936) and elaborated by Kay (1951).

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Eskimo residents at Resolute, N.W.T., were employed as dog drivers during the field seasons of 1956 and 1957. They included Amagualik and Jebbardi during the first year; and Jebbardi and Jackoosie during the second year. Serving as pilots of the Piper Super Cub aircraft in 1961 were V. Andreason, J. Jamieson (chief pilot and flight engineer) and J. Kershaw. In 1962, M. Olson served as helicopter pilot, and his flight engineer was A.G. Hisock. J. Jamieson piloted the Piper Super Cub aircraft contracted during the 1962 and 1963 seasons. In 1961, J. Kyer served as cook, while J. Siddon operated the radio. In 1962 and 1963, J. Siddon performed both the duties as cook and radio operator. All of the above persons preformed their duties in a very satisfactory manner.

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1 The ages of the majority of formations described in this report are based directly or indirectly on fusulinaceans and ammonoids. The writer is responsible for identifications of the fusulinaceans. The ammonoids were identified by Drs. Furnish, Glenister and Nassichuk. For the most part, fusulinacean and ammonoid identifications are listed opposite their respective stratigraphic levels in the section that are illustrated graphically on figures 1 to 4.

STRATIGRAPHY

GENERAL STATEMENT

Carboniferous and Permian rocks of the Sverdrup Basin constitute a natural grouping of structurally conformable formations, in which the lower and upper boundaries of the combined systems are represented everywhere by clearly marked regional unconformities. Carboniferous rocks lie with angular unconformity on bevelled and truncated structures of the lower Paleozoic Franklinian Geosyncline. The top of the Permian is invariably a disconformity, and throughout the greater part of the basin it is the Lower Triassic Blind Fiord Formation, or correlative strata of the Bjorne Formation that lies on Permian rocks. Although Carboniferous and Permian rocks are separated by an unconformity along southern margins of the Sverdrup Basin in Melville Island (Tozer and Thorsteinsson, 1964) and Grinnell Peninsula (Nassichuk, 1965), throughout the greater and principal part of the basin the intersystemic boundary is not represented by a physical break. Moreover, sedimentation in the basin was apparently continuous across the Mississippian-Pennsylvanian boundary.

The preponderance of Carboniferous and Permian sediments are of marine origin. Arranged in decreasing order of abundance, the principal lithic types include carbonates, quartzose clastics and evaporites. Nonmarine quartzose clastic rocks with coal, and volcanic rocks are present locally. Permian carbonates and evaporites constitute the youngest deposits of their kind in the Canadian Archipelago, as Mesozoic and Cenozoic deposits consists almost exclusively of quartzose sandstone, siltstone and shale. It seems probable therefore, that the close of the Permian marked the end of warm-water conditions in this region.

Carboniferous and Permian rocks within the report area range in age from Early Carboniferous to Late Permian. Represented within this span of geologic time are the stages, Viséan, Namurian, Bashkirian, Moscovian, Zhigulevian, Orenburgian, Asselian, Sakmarian, Artinskian and Guadalupian. The lowermost stage of the Carboniferous (Tournasian), and uppermost stage of the Permian (Djhulfian) are apparently unrepresented in the Sverdrup Basin.

The nomenclature and correlation of Carboniferous and Permian Formation in the report area are summarized in table 1.

It is convenient for purposes of description and correlation to divide Carboniferous and Permian formations of the report area into five stratal sequences, the boundaries between which are marked by disconformities. Many of the complex lateral and vertical relationships that characterize these sequences, as worked out by the present study, are represented diagramatically in a cross-section of the Sverdrup Basin illustrated as text-figure 2. Two and possibly three volcanic formations occur within the Carboniferous and Permian succession, but because they are of limited distribution, and constitute such a minor part of the total thickness of rocks representing these systems consideration of them is deferred to later pages, and the salient features of the five stratal sequences which are outlined below include those of sedimentary rock, only.

1. Lower Carboniferous (Visean) nonmarine sequence. The sequence is represented by a single formation, the Emma Fiord, which consists principally of quartzose clastic sediments. The formation occurs sporadically at the base of the Carboniferous and Permian succession in northern Axel Heiberg and heighbouring parts of northwestern Ellesmere Island.

2. Upper Carboniferous (Namurian) to Lower Permian (Artinskian) marine sequence. This sequence includes the preponderance of Carboniferous and Permian rocks in the Sverdrup Basin (see Text-fig. 2).

The Borup Fiord Formation represents the oldest deposits of this sequence. Outcrops of the formation are limited to northern Axel Heiberg Island and northwestern Ellesmere Island, and where Emma Fiord rocks are absent the Borup Fiord constitutes basal deposits of the Sverdrup Basin. The formation is composed mainly of red quartzose sandstone and conglomerate. It is Namurian in age, and retains relatively uniform characters throughout its areal extent.

In contrast to the Borup Fiord, stratigraphically higher formations in the sequence (early Bashkirian to early Artinskian), change radically in character across the Sverdrup Basin. Five facies belts are developed in these rocks, and they trend southwest to northeast, paralleling the axis of the basin (see Text-fig. 3). From northwest to southeast the belts are characterized as follows: (a) The northwestern carbonate belt is underlain by the Nansen Formation, a thick unit of relatively pure, light coloured limestone; (b) The Basinal evaporitic and clastic belt includes in order upward, the Otto Fiord Formation consisting mainly of anhydrite, and the Hare Fiord Formation made up mainly of dark coloured siltstone, shale, and limestone; (c) Southeastern carbonate belt underlain by the Nansen Formation. This facies belt unites with the northwestern carbonate belt in northwestern Ellesmere Island, (d) Marginal clastic and carbonate belt. The border of the southeastern carbonate belt and the marginal clastic and carbonate belt marks the approximate line along which the Nansen Formation passes southeastward either into combinations of two, or four formations. The twofold combination is most common and includes redbeds of the Canyon Fiord Formation, overlain by carbonate and clastic rocks of the Belcher Channel Formation. The combination of four formations include in ascending stratigraphic order: Canyon Fiord (redbeds); Antoinette (mainly limestone); Mount Bayley (anhydrite); and Tanquary (carbonate and clastic rocks). In general the formations, Antoinette, Mount Bayley and Tanquary are lateral equivalents of the Belcher Channel Formation which ranges from Late Carboniferous to Early Permian. Where the Canyon Fiord Formation is overlain by either the Belcher Channel or Antoinette, its age is mainly Moscovian.

(e) The marginal clastic belt occupies a limited area along the southeast side of the marginal clastic and carbonate belt, in the environs of Cañon Fiord. This belt is underlain by the Canyon Fiord Formation only, which here ranges in age from Bashkirian to Early Permian, and therefore includes strata correlative with the Belcher Channel Formation.

3. Lower Permian (Artinskian) nonmarine sequence. This sequence is represented by a thin unit of light coloured, quartzose sandstone that is referred to the Sabine Bay Formation. The formation is confined to the margin of the Sverdrup Basin where it forms a narrow belt of exposures extending from a short distance south of Cañon Fiord to the north side of Greely Fiord. Insofar as known rocks of the Sabine Bay have no correlatives in deeper parts of the Sverdrup Basin.

4. Lower Permian (Artinskian) marine sequence. Strata of this interval include the Assistance and van Hauen Formations, two relatively thin, correlative rock-units that represent marginal and basinal facies, respectively (see Text-fig. 2). The Assistance is composed mostly of quartzose sandstone. It is distributed along the southeastern margin of the Sverdrup Basin in western Ellesmere Island. The van Hauen consists largely of dark coloured, shale, siltstone and chert, and crops out sporadically over large areas of southwestern and northwestern Ellesmere Island and eastern and northern Axel Heiberg Island.

5. Upper Permian (Guadalupian) marine sequence. Upper Permian rocks have several features in common with the Artinskian marine sequence described above. The Upper Permian sequence includes two, relatively thin, contrasting types of correlative deposits: The Trold Fiord Formation consisting mainly of green glauconitic sandstone, which is exposed along the southeastern margin of the Sverdrup Basin in western regions of Ellesmere Island. Correlative rocks are represented by the Degerböls Formation that consists mainly of light coloured limestone and chert. The Degerböls Formation is exposed over widely separated regions of northern Axel Heiberg, southwestern and northwestern Ellesmere Island. The Trold Fiord and Degerböls Formation are the youngest Paleozoic strata in the Canadian Arctic Archipelago.

1. Lower Carboniferous (Visean) Nonmarine Sequence

Emma Fiord Formation

Definition, Structural Relations and Distribution. The oldest rocks in the Sverdrup basin are made up of nonmarine quartzose clastic deposits that are here designated the Emma Fiord Formation. The type section is located on Kleybolte Peninsula that forms the northwestern extremity of Ellesmere Island (see Pl. 1). The formation is named for a prominent fiord about 18 miles southeast of the type section. Rocks herein referred to this formation were described from exposures in Svartevaeg Cliffs in northern Axel Heiberg Island (see locality 162, *Cape Stallworthy*)[1] by Kerr and Trettin (1962). Their paper was the first to demonstrate the presence of Lower Carboniferous deposits in the Sverdrup Basin. The age of these rocks was based on a microflora determined by Playford and Barss (1963).

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1 Italicized names in parenthesis refer to geological map-areas accompanying this report.

Emma Fiord rocks lies with angular unconformity on various formations of the Franklinian Geosyncline, and they are overlain disconformably by redbeds of the Borup Fiord Formation. The Emma Fiord is of limited distribution. Outcrops of the formation are confined to three general localities: several small areas of exposures on Kleybolte Peninsula; Svartevaeg Cliffs; and on a nunatak about 8 miles northwest of the terminus of Clements Markham Glacier in northeastern Ellesmere Island, which has been reported by R.L. Christie (1964, p. 34).

Lithology and Thickness. The Emma Fiord is a rather uniform sequence of strata with subdued topographic expression. It consists mainly of siltstone that is variably argillaceous, micaceous and carbonaceous, dark grey to black, and thin to medium bedded. Minor constituents include shale that is variably argillaceous and carbonaceous, light grey quartzose sandstone, quartzite pebble conglomerate, and thin coal seams. The type section of the formation is 1,140 feet thick; it is illustrated graphically in section 66 on figure 3. The thickness of Emma Fiord strata at Svartevaeg Cliffs has not been accurately determined, but it is probably in the order of 400 feet. In these exposures three coal seams, each about three feet thick, occur in the basal 100 feet or so of the formation.

Age. The late W.A. Bell has identified the plant fossil Cardiopteris abbensis Read, from a collection made 130 feet stratigraphically above the base of the type section of the Emma Fiord (GSC Cat. No. 6826). Bell comments as follows:

"A single identifiable species is hardly sufficient for refined age reference. The genus _Cardiopteris_, however, is a characteristic element in late Mississippian and early Namurian floras, and the types of _C. abbensis_ were derived derived from a late Mississippian formation (Bluefield Shale, Virginia U.S.A.). A Viséan age is considered most likely".

M.S. Barss has identified a spore assemblage from the same locality and horizon, and his report is given below:

Convolutispora tuberculata (Waltz) Hoffmeister, Staplin and Malloy
Convolutispora clavata (Ishchenko) Hughes and Playford
Reticulatisporites cancellatus (Waltz) Playford
Reticulatisporites peltatus Playford
Reticulatisporites cf. _R. rudus_ Staplin
Microreticulatisporites lunatus Staplin
Murospora aurita (Waltz) Playford
Murospora sublobata (Waltz) Playford
Anulatisporites anulatus (Loose) Potonie and Kremp
Densosporites bialatus (Waltz) Potonie and Kremp
Densosporites rarispinosus Playford
Lycospora uber (Hoffmeister, Staplin and Malloy) Staplin
Lophozonotriletes appendices (Hacquebard and Barss) Playford

"In addition, specifically indeterminable representatives of the following genera occur: _Leiotriletes_, _Punctatisporites_, _Convolutispora_, _Mursopora_, _Densosporites_, and _Reticulatisporites_.

The spore assemblage detailed above is almost identical to the Mississippian microfloras recorded on Axel Heiberg Island by Playford and Barss (1963). These assemblages are considered to be of Viséan age because of their close similarity to Viséan floras of the U.S.S.R. and Spitsbergen".

2. Upper Carboniferous (Namurian) to Lower Permian (Artinskian) Sequence

Borup Fiord Formation

Definition and Distribution.

Emma Fiord strata are succeeded disconformably by a formation of redbeds on Kleybolte Peninsula in northwestern Ellesmere Island, and at Svartevaeg Cliffs on the north coast of Axel Heiberg Island (Cape Stallworthy). The redbeds are more extensively distributed than the Emma Fiord, and constitute basal deposits of the

Carboniferous and Permian succession over large areas of northern Ellesmere Island and northern Axel Heiberg Island, where Emma Fiord strata are absent (see Tanquary Fiord, Otto Fiord West, Cape Stallworthy, Bukken Fiord). In such circumstances the redbeds lie with angular unconformity on lower Paleozoic rocks. The redbeds are here named Borup Fiord Formation. This formation is nowhere better exposed than in the spectacular mountains that border the north side of Hare Fiord, northeast of van Hauen Pass, and outcrops that occur near the headwaters of Stepanow Creek are chosen as the type section (see locality 106, Otto Fiord). The formation is named for a prominent fiord in northern Ellesmere Island, some 47 miles south of the type locality.

Lithology and Thickness. Although locally variable in lithology, the Borup Fiord is uniform in gross aspect. The formation consists mostly of alternating units of dusky red quartzose sandstone and conglomerate, with very small amounts of siltstone, shale, dolomite and limestone. Probably the most distinctive features of the Borup Fiord are its well-bedded character, and prevailing dusky red weathering colours.

The environment represented by the Borup Fiord is not entirely certain. The single collection of fossils found in the type section indicates that the formation is at least, in part marine. Characters suggesting that the formation is mainly, if not entirely marine are: apparent absence of plant remains; rather common occurrence of calcareous cement; scarcity of shallow water sedimentary structures; and well-developed bedding.

The type section of the Borup Fiord Formation on Stepanow Creek is described as follows:

Unit No.	Lithologic Character	Thickness in Feet
	Overlying strata, Nansen Formation, limestone........	unmeasured
	Covered interval, probably tongue of Otto Fiord Formation, anhydrite	100.0
5	Sandstone, quartzose, dusky red, in part greenish grey, fine to coarse grained, thin to medium bedded, variably calcareous	115.0
4	Sandstone, quartzose, dusky red, fine to coarse grained, thin to mainly thick bedded, in part conglomeratic with clasts of quartzite and chert pebbles, minor red siltstone; bed of hematite 10 inches thick occurs at base of unit	35.0
3	Limestone, bioclastic, in part sublithographic greenish grey and medium grey, weathering grey and red, thin to medium bedded; dark grey shale and medium grey siltstone, alternate in basal 5 feet of unit......	25.0
2	Sandstone, quartzose, red, fine to coarse grained, thin to generally thick bedded; in part conglomeratic, clasts formed of granules and pebbles of chert and quartzite	90.0
1	Conglomerate, dusky red, thin to mainly thick bedded; clasts angular to subrounded, varying from granules to cobbles and formed of multicoloured chert, quartzite, quartz and siltstone	275.0
	Total thickness of Borup Fiord Formation	540.0
	Underlying strata, Grant Land Formation, Lower Ordovician and/or Cambrian	

The maximum recorded thickness of the Borup Fiord is 1,290 feet on Girty Creek near the head of Hare Fiord (see Pls. II and VI). The rocks there are summarized as section 68 on figure 3. They consist mainly of alternating sandstone, conglomerate and lesser amounts of siltstone, but a single stratum of mottled pink and yellow, aphanitic limestone, two feet thick occurs 610 feet above the base. The sandstone is dusky red to greyish green, thin to generally medium and thick bedded, fine to coarse grained, partly calcareous and variably resistant. Conglomerate comprises about 25 per cent of this section and consists of granules, pebbles and cobbles of mainly chert and quartzite embedded in a groundmass of sandstone. The phenoclasts vary from angular and subangular to forms which are well rounded. A unit of conglomerate 40 feet thick forms the base of the formation.

The Borup Fiord is 1,240 feet thick on Kleybolte Peninsula (see Pl. 1; section 66, Fig. 3), and it is roughly estimated as 400 feet thick at Svartevaeg Cliffs. The thickness of the Borup Fiord is highly variable, a character that probably results from the fact that the formation was deposited on an unevenly eroded pre-Carboniferous surface of considerable local relief. The minimum measured thickness of the formation - 330 feet - was obtained by H.P. Trettin south-southeast of the head of Fire Bay, a small indentation on the southeast side of Emma Fiord (see locality 111, Cape Stallworthy). Trettin has contributed the following description and comments of of the section at Fire Bay.

Unit No.	Lithological Character	Thickness in Feet
	Overlying strata: Nansen Sound Formation	
4	Mainly dolomite, lesser amounts of sandstone, conglomerate, siltstone as below, reddish weathering; poorly exposed, mostly recessive interval	98
3	Pebble conglomerate, pale olive grey, pale red weathering; fragments of chert, shale, etc. in dolomitic, calcareous and quartzose matrix; fragments observed range up to about 35 mm; poorly sorted and poorly bedded	90
2	Conglomeratic sandstone, greyish red, greyish red to pale red weathering, laminated to thinly laminated; fragments observed range up to a few millimeters; fragments of chert, shale, etc. in dolomitic, calcareous, and quartzose matrix	33

Unit No.	Lithological Character	Thickness in Feet
1	Dolomite, greyish red, greyish red to pale red weathering, calcareous, argillaceous, quartzose, very thin bedded; minor conglomerate with pebbles of chert, shale, etc. in dolomitic, calcareous, quartzose and chloritic matrix	110
	Total thickness of Borup Fiord Formation	331

Underlying strata, member A of the Lands Lokk Formation (Silurian)

Trettin's remarks concerning the section are as follows:

"The conglomerates are poorly sorted and the phenoclasts (fragments more than 2 mm in diameter) in them are subangular to subrounded and of irregular, elongate shapes. The fragments consist of pure chert, shaly chert, dolomitic and calcareous chert, cherty shale, shale, vein quartz, and carbonate rock in about that order of abundance. Relatively clear nodules, about 0.08 to 0.2 mm in diameter that may represent radiolarian remains were observed in several chert fragments, and remains of a sponge spicule was seen in one fragment. Most shale fragments are coated with red weathering hematite.

The sandstone, siltstones, and the sandy and silty matrix of the conglomerates consist of subequal proportions of carbonate and silicate materials. Euhedral to subhedral dolomite of silt to fine sand grade is the predominant carbonate mineral, but anhedral calcite is invariably associated with it. The most abundant silicate is quartz; chert, muscovite, feldspar, and fragments of quartzite and phyllite are present in lesser amounts. A specimen from unit 1 contains sand-sized aggregates of microcrystalline chlorite or glauconite. The sand grains are mostly subangular to subrounded. They are mostly cemented by carbonates, but by quartz where siliceous grains are in contact with each other.

Statistical analysis of 100 points in a thin section established the following approximate composition for a dolomite specimen from unit 1.

Carbonates	60%
Quartz	5%
Phanerocrystalline muscovite	2%
Chert (?)	1%
Feldspar (?)	1%
Opaque and semiopaque materials	30%

The carbonate consists mainly of euhedral to subhedral dolomite of silt grade with interstitial anhedral calcite. An X-ray analysis by A.E. Foscolos indicates that the dolomite: calcite ratio is about 2.5:1, and that small amounts of siderite are also present.

The opaque to semiopaque materials include hematite and clay minerals, identified by Foscolos as muscovite, iron rich chlorites, and kaolinite. The red colour of the rock is due to the hematite.

The rock fragments and silicate minerals in the Borup Fiord Formation at Fire Bay appear to have been derived from relatively close terrestrial sources, and they appear to have been deposited rapidly, without much reworking; this is inferred from the coarse grade of part of the sediments, and from their poor sphericity and roundness. Bedded chert is common in the Ordovician succession of the Hazen Plateau (Trettin, 1968), and in the Ordovician or older Rens Fiord Complex of northern Axel Heiberg Island (Trettin, 1969), and early Paleozoic units such as these may have been the source of the cherty materials.

The dolomite, on the other hand, is probably not terrigenous, but originated contemporaneously with the strata in the depositional environment; this conclusion is based on the commonly euhedral habit of the mineral, and on the scarcity of dolomite in the pre-Pennsylvanian succession of the region.

Features characteristic of open marine environments on the one hand, and of unequivocally nonmarine, fluvial environments, on the other hand, are lacking in these sediments. Shallow marine, intertidal environments are suggested by the combination of the following criteria: coarse grade of part of the clastic sediments; red colour; association of clastic sediments and carbonates, with dolomite as the predominant carbonate mineral; apparent absence of marine fossils at this locality. Oxidizing conditions are indicated by the hematite content and red colour of the sediments and by the absence of carbonaceous matter".

Age and Correlation.

The Borup Fiord has yielded only one collection of fossils, an assemblage of foraminifera (GSC Cat. No. C-266), obtained from unit 3 of the type section. The fauna is reported by B.L. Mamet (see Appendix). Mamet dates this fauna as early Namurian, and as such it represents the oldest marine fauna in the Sverdrup Basin.

Audhild Formation

A sequence of volcanic rocks interposed between the underlying Borup Fiord Formation and overlying Nansen Formation are here named the Audhild Formation. The formation is named for Audhild Bay which forms the southeastern limits of Kleybolte Peninsula. Outcrops of the Audhild are confined to Kleybolte Peninsula where the formation occurs in several isolated fault blocks. The best exposures occur near the southwestern extremity of the peninsula and are chosen as the type section (see locality 66; Cape Stallworthy). The type section is 1,840 feet thick and is illustrated in plate I, and in section 66 on figure 3. It is made up of dark coloured basaltic and spilitic flows and lesser amounts of pyroclastic sediments. The age of the Audhild, as judged from its stratigraphic position, is late Namurian or early Bashkirian.

Otto Fiord Formation

Definition.

Overlying the Borup Fiord Formation is a succession of strata as much as 1,100 feet thick and consisting largely of anhydrite, herein named Otto Fiord Formation for one of the major fiord in northwestern Ellesmere Island. The type section of the Otto Fiord Formation is situated on the north side of Hare Fiord, about three miles northeast of van Hauen Pass. It is illustrated graphically in section 69 on figure 3 and shown in plates III and IV.

Lithology.—

The type section of the Otto Fiord is composed mainly of anhydrite that varies from medium to very thick bedded and massive. At the surface, the formation consists largely of gypsum, an alteration product of anhydrite, but fresh exposures in rapidly eroding streams reveal that the rock is in fact, anhydrite. Anhydrite constitutes about 80 per cent of the total thickness of strata. Interbedded with the anhydrite are 8 units of dark grey limestone varying from two to 50 feet, including a bed of shale about three feet thick.

The Otto Fiord maintains relatively uniform lithologic characters throughout its areal extent. Consequently the description of the type section serves well for all exposures observed in normal stratigraphic position, including the core rocks in all diapirs in the Sverdrup Basin for which the Otto Fiord has almost certainly provided most of the source materials.

The striking white colour of the Otto Fiord as a whole, is a useful criterion for identifying the formation from a distance, or on aerial photographs.

Thickness.—

The greatest known thickness of the Otto Fiord is 1,100 feet, which was obtained for an incomplete section cropping out immediately above the Blue Mountain thrust on the east side of Hare Fiord (see section 70a, Fig. 3). Although the type section of the Otto Fiord does not represent a full section of the formation - the base of the formation there is also a thrust fault - it is nevertheless 1,000 feet thick and very probably represents the greater portion of the formation. Support for this conclusion comes from outcrops of the Otto Fiord on Stepanow Creek, some 17 miles northeast of van Hauen Pass, where a full section of the formation has been measured as 700 feet thick (see Pl. VII).

Stratigraphic Relations.

The Otto Fiord, throughout much of its areal extent, is overlain by the Hare Fiord Formation which consists largely of dark coloured siltstone, shale and limestone. This contact of the Otto Fiord has been observed at a number of places where it appears to be relatively sharp. The basal contact of the Otto Fiord with the Borup Fiord Formation has been observed only on Stepanow Creek, where the contact of the Otto Fiord and Hare Fiord is also exposed. At this locality both contacts appear gradational, suggesting that sedimentation was continuous across these boundaries. Locally, the Otto Fiord is overlain by the Nansen Formation, a thick unit of light coloured limestone.

The facies relationship of the Otto Fiord is well exhibited in the mountains on the north side of Hare Fiord, east of Stepanow Creek. There, on the basis of physical continuity of strata, it is evident that the Otto Fiord is a facies equivalent of the lower portion of the Nansen Formation, the upper and greater portion of which is a facies equivalent of the Hare Fiord Formation. In places, what appears to be completely developed sequences of the Otto Fiord are overlain by the Nansen Formation. In other places however, partial developments of the Otto Fiord in the form of anhydrite, a few tens of feet in thickness are interbedded with limestone in the lower part of the Nansen (see section 68, Fig. 3).

Distribution.

Outcrops of the Otto Fiord occurring in normal stratigraphic position, are shown in geologic maps Eureka Sound South, Greely Fiord West and Otto Fiord.

The Otto Fiord comprises a relatively wide belt of sediments along the axis of the Sverdrup Basin, extending northeasterly across central Axel Heiberg Island into northwestern Ellesmere Island, and terminating northeast of the head of Hare

Fiord. The areal distribution of the Otto Fiord including that of the overlying Hare Fiord Formation are shown as the basinal clastic and evaporitic belt in text-figure 3. While the areal extent of the Hare Fiord Formation is believed to be fairly accurately portrayed in this text-figure, that of the Otto Fiord is an approximation, only. That the Otto Fiord, particularly partial developments of the formation, has a somewhat greater distribution than the Hare Fiord Formation has been noted in previous discussions concerning the relationships of the Otto Fiord and Nansen Formations around the head of Hare Fiord. Further support to this conclusion is found in sporadic, small anhydrite diapirs, obviously derived from Otto Fiord rocks, that intrude the Nansen Formation in widely separated parts of Axel Heiberg and Ellesmere Islands outside of the boundaries of the basinal facies belt in text-figure 3 (<u>see</u> for example <u>Bukken Fiord</u>).

<u>Age</u>.

With the exception of diapirs which are judged to have been derived from the Otto Fiord, outcrops of the formation in normal stratigraphic position have not yielded datable fossils. Nevertheless the Otto Fiord can be dated within fairly narrow limits on the basis of its stratigraphic position above the Borup Fiord Formation, dated as Namurian, and below the Hare Fiord Formation, basal beds of which contain ammonoids of early Moscovian age. On this basis it is reasonable to conclude that while the Otto Fiord may include strata of Namurian and/or Moscovian ages, the formation is probably mainly Bashkirian in age. Evidence that the Otto Fiord is in part at least, Bashkirian comes also from the study of ammonoids obtained from interbedded limestone and shale in two widely separated diapirs in the Sverdrup Basin. Ernst W. Hoen (1964, p. 8), geologist to the "Jacobsen-McGill Arctic Research Expedition, 1959-1962", collected the following ammonoids from limestone interbedded with anhydrite and gypsum in the centre of the South Fiord Diapir in western Axel Heiberg Island.

Locality 181; GSC Cat. No. 47996
cf. "Eumorphoceras carinatum" Schmidt
Bisatoceras sp.
Reticuloceras reticulatum Phillips

Identifications are by W.M. Furnish and B.F. Glenister who regard the ammonoids as Namurian in terms of the European standard, an age that equates with the Bashkirian as used in this report. W.W. Nassichuk (1968, p. 205) has collected ammonoids from limestone and shale interbeds in the Barrow Diapir in northeastern Melville Island. One collection included species of Reticuloceras Bisat, and Bisatoceras Miller and Owen. A stratigraphically higher bed yielded representatives of Gastrioceras Hyatt, and Branneroceras Plummer and Scott. Nassichuk (personal communication) regards these collections as indicating early and late Bashkirian ages, respectively.

Hare Fiord Formation

Definition.

This formation is a body of mainly dark coloured siltstone, shale and limestone. It is named for Hare Fiord in northwestern Ellesmere Island where the formation is splendidly displayed in a series of outcrops long the north side of the fiord, northeast of van Hauen Pass. The type section is located about three miles northeast of the pass and is shown on plates III and IV. Throughout its areal extent the Hare Fiord Formation lies conformably on evaporitic rocks of the Otto Fiord Formation and is overlain by the van Hauen Formation. A disconformity marks the surface of separation between the Hare Fiord and van Hauen, a rock unit that the Hare Fiord more closely resembles than any other within the Carboniferous and Permian succession in the area of this report.

Distribution.

The Hare Fiord Formation crops out in the environs of Hare Fiord and Nansen Sound in northwestern Ellesmere Island, and in eastern Axel Heiberg Island (see Otto Fiord, Greely Fiord West, Bukken Fiord, and Eureka Sound North). Its areal distribution, including that of the underlying Otto Fiord Formation, is shown also in text-figure 3 as the basinal clastic and evaporitic belt. It is of interest to note that the northeastern extent of the formation is limited northeast of the head of Hare Fiord by the coalsecence of the flanking belts formed by contemporaneous sediments of the Nansen Formation. The Hare Fiord Formation appears to represent deposits laid down along the axis of the Sverdrup Basin as it existed in Carboniferous and Permian times.

Thickness and Facies Equivalent.

The formation is shown graphically in sections 69, 70b and 70c on figure 3, and in sections 59 and 60 on figure 2. These sections indicate a range in thickness of 1,000 to about 4,100 feet.

The Hare Fiord is a facies equivalent of the generally thicker Nansen Formation which is characterized by relatively pure carbonate rocks (see Text-fig. 2). The facies boundary of the Hare Fiord and the Nansen is arbitrarily established at the change from dark coloured, dominantly clastic rocks, to light coloured dominantly carbonate rocks, respectively. Transitional rocks of the two formations are prominently displayed in the territory between the heads of Otto Fiord and Hare Fiord in northwestern Ellesmere Island.

While little information is available on regional variations in thickness of the Hare Fiord, the formation appears to be thickest near the region of facies change into the Nansen Formation. It is there also that limestone constitutes a significant percentage of Hare Fiord rocks. The Hare Fiord is thinnest in central regions of its outcrop area where siltstone and shale make up most of the formation.

Lithology.

Although the proportion of lithologic types represented in the Hare Fiord vary from place to place, the formation on the whole consists of quartzose siltstone, shale and limestone, and lesser amounts of chert and quartzose sandstone.

A broad two-part subdivision appears to characterize virtually all complete sections of the Hare Fiord. It includes a basal unit that consists mainly of bedded limestone, and an upper, thicker unit that is made up largely of noncalcareous siltstone and shale.

The limestone is of three main types (1) It is represented predominantly as an aphanitic to finely crystalline rock that is variably argillaceous or silty, and more rarely cherty. This rock occurs in beds that are ordinarily thin to medium bedded (<u>see</u> Pl. VII), but it also includes some which are very thin, thick and very thick bedded. (2) It occurs less commonly as thin to thick beds of bioclastic limestone, or as coquinas consisting of varying combinations of fusulinaceans, brachiopods, solitary corals, bryozoans and crinoid columnals. (3) It is represented also as unbedded reefs.

The siltstone is variably argillaceous and siliceous, and typically medium to thick bedded. It is mostly noncalcareous and hard, but it is represented also as beds that are noticeably calcareous and others that are soft. Carbonaceous impressions suggesting fossil algae are commonly observed on bedding planes in the siltstone.

The shale occurs generally as thin interbeds or as bedding plane partings in the limestone and siltstone, but in places it forms units varying in thickness from a few feet to several tens of feet. There is nothing especially distinctive about this rock type except that it is commonly noncalcareous and variably silty.

The sandstone is generally very fine to fine grained, and thin to medium bedded.

The chert occurs as bedded deposits and as nodules and irregular masses distributed in the limestone. The principal colours represented by the chert include shades of grey, blue and purple.

Two outstanding characteristics of the Hare Fiord are: (1) The prevailing medium grey to dark grey fresh surface and weathering colours of its rocks. Various shades of brown also constitute fairly common weathering colours, especially in the siltstone and bedded limestone. (2) The presence of unbedded, light coloured reefs that occur in the region of facies change with the Nansen Formation in the vicinity of Hare Fiord. The reefs are distributed sporadically in the lower and middle portions of the formation. They vary from a few feet to as much as 200 feet in thickness (see Pl. VII). They are represented as lens-shaped masses and mounds that are generally surrounded by thin- to medium-stratified, impure limestone and siltstone which dip outward from the reefs in such a manner as to indicate that the latter developed as topographic prominences on the sea floor. The reefs are made up of limestone that is light grey to medium light grey, and yellowish grey, and weather to yellowish grey and greyish yellow. The limestone is commonly characterized by a granular texture and is variably porous or vuggy. It contains many grains identifiable as fossils, and in rare instances yields well preserved forms such as ammonoids, brachiopods, fusulinaceans, ostracods and algae. Fusulinaceans and ammonoids collected from various reefs indicate a range in age of Moscovian to about Zhigulevian.

Despite the prevailing dark colour of Hare Fiord rocks they are nowhere markedly bituminous. When struck or broken, however, they commonly yield a slight fetid odour.

Composed mainly of relatively hard, dark siltstone and limestone, the Hare Fiord is only moderately resistant to erosion. The formation presents a characteristic dark appearance on aerial photographs.

The type section of the Hare Fiord is represented graphically in section ~~67~~ 69 on figure 3. It consists of four, broadly defined lithologic units of local extent. The unusually high percentage of limestone in this section reflects proximity to correlative rocks of the Nansen Formation. Details of the section are given below.

Unit No.	Lithologic Character	Thickness in Feet
	Overlying strata, van Hauen Formation	
4	Limestone, siltstone, shale and chert; limestone and siltstone are of about equal proportions and interbedded with lesser amounts of shale; limestone, variably argillaceous or silty, medium dark grey to dark grey; aphanitic to very fine grained, thin to medium bedded, weathering to various shades of grey and brown; siltstone, variably calcareous or variably argillaceous, medium dark grey to dark grey, thin to medium bedded, weathering to various shades of grey and brown; shale, noncalcareous, variably silty, dark grey to black; a 10-foot unit of thin bedded, dark grey chert forms base of unit	1,000.00
3	Shale, and lesser amounts of siltstone; shale, noncalcareous, dark grey to black; siltstone, variably argillaceous dark grey to black	240.00
2	Limestone, shale and subordinate chert; unit is similar in most respects to unit 1 which is described below, with the exception that shale constitutes about 1/4 of unit and the amount of chert is very small. Fauna collected 100 feet above base of unit; <u>Fusulinella</u> sp., <u>Fusulina</u> sp., and <u>Triticites</u> sp., Fauna collected 220 feet above base of unit; <u>Fusulinella</u> sp., and <u>Triticites</u> sp.	800.00

Unit No.	Lithologic Character	Thickness in Feet
1	Limestone, subordinate shale and chert; limestone constitutes about 4/5 of unit; it is typically argillaceous or cherty, medium grey to black, aphanitic, thin to thick bedded, hard and dense; shale comprises about 1/10 of unit; it is dark grey to black and commonly sooty; chert, various shades of grey, blue and purple, occurs in beds up to 5 feet thick and as irregular intergrowth in limestone. Reef knolls up to 40 feet in thickness occur in this unit and unit 2, along the mountain front on either side of type section. Fauna collected 90 feet above base of unit; Stenopronites cf. S. arkansasensis, Diaboloceras D. varicostatum, Pseudoparalegoceras cf. P. kesslerense, Eosianites cf. E. smithwickensis. Fauna collected 150 feet above base of unit; Fusulinella sp.	440.00
	Total thickness of Hare Fiord Formation	2,480.00
	Underlying strata, Otto Fiord Formation	

Blue Mountains, Northwestern Ellesmere Island

An unusual development of the Hare Fiord is exposed in the Blue Mountains between Hare Fiord and Greely Fiord (see Greely Fiord West). There the formation is exposed in a series of excellent exposures above the southeast dipping Blue Mountains thrust which crops out variously within evaporitic rocks of the Otto Fiord Formation, or near the base of the Hare Fiord (see Pls. VIII and IX). Two sections of the Hare Fiord in this area are illustrated graphically in sections 70b and 70c of figure 3.

Section 70c was studied about a mile northeast of Hare Fiord Diapir. At this locality basal beds of the Hare Fiord are represented by a unit of alternating siltstone and fine-grained sandstone, about 160 feet thick. The siltstone and sandstone are variably calcareous, light grey to greenish grey, and occur in thin-to thick-beds. This siltstone-sandstone unit is surmounted by about 5 feet of dark grey, thin-bedded limestone, above which follows a covered interval of some 40 feet. The covered interval is in turn overlain by strata that is similar lithologically to the basal portion of section 70b discussed below. The basal siltstone-sandstone unit lies with sharp, yet conformable contact on the Otto Fiord Formation, and is of interest in that it represents the only known occurrence of significant amounts of quartzose clastic rocks at the base of the Hare Fiord.

A broad twofold subdivision is evident in section 70b which was measured in a ravine about three miles northeast of section 70c. The upper division underlies the van Hauen Formation, and is 3,300 feet thick. It consists largely of dark coloured siltstone, limestone and shale, and minor amounts of sandstone, all of which exhibit typical Hare Fiord characters. Fossils in these rocks indicate a range in age of about Zhigulevian or Orenburgian to early Permian. The lower unit is 650 feet thick, and though the base is marked by the Blue Mountain thrust this thickness is judged to represent a nearly complete sequence of the unit along the line of section. This unit is composed mainly of limestone that is massive to poorly bedded, and weathers to medium light grey and greyish yellow. The thickness of the lower unit is highly variable and varying from about 400 to 1,800 feet over short distances along the fault line scarp. About seven miles northeast of the section 70b the lower unit grades laterally into dark coloured limestone and clastic rocks that are indistinguishable from the upper member. In most places the upper surface of the lower unit is moderately level and appears to be overlain conformably by beds of the upper unit. In other places however, beds of the upper unit abut against irregular protuberances of the upper surface of the lower unit suggesting disconformable relations (see Pls. VIII and IX). Fusulinaceans collected in the lower unit indicate that these rocks are mainly Moscovian in age. Hare Fiord rocks in this region are the subject of a detailed study by G.F. Bonham - Carter (1966, 1969), who interprets the lower, light coloured limestone as representing a "back-reef" deposit.

Age.

The Hare Fiord is considered to range in age from early Moscovian to early Artinskian. Evidence for this conclusion is based partly on the study of ammonoids and fusulinaceans obtained from the Hare Fiord, and partly on the age of correlative formations within the report area.

The ammonoids, Stenopronorites cf. S. arkansasensis, Diaboloceras cf. D. varicostatum, Pseudoparalegoceras cf. P kesslerense, and Eoasianites cf. E. smithwickensis which were collected 90 feet above the base of the type section were identified by W.M. Furnish and B.F. Glenister who date the fauna as early Atokan (= early Moscovian).

A correlative, but larger fauna of early Moscovian ammonoids was collected by R.L. Christie and W.W. Nassichuk from a bioherm in the lower portion of the Hare Fiord, some 12 miles northeast of the type section (see Pl. VII). Nassichuk and Furnish (1965) have identified this fauna as including species of the following genera. Maximites Miller and Furnish; Proshumardites Rauser; Bisatoceras Miller and Owen; Eosianites Ruzhencev; Syngastrioceras Librovitch; Pseudoparalegoceras Miller; Neoiceras Hyatt; Winslowoceras Miller and Downs; Neodimorphoceras Schmit; Boesites Miller and Furnish; Stenopronorites Schindewolf; Metapronorites Librovitch; and Christioceras Nassichuk and Furnish.

The fusulinaceans, Fusulinella sp., Fusulina sp., and Triticites sp., obtained from unit 2 of the type section, suggest correlation with the Zhigulevian Series.

The ammonoid, Paragastrioceras n. sp. identified by Nassichuk, Furnish and Glenister (1965), from Hare Fiord rocks east of Hare Fiord (see Pl. VIII) is dated by these authors as Early Permian.

Environment of Deposition. With the exception of the reefoid masses described earlier, there is evidence to indicate that the dark coloured, bedded rocks of the Hare Fiord were deposited in stagnant, and possibly deep water. The formation is nearly unfossiliferous and it is evident that normal bottom living organisms were unable to live in the environment represented by these sediments. The scarce fossils, represented principally by brachiopods, corals and bryozoans, are commonly broken and abraded suggesting that they may have been transported from neighbouring shelf areas, and pelagic forms such as the ammonoids provide no indication as to depth of water. In contrast, it seems reasonable to assume that the relatively pure, shelf-type limestone of the correlative Nansen Formation was laid down in shallower, clearer and better aerated water.

The distribution of Hare Fiord exposures, more or less surrounded by the Nansen Formation, suggests that the clastic deposits of the Hare Fiord were winnowed in periodically from the southeast, across the shelf areas that were receiving Nansen deposits. However, the possibility of a contributing source area to the northwest cannot be ruled out (see p. 00). It seems reasonable to assume that the basin subsided more rapidly than the surrounding shelf areas in order to receive and entrap these clastic deposits. It is also possible that subsidence of the basin was so rapid that sedimentation did not keep pace with it and the sea floor stood lower in the basin than on the surrounding shelf areas.

Nansen Formation

Definition and Distribution.

The Nansen Formation is here named for a thick sequence of limestone with subordinate amounts of quartzose clastic sediments that constitute the most widespread unit of the late Paleozoic succession in the area of this report. The formation is named for Nansen Sound that separates Axel Heiberg Island from northwestern Ellesmere Island, and which together with Greely Fiord and connecting fiords represents the longest fiord system in the world. Superb outcrops of the Nansen Formation that occur along Girty Creek near the head of Hare Fiord in northwestern Ellesmere Island are here chosen as the type section. These outcrops are shown in plates II and VI, and illustrated graphically in section 68 on figure 3.

The Nansen occupies two belts of exposures shown on text-figure 3 as the northwestern carbonate belt, extending from northwestern Axel Heiberg Island into northwestern Ellesmere Island; and the southeastern carbonate belt, which traces a northeasterly path along western Ellesmere Island and unites with the northwestern belt east of the head of Hare Fiord in northwestern Ellesmere. Distribution of the Nansen is shown also in geologic maps, Eureka Sound South, Tanquary Fiord, Greely Fiord west, Otto Fiord, Cape Stallworthy, and Bukken Fiord.

The Nansen is topographically prominent and offers many striking features in the landscape. It stands in steep fiord walls, forms craggy mountain peaks, nunataks and the crests of numerous ridges, all of which contribute to the grandeur and scenic beauty of these two northern islands.

Stratigraphic Relations.

Facies relations of the Nansen are shown in figures 2 and 3. That the formation is a facies equivalent of the Otto Fiord and Hare Fiord Formations which occupy axial regions of the Sverdrup Basin has already been noted in the description of these formations. Along the boundary of the southeastern carbonate belt and the marginal clastic and carbonate belt (see Text-fig. 3), the Nansen gives way in a southeasterly direction, either to a combination of two formations (in order upwards, Canyon Fiord, and Belcher Channel), or a combination of four formations (in order upwards, Canyon Fiord, Antoinette, Mount Bayley and Tanquary). The transition from the Nansen to the Canyon Fiord and Mount Bayley Formations involves changes from one rock type to another. On the other hand the Antoinette, Tanquary and Belcher Channel Formations are lithologically similar to the Nansen, and separated from it by arbitrary boundaries.

The upper contact of the Nansen is everywhere a disconformity, and in different regions different formations overlie the Nansen. The Nansen is generally overlain by one of four Permian formations: van Hauen, Esayoo, Degerböls or Trold Fiord. Locally east of Tanquary Fiord in northern Ellesmere Island, the Nansen is succeeded by the Lower Triassic Bjorne Formation (see Pl. XXVI). The lower contact relations of the Nansen are also variable and involve four stratigraphic situations. (1) Throughout the greater part of its areal extent, the Nansen grades upward from the underlying Borup Fiord Formation without a sharp break. (2) Locally, in the vicinity of facies change with the Hare Fiord Formation, Nansen strata lie gradationally on Otto Fiord evaporites. (3) On Kleybolte Peninsula in northwestern Ellesmere Island, volcanic rocks of the Audhild Formation are intercalated between the Borup Fiord and Nansen Formations (see section 66, Fig. 3). (4) On Raanes Peninsula in western Ellesmere Island, Nansen beds lie with angular unconformity on the Middle Ordovician Cornwallis Group (see section 63, Fig. 2).

Thickness.

Little concrete information is available on regional variations in the thickness of the Nansen, as only two uninterrupted sections were measured. One of these is the type section of the formation which is 7,780 feet thick; the other section occurs near the northwestern extremity of Ellesmere Island and included about 4,000 feet of strata (see section 66, Fig. 3). Nevertheless, on the basis of information provided in figures 2 and 3, in which widely separated, complete and incomplete sections of the Nansen, and formations correlative with the Nansen, are arranged in consecutive lines across the Sverdrup Basin, it seems reasonably safe to conclude that: (1) the Nansen is thickest in the vicinity of facies with the Otto Fiord and Hare Fiord Formations, and that it thins in either a northwesterly or southwesterly direction; (2) the thicknessess of 4,000 feet and 7,780 feet probably represent orders of minimum and maximum thickness respectively, for the Nansen.

Lithology.

Measured sections of the Nansen are shown graphically in sections 57 and 58 on figure 2, sections 65 to 68 on figure 3, and section 78 on figure 4. As typically developed the Nansen is a remarkably uniform body of evenly bedded, ordinary limestone that is sparingly fossiliferous. The most common limestone is a compact, aphanitic to fine-grained, mainly thick-bedded rock that contains no recognizable organic structures. Interstratified with these rocks are subordinate biogenic limestones that range from rare coquinas of fusulinaceans, brachiopod shells, bryozoans, to limestone with granular texture containing many grains identifiable as fossil remains, particularly crinoid columnals, and the occasional bed of oolitic and pisolitic limestone. The limestones are commonly light grey to medium grey on fresh surfaces, and the prevailing weathering colours are light grey, yellowish grey or greyish yellow.

In certain areas, chert that is bluish grey or light grey, and occurs as nodules and beds, constitutes an important lithologic type, particularly in the upper part of the formation on Axel Heiberg Island and on Kleybolte Peninsula of northwestern Ellesmere Island (see section 65, Fig. 3; and sections 57 and 58, Fig. 2).

The transition from Nansen strata to the predominantly dark coloured clastic sediments of the correlative Hare Fiord Formation takes place along a fairly definite boundary, primarily by intergrading, and partly by intertonguing of lithic units. Traced toward this facies boundary, the limestones of the Nansen become progressively darker in colour, and more distinctly bedded by virtue of shale and siltstone that occur as interbeds and bedding plane partings. These transitional features are well displayed in an imposing line of cliffs on the south side of Otto Fiord (see Pl. X).

Outcrops of the Nansen in the southeastern carbonate belt (see Text-fig. 2) provide another interesting example of transitional rocks in that formation. In this belt, which can be followed from Blind Fiord to near the head of Tanquary Fiord, the Nansen is characterized by alternating units of limestone, siltstone and sandstone, and minor amounts of shale. Here as elsewhere in the Nansen, limestone is the dominant lithology, particularly in the upper few hundred feet of the formation where it is commonly thick bedded, coarse grained, and biogenic, and occasionaly reefoid (see Pl. XIII). Indeed, biogenic limestones represent the dominant carbonate, and grano-blastic varieties are reduced to a subordinate role. Moreover, the limestones commonly contain various admixtures of silt, sand and clay, and are characterized by medium to dark grey fresh surface colours.

The sandstone and siltstone commonly occur in units up to 50 feet or more in thickness. The weathering colours of these rocks, in harmony with the units of limestone, are generally light grey to greyish yellow and yellowish grey; and they are variable calcareous and soft. Thus, while the overall light colours that typify the Nansen throughout most of its areal extent persist in ~~this~~ transitional rocks, the recessive weathering clastics betweeen harder units of limestone impart a distinctive banded appearance to the formation when viewed from a distance (see Pls. XIII, XXVI).

An unusual development of the southeastern transitional facies of the Nansen, mentioned earlier as lying with angular unconformity on Ordovician rocks on Raanes Peninsula, merits further note. More specifically the Nansen Formation in question is situated between the north trending Blind Fiord thrust and Trold Fiord thrust (see Eureka Sound South). Two partial, but nevertheless overlapping sections of the formation in this area are illustrated graphically in sections 62 and 63 on figure 2. In territory east of the Trold Fiord thrust, stata correlative with the Nansen are represented by the Canyon Fiord Formation (mainly red sandstone), and the overlying Belcher Channel Formation (mainly grey carbonate and clastic rocks). While strata correlative with the Canyon Fiord and Belcher Channel can be differentiated on faunal grounds in the Nansen between these thrust faults, no well marked lithologic break is evinced, as Canyon Fiord equivalents are characterized by greater amounts of light- coloured limestone and clastic rocks than typical developments of that formation, and units of red clastics which are normally absent in the Belcher Channel, occur within Belcher Channel equivalents. Indeed, strata assigned to the Nansen between the thrust faults seem to represent a facies precisely intermediate between typical developments of that formation and typical developments of the Canyon Fiord and Belcher Channel Formation.

The northwesternmost exposures of the Nansen are found on the south side of Bunde Fiord on the west coast of Axel Heiberg Island, and an incomplete section studied there is of special interest for a unit of quartzose sandstone, 360 feet thick that occurs in an otherwise typical development of the formation in northwestern regions of the report area (see section 57, Fig. 2). The section includes 2,700 feet of beds, and its base is the Bunde Fiord thrust. The sandstone is situated 1,180 feet above the thrust. It is light grey to medium light grey, fine grained, thin to medium bedded, and variably hard and very soft. It represents the only significant occurrence of sandstone known in northwestern regions of the northwestern carbonate belt of the Nansen (see Text-fig. 3), and may indicate the presence of a northwest source area of quartzose clastic deposits in Nansen time.

The most common fossils in the Nansen are fusulinaceans, corals, brachiopods and bryozoans. Fossils are sparingly represented in typical developments of the Nansen where they are commonly silicified, but relatively abundant in strata transitional between the southeastern carbonate belt and marginal clastic and carbonate belt. There fusulinaceans are important rock-formers and commonly compose more than half the volume of individual beds (e.g. section 61, Fig. 2).

Age.

Sections of the Nansen that lie directly on the Borup Fiord Formation are considered to range from early Bashkirian to early Artinskian. Where the Nansen lies on complete developments of Otto Fiord evaporites the formation ranges from early Moscovian to early Artinskian. The latter age range is assigned also to the Nansen between Trold Fiord and Blind Fiord where the formation lies unconformably on Ordovician rocks.

The presence of strata representing each and every series included in the span of time given above cannot be demonstrated solely on the basis of fossils collected in the Nansen. For instance there is no faunal evidence to indicate the presence of Bashkirian and Orenburgian rocks. That all series from the Bashkirian to early Artinskian are represented is based on: (1) studies of fusulinaceans and ammonoids collected in the Nansen; (2) faunal evidence obtained from correlative formations; and (3) apparent absence of physical breaks in the formation that might suggest missing series.

The presence of Moscovian strata in the Nansen are indicated by such fusulinacean genera as *Profusulinella*, *Paraeofusulina* and *Fusulina* found in Raanes Peninsula (*see* section 63, Fig. 2). In section 62 on figure 2, measured also on Raanes Peninsula, several hundred feet of the formation are characterized by associated species of *Triticites* and *Fusulinella* that suggest a Zhigulevian age. Higher beds in the same section yield species of *Schwagerina* and *Fusulinella* which are probably Asselian or Sakmarian in age. *Schwagerina hyperborea* (Salter), a form considered to indicate an early Artinskian age, was collected 20 feet stratigraphically below the top of the Nansen near McKinley Bay in northern Ellesmere Island (*see* Pl. XXVI).

Nassichuk (1969) has described the ammonoid *Parashumardites* sp., which he considers Zhigulevian in age, from rocks occurring in the region of facies change between the Hare Fiord and Nansen Formations on the north side of Hare Fiord in northwestern Ellesmere Island. Nassichuk originally regarded the host rock of this ammonoid as the Hare Fiord Formation, but he (personal communication) now considers the rock more properly assigned to the Nansen.

Problem of the Nansen in Western Axel Heiberg Island.

Westernmost exposures of the Nansen occur in the upthrown sides of several major faults in the environs of Bunde Fiord in western Axel Heiberg Island (see Bukken Fiord). There is a possibility that Permian rocks may be absent in the Nansen of this region as fusulinaceans and other fossils that would indicate the presence of these rocks have not been found. This interesting possibility is illustrated by an incomplete section of the Nansen that was studied on the south side of Bunde Fiord (see section 58, Fig. 2). The Nansen in this section is 2,400 feet thick. It is overlain disconformably by the late Artinskian van Hauen Formation, and its base is the Griesbach Creek thrust. The section has yielded fusulinaceans from two different stratigraphic levels. One collection was obtained 610 feet above the base of the section. It consisted of species of *Fusulinella* that exhibit affinities with Moscovian forms. The second collection was made 150 feet below the top of the formation, and identified as *Triticites* sp. A. *Triticites* sp. A is a relatively primitive member of the genus, and suggests a Zhigulevian rather than Orenburgian age.

Triticites sp. A is known from one other locality in the report area. It occurs in the Antoinette Formation in western Ellesmere Island (see section 71, Fig. 3). There, 3,800 feet of strata that are demonstrately correlative with the upper portion of the Nansen in other regions of Ellesmere Island, overlie *Triticites* sp. A. Included in this interval of strata is the upper, about one third of the Antoinette Formation, and the Mount Bayley and Tanquary Formations, which collectively span the Zhigulevian or Orenburgian to early Artinskian Series (see Table I).

It is possible that the unusual small thickness of Nansen strata (150 feet) that overlies Triticites sp. A in section 58 south of Bunde Fiord, is the result of depositional thinning in this region, and that these strata in fact, accommodate the Zhigulevian or Orenburgian to early Artinskian Series. Nevertheless, it seems more reasonable to assume that the absence of latest Carboniferous and early Permian fossils reflects erosional thinning, particularly in view of the disconformity that everywhere marks the top of the Nansen. If this is in fact the case, the Bunde Fiord area was probably the site of considerable uplift and erosion, postdating the Nansen and predating the van Hauen Formation. No clear choice of these two hypotheses can be made without further investigations of the Bunde Fiord region.

Volcanic Rocks of Uncertain Age in Northwestern Ellesmere Island.

An unnamed formation composed of nearly flat-lying volcanic flows and pyroclastic rocks of undetermined thickness, is exposed over a large area of the peninsula formed by Audhild Bay and Emma Fiord in northwestern Ellesmere Island (see Cape Stallworthy). The volcanic rocks lie concordantly on limestone strata of the Nansen Formation, which on this peninsula is only a few hundred feet thick. A collection of fusulinaceans that indicate a Late Carboniferous (Moscovian) age was obtained in the Nansen at locality 110, about 100 feet stratigraphically below the volcanic rocks. The unusually small thickness of the Nansen in this region and the absence of younger Carboniferous and Lower Permian faunas that are generally represented in the formation, suggest that the lower part of the Nansen is all that is represented here. Unfortunately, no formation is known to overlie the volcanic rocks, and their age is therefore uncertain. Possibly these unnamed volcanic rocks were at one time intercalated in the Nansen Formation. Nevertheless, the possibility that these rocks are in fact the Lower Permian Esayoo Formation (see p. 00), or represent a still younger episode of extrusion, cannot be excluded on the basis of available evidence.

Canyon Fiord Formation

Definition, Distribution and Stratigraphic Relations.

The Canyon Fiord Formation is a unit of redbeds that crops out along the southern and southeastern margins of the Sverdrup Basin where it lies with angular unconformity on rocks of the Franklinian Geosyncline. The formation forms a narrow belt of exposures that trends west to east across northern Melville Island (Tozer and Thorsteinsson, 1964, p. 93; Nassichuk, 1965); and it is exposed over a limited area on Grinnell Peninsula, Devon Island (Nassichuk, op. cit.). Exposures of the Canyon Fiord in the report area are confined to western Ellesmere Island where they are divisible into two belts characterized by different ranges in age. 1. The formation is most widely distributed in the marginal clastic and carbonate belt (see Text-fig. 3) which forms a narrow strip of territory trending northeasterly from Bjorne Peninsula to, and beyond Tanquary Fiord. In this belt the Canyon Fiord is represented, for the most part, by strata of Late Carboniferous (Moscovian) age only, that is overlain gradationally by either the Belcher Channel Formation (mainly carbonate and Late Carboniferous to Early Permian in age), or a succession of three formations (which are collectively correlative with the Belcher Channel Formation) in order upwards, Antoinette, Mount Bayley and Tanquary (see Pls. XIX, XX, XXI and XXVII). An exception to the above generalization is found near the headwaters of the Tschernyschew River on Hamilton Peninsula where the Canyon Fiord includes rocks as old as Bashkirian (see Pl. XVI). 2. The type section of the formation is a little over two miles southeast of Caledonian Bay, a small indentation on the north side of Cañon Fiord in western Ellesmere Island (see Pl. XIV). This section is part of a relatively narrow belt of Canyon Fiord outcrops - the marginal clastic belt of text-figure 3 - that extends north and south of Cañon Fiord. The Canyon Fiord in this belt is unique insofar as it ranges in age from Late Carboniferous (Bashkirian) to Early Permian (Sakmarian and possibly up to early ~~Permian~~), and includes beds that represent the facies equivalents of the Belcher Channel Formation. The areal distribution of the Canyon Fiord is shown also in geologic maps, Baumann Fiord, Eureka Sound south, Greely Fiord East, Greely Fiord west and Tanquary Fiord.

History of Study. The Canyon Fiord Formation was named by J.C. Troelsen (1950, p. 65), geologist to the "Danish Thule and Ellesmere Land Expedition, 1939-41", under the leadership of James van Hauen. On this expedition, his first of two journeys to Cañon Fiord[1, 2], Troelsen (op. cit.) did not observe the base to his Canyon Fiord Formation,

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1 Cañon Fiord was discovered and named by members of Otto Sverdrup's "Second Norwegian Expedition in the Fram, 1898-1902". (Sverdrup, 1904). For several years following Sverdrup's work, many published maps applied the alternative spelling of "Canyon Fiord" to Sverdrup's "Cañon Fiord", which accounts for Troelsen's spelling of the name of the formation. Although the officially adopted spelling is now "Cañon Fiord", it seems most practical to retain Troelsen's original spelling of the formation's name (see Article 12, Code of Stratigraphic Nomenclature).

2 Troelsen (1950, p. 67) proposed the name Greely Fiord Group for nine stratigraphic divisions, aggregating about 700 meters in thickness, that crop out along the north shore of Greely Fiord, on either side of the junction with Tanquary Fiord. Troelsen's stratigraphic divisions are described briefly as follows: Division 1; reddish weathering fossiliferous limestone, about 60 meters thick, and apparently lying with angular unconformity on intensely folded rocks of the Cape Rawson Formation. Division 2; yellow, crossbedded, unfossiliferous sandstone and conglomerate, about 30 meters thick. Division 3; gray, massive, commonly arenaceous limestone with nodules of brown chert, at least 100 meters. Division 4; east of the mouth of Tanquary Fiord this division consists of slightly metamorphosed and folded shale and limestone; whereas west of the fiord it consists of "white and gray, fine-grained marble, certain layers of which are strongly brecciated, while others are locally folded because of differential movement between enclosing, more competent bed . . . ". This division is at least 162 meters thick. Division 5; brown limestone, commonly argillaceous or arenaceous, and characterized by nodules of chert; at least 65 meters thick. From this sequence Troelsen identified the following: *Dictyoclostus transversalis* (Tschernyschew), *Marginifera involuta* Tschernyschew, *Marginifera* sp., *Camarophoria* sp., of the group of *C. mutabilis* Tschernyschew, and *Fenestella* sp. Division 6; greenish-white, unfossiliferous limestone; about 60 meters thick.

and he considered the type section to represent only the uppermost part of the formation. Troelsen described the type section as comprising ". . . gray impure, highly fossiliferous limestone overlain by gray sandstone". He correlated the Canyon Fiord Formation with the Moscovian Series (Upper Carboniferous), principally on the basis of fusulinaceans collected from the type section. It is of interest to note that this was the first authentic record of Carboniferous rocks in the Canadian Arctic Archipelago. Moreover, the Canyon Fiord Formation represented the oldest known Carboniferous rocks in this region until Kerr and Trettin's (1962) discovery of Viséan beds (Emma Fiord Formation of this report) on the north coast of Axel Heiberg Island.

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2 (continued)
Division 7; yellow sandstone, about 40 meters thick. Division 8; red calcareous sandstone, replete with productid brachiopods, and 5 to 10 meters thick. Division 9; calcareous, glauconitic sandstone, replete with brachiopod and bryozoan biostromes. This division is described as resting gradationally on division 8, and as overlain disconformably by Mesozoic sandstone. It is about 100 meters thick.

Photographs of the Greely Fiord area displayed as figures 11, 15 and 16, in Troelsen's report portray vividly the adverse conditions of heavy snow cover under which he worked. Moreover, it is understandable that Troelsen's observations, made in subzero temperatures and without an adequate topographic map, were necessarily brief and probably partly in error. Consequently, identification of Troelsen's nine stratigraphic divisions of the Greely Fiord Group with the formation delineated and mapped by the present studies in this territory is uncertain (<u>see</u> <u>Greely Fiord East</u>). The most probable relationships are as follows:

Divisions 1 and 2 = Canyon Fiord Formation
Division 3 = Antoinette Formation
Division 4 = Mount Bayley Formation
Divisions 5 and 6 = Tanquary Formation
Division 7 = Sabine Bay Formation
Divisions 8 and 9 = Trold Fiord Formation

Troelsen found no evidence of disconformities within the Greely Fiord Group, for which available evidence indicated an Early Permian age. The present investigations however, have shown that the Greely Fiord Group embraces three separate sedimentary successions, all of which are bounded below and above by unconformities (1, Canyon Fiord Formation, Antoinette Formation, Mount Bayley Formation and Tanquary Formation; 2, Sabine Bay Formation; 3, Trold Fiord Formation). Moreover, the total time range of rocks included in the Greely Fiord Group is Late Carboniferous to Late Permian. Because of these circumstances the writer recommends that the name Greely Fiord Group be abandoned.

Troelsen (op. cit., p. 66) gave a more detailed description of the "gray sandstone" which he judged to represent a distinct formation surmounting the Canyon Fiord Formation, as follows: " . . . yellowish-gray, cross-bedded sandstone with conglomerate layers of varying thickness. The fragments in the conglomerate are ordinarily very small, but a few attain diameters of about 10 centimeters. They consist of quartzite, reddish sandstone, chert and gray limestone . . . The cross-bedded sandstone with the conglomerate layers cannot be said to belong to the same lithologic unit as the Canyon Fiord Formation, but as the sandstone is so imperfectly known that it will hardly be possible for the surveyor to recognize it in other localities, it does not merit a name of its own. About the geological age of the sandstone nothing is known except that it must be younger than the Canyon Fiord Formation".

In 1952, Troelsen (1952) returned to Cañon Fiord where he made the important discovery that Carboniferous rocks in the general vicinity of the type section of the Canyon Fiord lay with angular unconformity on Silurian strata[1]. This was the first unequivocal evidence that an orogeny of about mid-Paleozoic age had affected the Canadian Arctic Archipelago. Although Troelsen did not discuss the Canyon Fiord Formation <u>per se</u>, he implicitly included the type section of that formation in rocks described as Carboniferous conglomerate, sandstone and limestone in the geologic sketch map in his report (Troelsen op. cit., fig. 8, p. 206). Also included in the area shown as underlain by Carboniferous rocks in this map is the "gray sandstone" which Troelsen originally regarded as overlying the Canyon Fiord Formation, and Carboniferous strata overlying directly the unconformity with Silurian

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[1] In fact the Canyon Fiord at this locality overlies rocks as young as Early Devonian according to H.P. Trettin (personal communication).

rocks which he observed for the first time in 1952, and obviously considered to be older, in part at least, than strata in his type section of the Canyon Fiord Formation.

Although the principal results of Troelsen's second journey to Cañon Fiord were published in 1952, a somewhat fuller account is given in a manuscript report dated 1954, a copy of which is housed in the library of the Geological Survey of Canada. In this report, Troelsen gives a more accurate characterization of the Canyon Fiord Formation than is found in his two previous accounts. He described the formation as "composed mianly of conglomerate, quartzose sandstone and impure limestone. The colours vary from grey and yellow to violet and upon weathering the rocks in some cases assume brilliant red colours". Troelsen also reported the discovery in these rocks of the fusulinacean genus Triticites which extended the age of the Canyon Fiord into latest Carboniferous or Early Permian.

Subsequent studies of the Canyon Fiord Formation on Ellesmere Island include those of, McLaren (1963, p. 332) in the environs of Eids Fiord, Thorsteinsson (1963, p. 399) south of Caledonian Bay, and Tozer (1963, p. 376) around the head of Trold Fiord. These studies provided some additional information on the areal extent and lithologic characters of the formation.

Type Locality of Canyon Fiord Formation. The writer has examined in considerable detail rocks in and around the type section of the Canyon Fiord. It seems appropriate at this juncture to record some of his general observations, particularly those that relate to the definition of the Formation, and Troelsen's work in this region.

The entire unit of redbeds that lie with angular unconformity on lower Paleozoic rocks southeast of Caledonian Bay in Canon Fiord constitute a single formation in which Troelsen's type section is but a part (see Pl. XIV). Three measured sections in this region are illustrated graphically as composite section 75 on figure 3. The basal portion of this section (75a) is Bashkirian and possibly also Moscovian in age; the middle portion which represents the entire type section (75b), is Moscovian in age; and the upper part (75c) is about Zhigulevian to Sakmarian in age. The Canyon Fiord Formation as herein emended includes the type section, and sections 75a and 75c as reference sections. (The total thickness of Canyon Fiord beds in this area may be as much as 4,300 feet but accurate determination is impossible because of extensive folding and faulting). A third reference section is discussed below.

The upper contact of the Canyon Fiord is not preserved in the vicinity of the type section of the formation southeast of Caledonian Bay, and the formation in this region is therefore incomplete. However, a full thickness of the formation is preserved south of Canon Fiord in the southerly extension of the belt of exposure that includes the type section. A section measured in this region which comprises the upper 1,900 feet of the Canyon Fiord, overlain disconformably by the Upper Permian Trold Fiord Formation, is illustrated graphically in section 76 on figure 3 (see also Pl. XV). The relationship of section 76 to section 75c discussed earlier, is indicated by the common occurrence in these sections of the fusulinacean Eoparafusulina sp. A. Although section 76 is largely, if not entirely Sakmarian in age, much of the section is younger than section 75 across the fiord. Moreover, in view of the fact that section 76 is correlative with upper beds of the Belcher Channel Formation (see p. 00) in other parts of Ellesmere Island, it is possible that the upper, unfossiliferous portion of this section also includes rocks of Early Artinskian age. Section 76 represents an important reference section which together with reference sections 75a and 75c supplements type section 75b. The maximum aggregate thickness of the Canyon Fiord Formation in general vicinity of the type section is estimated as 5,500 feet on the basis of the correlated sections illustrated in figure 3.

The "gray sandstone" that Troelsen (1950, p. 66) considered to represent a distinct formation overlying the type section of the Canyon Fiord constitutes a part of the Canyon Fiord. Moreover the sandstone is separated from the type section by a fault, and is in fact older and not younger, than strata in the type section.

The estimated thickness of 5,500 feet for the Canyon Fiord Formation in environs of the type section in Canon Fiord, noted above, represents the greatest known thickness of the formation on Ellesmere Island. In places the Canyon Fiord thins to a feather edge. The highly variable thickness of the formation is the result of three circumstances, partly explained in the foregoing discussions, but summarized as follows: (1) The Canyon Fiord disappears in a northwesterly direction through gradation and intertonguing with the Belcher Channel and Antoinette Formations (see Fig. 3), or with the lower part of the Nansen Formation (see Figs. 1 and 2). (2) The formation thins southeastward as a result of truncation of upper beds by post-Canyon Fiord erosion. Plate XVIII gives a good illustration of this kind of thinning in the territory northeast of Vesle Fiord. Another example is found east of Tanquary Fiord where the Belcher Channel Formation oversteps Canyon Fiord strata (see Fig. 4). (3) The Canyon Fiord thins also in the direction of the southeastern margin of the Sverdrup Basin by virtue of overstep of lower strata of the formation on to pre-Carboniferous basement rocks, as indicated by the Bashkirian age of basal beds in certain sections, and the Moscovian age in others.

Lithology.

Measured sections of the formation on Ellesmere Island are shown graphically on figures 1, 2, 3 and 4.

Like most predominantly clastic formations the Canyon Fiord differs in lithology from bed to bed and from area to area. Hence a detailed description of its lithology at one place does not serve as a competent identification at another. In general however, the formation is largely composed of quartzose sandstone with varying amounts of limestone, and subordinate amounts of mudstone, siltstone and shale.

The sandstone varies from very fine to very coarse grained, and from very thin to very thick bedded and massive. It is however, characteristically fine to medium grained, and medium to thick bedded. Ripple marks and crossbedding are rare but occur in most sections. A few beds are sparsely glauconitic, and ferruginous sandstone beds are fairly common. Many sandstone beds contain lenses or sparsely distributed granules and pebbles made up of rounded to subrounded brown or dark grey chert. A large variety of fresh surface colours are represented of which the most common are light grey, greenish grey and greyish green. Other colours present include various hues of red, blue, yellow and brown. Much of the sandstone is soft, porous and friable, although dense resistant layers are present also in most outcrops. A few grains of chert and feldspar can generally be found in most sandstone beds.

In general the proportion of limestone intercalated in the sandstone is most prominent in regions to the northwest and less prominent to virtually absent towards the southeast. The limestone is characteristically sublithographic or bioclastic, and both rock types are commonly quartzose or argillaceous. As in the case of the sandstone, the sublithographic limestone is notable for a large variety of fresh surface colours including hues of red blue, yellow, brown, grey and purple. Mottled effects in these rocks are also common. The limestone beds commonly contain chert in the form of irregular replacement masses, fossil replacements and lenses parallel to the bedding.

The base of the formation commonly contains a conglomerate that ranges from a few inches to over 250 feet in thickness. The conglomerate is generally resistant and stands out as prominent ledges and ridges in the landscape (see Pl. XIV). It is most commonly represented by cobble-size phenoclasts embedded in a groundmass of calcareous quartzose sandstone and iron oxide. However, the size of the phenoclasts vary from place to place and they may run the whole gamut of granules to boulders, their shapes varying from angular and subangular to forms which are well rounded. Chert phenoclasts are represented in varying proportions in all studied sections. However, the composition of the phenoclasts in the basal conglomerate of any given section generally reflects the lithology of the local bedrock formation underlying the Canyon Fiord. Thus for example, basal conglomerates that overlie the Ordovician Cornwallis Group commonly contain a large percentage of limestone phenoclasts (including fossils of that group) that are lithologically similar to Cornwallis rocks. McLaren (1963, p. 332), has identified a fauna, obviously derived from the Middle Devonian Blue Fiord Formation, which he collected from basal conglomeratic beds of the Canyon Fiord south of Eids Fiord in southwestern Ellesmere Island. At this locality the Canyon Fiord overlies the Blue Fiord Formation. It seems probable therefore, that the basal conglomerate of the Canyon Fiord represents in part at least, debris resulting from the breaking up of lower Paleozoic basement rocks.

Conglomerate layers that are seldom more than 10 feet thick are sparsely represented throughout most sections of the formations. They are generally similar lithologically to the basal conglomerate described above, with the exception that the phenoclasts are seldom greater than cobble-size, and generally represented as either varicoloured chert or limestone.

Rocks of the Canyon Fiord lend colourful features to the landscape and enhance the scenic beauty of Ellesmere Island. Although a good deal of the various lithologic types in most sections of the Canyon Fiord exhibit red weathering colours, other weathering colours such as shades of grey, brown, green and yellow may be equally prominent, especially upon close inspection. Nevertheless a characteristic feature of the Canyon Fiord, particularly as viewed from a distance, is the dusky red and moderate red weathering colours that dominate most outcrops and the soil that develops on the formation. Much of this red colour appears to originate from iron oxide stain that is derived from the breaking up of the subordinate mudstone, siltstone and shale interbeds - the only particular outstanding characteristics of these lithologic types. It is largely on the basis of these weathering colours that the Canyon Fiord is differentiated from the Belcher Channel Formation or the Antoinette Formations, either of which may overlie the Canyon Fiord, and both of which are characterized generally by shades of drab grey and yellow weathering colours.

Composed of alternating hard and soft weathering beds, the Canyon Fiord is not especially topographically prominent. The formation generally weathers to smoothly contoured ridges and hills, and presents a characteristically banded appearance on aerial photographs (see Pls. XXIV, XIX, and XXVII). This contrasts markedly with the underlying lower Paleozoic terrains, but not with the Belcher Channel or Antoinette Formations.

The regular bedded aspect of the Canyon Fiord throughout its areal extent, the scarcity of crossbedding and ripple marks, and the local presence of carbonate rocks indicate that the formation was deposited in relatively quiet, marine water of moderate depth and stable tectonic conditions. Moreover, the increasing prominence of clastic sediments to the southeast indicates that much of the detritus came from that direction, probably from uplands developed on exposed parts of the Franklinian miogeosyncline. In this region the Okse Bay Formation (McLaren, 1963) and Vendom Fiord Formation (Kerr, 1967) which are largely composed of red quartzose sandstone of Devonian age provide a probable source of much of the Canyon Fiord.

An unusual section of the Canyon Fiord merits special note. Basal beds of the formation that overlie the Cornwallis Group (Ordovician) at locality 137, west of Trold Fiord (see Pl. V; and Eureka Sound South) include: (1) basal limestone and chert pebble conglomerate, 20 feet thick; (2) covered interval apparently concealing redbeds, 15 feet thick; and (3) anhydrite, 200 feet thick. No fossils were obtained from these units. The anhydrite is overlain by several hundred feet of beds that are typical of the Canyon Fiord. Fusulinaceans of Moscovian age were collected in strata immediately overlying the anhydrite. The anhydrite forms a belt of outcrops that extend about a mile along strike. Covered intervals occupy either end of this belt so that the stratigraphic relations of the anhydrite to alternating limestone and sandstone that normally occupy the position of the anhydrite could not be determined. The anhydrite, if assigned correctly to the Canyon Fiord, represents a unique occurrence of evaporitic rocks in this formation. On the other hand it is possible that the anhydrite represents a thin outlier of the Otto Fiord Formation (see p. 00).

Age.

The Canyon Fiord Formation exhibits its longest span of geologic time in the environs of Cañon Fiord, where the formation ranges from early Bashkirian to about Sakmarian. Evidence for this conclusion is derived entirely from Foraminiferida, particularly Fusulinacea. Mamet has identified four faunas consisting largely of Endothyracea, from lower strata in the Canyon Fiord. Collectively these faunas indicate a range in age of early Bashkirian to Moscovian. Mamet's report is given on page 00.

Fusulinaceans that indicate correlation with the Moscovian Series constitute some of the most abundant and widespread fossils in the formation, and include such characteristic genera as Profusulinella, Paraeofusulina and Fusulina. The association in section 75 on figure 3 of Fusulinella sp., and Quasifusulina cf. Q. eleganta Shlykova, with Triticites sp., suggests a Zhigulevian age. Species of Eoparafusulina appear to characterize a persistently developed faunal zone in the Canyon Fiord, and correlative strata of the Belcher Channel and Tanquary Formations. This genus, according to Ross (1967), ranges from early to middle Wolfcampian, and is widely distributed in western North America. Reference of Eoparafusulina to the Sakmarian is provisional, and is based on the presumed relationship of the American Wolfcampian Series to the Russian Permian. The possibility that species of Eoparafusulina in the Canadian Arctic Archipelago are in fact Asselian in age can not be ruled out. However, members of the genus are restricted to middle and upper portions of Permian sections in the Archipelago. For this reason they are judged to correlate with the Sakmarian, rather than Asselian Series.

Belcher Channel Formation

Definition. The formation was originally defined by Harker and Thorsteinsson (1960; see also Thorsteinsson, 1963) for Permian rocks lying with angular unconformity on the Cornwallis Formation (Ordovician) and overlain disconformably by the Assistance Formation on the north coast of Grinnell Peninsula, Devon Island. The type section is along the lower reaches of the Lyall River where Harker and Thorsteinsson (op. cit.) recognized three main units in the Belcher Channel Formation. These units are described briefly in ascending stratigraphic order as follows: Unit 1, pebble conglomerate, 20 to 200 feet thick; Unit 2, green and red quartzose sandstone, about 140 feet thick; and Unit 3, mainly limestone, 490 feet thick. The possibility that Units 1 and 2 might, in fact, represent the Canyon Fiord Formation was recognized by Harker and Thorsteinsson. This was confirmed later by Nassichuk (1965, p. 9), who also demonstrated that the surface of separation between the two formations is a disconformity.

As described by Harker and Thorsteinsson (op. cit.), the Belcher Channel (their Unit 3) consisted of " . . . limestone, which is mainly light grey, fine to coarse grained and thin to medium bedded . . . The upper 330 feet is a highly fossiliferous, coarse-grained, bioclastic limestone which is variably quartzose with grey, green and dusky red shale, occurring as bedding plane partings. Many of the upper beds are veritable biostromes of colonial corals situated in the position of growth. Specks of limonite are common in beds throughout the entire unit and are especially characteristic of the bioclastic beds. These specks occur as pore fillings and as an intimate part of the matrix. The lower 160 feet of the unit consists of yellowish grey to light grey, fine-grained limestone and quartzose limestone, with minor beds of light grey, fine-grained quartzose sandstone. Bioclastic limestone is a minor constituent in these lower beds".

Distribution.

The Belcher Channel is widely distributed along the southern and southeastern margins of the Sverdrup Basin. It occurs on Sabine Peninsula, Melville Island where it is 75 feet in thickness and lies disconformably on the Canyon Fiord Formation (Tozer and Thorsteinsson, 1963, p. 101). A thin selvage of the formation that overlies the Griper Bay Formation (Devonian) with angular unconformity has been identified on Helena Island, a small island lying off the north coast of Bathurst Island (Kerr and Christie, 1965, p. 924). Reference has already been made to the occurrence of the type section of Belcher Channel rocks on Devon Island. The Belcher Channel crops out extensively in western Ellesmere Island where it occupies a narrow, southwest to northeast trending belt extending from Bjorne Peninsula to Tanquary Fiord (i.e. within the marginal clastic and carbonate belt of text-figure 3). Distribution of the formation is shown also in geologic maps, Baumann Fiord, Eureka Sound South, Canon Fiord, Greely Fiord West, Greely Fiord East, and Tanquary Fiord.

Thickness.

Measured sections of the formation in Ellesmere Island are shown graphically in sections 50, 51, 52, 54 and 55 on figure 1, sections 73 and 74 on figure 3, and section 83 on figure 4. The section on figure 4, measured east of Tanquary Fiord, is 480 feet thick and represents the smallest known thickness of Belcher Channel strata in the report area. The greatest recorded thickness of the formation is 1,910 feet which represents the cumulative thickness of two complementary sections situated on Hamilton Peninsula and separated from one other by about 20 miles.

Lithology.

The description of the Belcher Channel in the type section on Devon Island serves moderately well for the entire extent of the formation on Ellesmere Island. Characteristically the formation on Ellesmere Island, consists of units of resistant limestone alternating with units of less resistant quartzose sandstone and siltstone, which present a banded appearance from the air and on aerial photographs (see Pls. XIX, XX and XXVI). Limestone is the dominant lithology, particularly in the upper few tens or hundred of feet of the formation, where it is generally coarse grained, in places biostromal, in part porous, and commonly thick bedded to massive. Limestone in the lower part of the formation is generally variably quartzose, fine to coarse grained, and occurs in beds that are ordinarily 6 to 8 inches thick. The limestone of the Belcher Channel is generally fossiliferous and most sections yield abundant solitary and colonial corals, and brachiopods. Locally, interbeds and lenticular layers of chert form minor, but conspicuous constituents in the limestone. The sandstone and siltstone occur in units as much as 400 feet in thickness. They are generally calcareous, rarely crossbedded, variably hard and soft, and commonly porous. Dominant fresh surface and weathering colours of both carbonate and clastic strata are various shades of grey (mainly light to medium grey) and yellow.

The sandstone is generally fine grained. East of Tanquary Fiord however, where the base of the Belcher Channel is locally represented by an unconformity the basal 75 feet or more of the formation is made up of green and red weathering, coarse grained sandstone, in part conglomeratic, and chert pebble conglomerate (see section 83, Fig. 4).

Age.

The Belcher Channel on Ellesmere Island ranges from Late Carboniferous to Early Permian. Evidence for this conclusion is based entirely on fusulinaceous. Lower beds in most sections have yielded various species of Triticites that suggest a Zhigulevian or Orenburgian age, but cannot be determined more accurately. Strata of Sakmarian age are recognized by the presence of Eoparafusulina sp. A sp. Schwagerina hyperborea, (Salter) which occurs in the upper few tens of feet of the formation, is apparently an advanced member of that genus, and suggests an Artinskian age. However, the principal reason for regarding upper beds of the formation as Artinskian in age is the occurrence of Parafusulina sp., 150 feet stratigraphically below S. hyperborea, on Hamilton Peninsula (see section 73, Fig. 3). This Parafusulina is an adanced member of the genus, comparing with Leonardian rather than late Wolfcampian forms, and therefore presumably about early Artinskian.

Stratigraphic Relations.

The upper contact of the Belcher Channel on Ellesmere Island as elsewhere in the archipelago, is a disconformity, and the formation is variously overlain by the Sabine Bay Formation, Assistance Formation, or the Lower Triassic Bjorne Formation. It is probable however, that this contact is nearly synchronous as judged by the common occurrence of Schwagerina hyperborea (Salter) in upper beds of the formation.

The Belcher Channel exhibits two kinds of basal contact relations on Ellesmere Island: (1) Throughout much of its areal extent, the formation lies gradationally on the Canyon Fiord Formation. The transition from one formation to the other is marked by a change in colour and composition, in which dominantly red weathering sandstone and lesser amounts of limestone in the Canyon Fiord, give way to dominantly grey and yellow weathering limestone and lesser amounts of sandstone and siltstone in the Belcher Channel. The contact of these formations is moderately well defined and generally only a few feet of beds are not readily assigned to either formation. (2) East of Tanquary Fiord, the Belcher Channel oversteps the Canyon Fiord and lies with angular unconformity on rocks of Ordovician and Silurian ages (see section 83, Fig. 4; and Tanquary Fiord).

It is noteworthy that there is no paleontological evidence to indicate the presence of rocks older than Permian in the Belcher Channel on Melville, Helena and Bathurst Islands, where the base of the formation is also an unconformity. Thus while exposures of the Belcher Channel on Ellesmere Island may be regarded for all practical purposes, as comprising wholly contemporaneous beds, this is not the case for the entire extent of the formation in the archipelago.

The stratigraphic relationship of Belcher Channel rocks to laterally equivalent formations is complex. In the environs of Blind Fiord (see Eureka Sound South; and Fig. 2), and Tanquary Fiord (see Tanquary Fiord), combinations of the Belcher Channel and underlying Canyon Fiord Formation, give way in a northwesterly direction to the Nansen Formation. In these regions the change from Belcher Channel to Nansen, both of which formations consist mainly of carbonate and lesser amounts of clastic rocks, is arbitrarily drawn stratigraphically above the facies change between redbeds of the Canyon Fiord and light coloured carbonate and clastic rocks in the lower part of the Nansen. Two other kinds of lateral relationships of Belcher Channel rocks are evidenced on Hamilton Peninsula where the formation comprises a northeasterly trending belt of exposures (see Cañon Fiord; and Text-fig. 2). (1) To the northwest the Belcher Channel gives way to a combination of three formations, in order upwards, Antoinette (mainly carbonate), Mount Bayley (anhydrite) and Tanquary (clastics and carbonate). The Antoinette and Tanquary Formations are lithologically similar to the Belcher Channel, and exist as discreet rock units, only by virtue of the Mount Bayley anhydrite which represents a facies equivalent of a middle portion of the Belcher Channel. Hence, in this region also an arbitrary separation is made between Belcher Channel rocks on one hand, and Antoinette and Tanquary rocks in the other. (2) To the southeast, the Belcher Channel passes gradationally into redbeds that form the upper part of the type section of the Canyon Fiord. Support for this conclusion is based on paleontological evidence only (see Fig. 3), as rocks representing the transition from one formation to the other have been removed by erosion.

Antoinette Formation

Definition and Correlation.

The name Antoinette is here proposed for a formation consisting mainly of dark grey, impure limestone with varying proportions of siltstone, sandstone, shale and anhydrite. The formation is named for Antoinette Bay which forms the eastern extremity of Greely Fiord. The type section is located in the north wall of Greely Fiord, about 23 miles west of the head of Antoinette Bay (see Pl. XXI). The formation is invariably overlain by evaporitic rocks of the Mount Bayley Formation. In some places the contact of these formations appears relatively abrupt; in others it is markedly gradational. Throughout much of its areal extent, the Antoinette overlies the Canyon Fiord Formation, and ranges in age from Zhigulevian or Orenburgian (Late Carboniferous) to Asselian (Early Permian). In this circumstance the formation represents the chronological and lateral equivalent of the lower part of the Belcher Channel Formation. However, a single, incomplete section of the Antoinette, described later, includes strata as old as Moscovian in age. Strata, laterally equivalent to the Antoinette are discussed under the heading of the Mount Bayley Formation (see p. 00).

Distribution.

Outcrops of the Antoinette are confined to territory in western Ellesmere Island around Cañon Fiord and Greely Fiord. There the formation is distributed, more or less coextensively with the Mount Bayley and Tanquary Formations which overlie Antoinette strata in that order. All three formations occupy a narrow strip of territory in the western part of the marginal clastic and carbonate belt shown in text-figure 3. Two relatively small areas of Antoinette exposures near Mount Bridgman on the south side of Cañon Fiord represent the southeasternmost extent of the formation (see Cañon Fiord).

The most extensive exposures of the formation form a belt that traces a northeasterly path across Hamilton Peninsula (see Greely Fiord West). Several smaller areas of outcrop, including the type section, that occur in the environs of the junction of Tanquary and Greely Fiord (Greely Fiord East), and a single small area between the head of Essayoo Bay and Greely Fiord (Greely Fiord West) represent the northeastern limit of the formation.

Lithology, thickness and age.-

Three sections of the Antoinette described below will serve to illustrate these characters.

1. The type section is about 1,550 feet thick and represents the only full thickness of the formation that was measured. It is illustrated graphically in section 81 on figure 4. It is composed mainly of dark grey limestone that is medium to generally fine grained, thin to generally medium bedded, in part porous, and variably argillaceous and silty. This section of the Antoinette exhibits unusually large amounts of gypsum and gypsiferous limestone, which are represented as thin beds distributed throughout the formation. Calcareous siltstone is the dominant lithology in the upper 400 feet of the section. It is commonly thin bedded, medium light grey, and variably argillaceous and gypsiferous. The dominant weathering colours of rocks in the sections are various shades of grey and yellow. Though the basal 330 feet of the type section is not exposed, beds representing this interval which were studied about 7 miles south of the type section (see section 82, Fig. 4) on the south side of Greely Fiord, and consist mainly of limestone, medium light grey to greenish grey, fine grained, and medium to thick bedded, that alternate with lesser amounts of light grey, thin-bedded siltstone, and silty limestone.

Species of the fusulinacean Triticites represent the only datable fossils taken from the type section of the Antoinette, and these cannot be dated more accurately than Zhigulevain or Orenburgian. As the youngest beds in the Canyon Fiord Formation are Moscovian in age on the basis of such fusulinaceans as Profusulinella sp., Eofusulina sp., and Fusulina sp., (see section 82, Fig. 4), it seems safe to conclude that like the Belcher Channel no part of the type section of the Antoinette is older than Zhigulevian or Orenburgian.

2. An incomplete section of the Antoinette, 2,650 feet thick, measured in the southern part at Hamilton Peninsula is shown graphically in section 71 on figure 3. There as elsewhere the formation is conformably overlain by the ~~Mounta~~ Mount Bayley Formation. Though the base of the section is marked by the East Cape thrust, the section represents, so far as is known, the greatest thickness of Antoinette strata. The dominant lithology is limestone that is generally dark grey, fine grained, and thin to thick bedded, and variably argillaceous. The section also includes minor interbeds of biogenic limestone, cherty limestone, fine grained, calcareous sandstone, and dark grey calcareous shale that is in places petroliferous. The section yields abundant fusulinaceans, which indicate three and possibly four stages. The fusulinacean genera and their indicated stages, arranged in order upwards are as follows: (a) Wedekindellina, Pseudostaffella and Fusulina - Moscovian; (b) Triticites - Zhigulevian and/or Orenburgian; and (c) Schwagerina - ?Asselian. Strata of Moscovian age are included in the Canyon Fiord Formation only a short distance to the northeast and southeast (see Text-fig. 3; and Fig. 3). Thus, while the base of the Antoinette appears to fall at the same stratigraphic horizon over most of the area, the inclusion in this section of Moscovian strata indicates that the formation becomes older in a northwesterly direction.

3. Another incomplete section of the formation was measured on the slopes of Mount Bridgman, south of Canon Fiord (see section 56 on Fig. 1; and Pl. XXV). This section is 710 feet thick, its base is also the East Cape thrust, and the lower approximately 200 feet is poorly exposed. The section is made up principally of dark coloured, thin- to thick-bedded calcareous siltstone and limestone that is variably argillaceous and silty, and minor units of dark grey, calcareous shale. These strata are particularly interesting for having yielded, among others, the fusulinacean Paraschwagerina sp., which indicates clearly an Early Permian (probably Asselian) age.

Mount Bayley Formation

Definition and Thickness.

The Mount Bayley Formation is mainly anhydrite and its alteration product gypsum. The type section of the formation is located along the north wall of Greely Fiord, ~~a little less than two miles south of~~ about three miles east of the junction of Tanquary and Greely Fiords, and near Mount Bayley for which the formation is here named (see Pl. XXI). The Mount Bayley ranges in thickness from zero to in excess of 800 feet. It overlies the, already described, Antoinette Formation and underlies the Tanquary Formation (clastic and carbonate rocks; see p. 00).

Distribution and Facies Relations of Antoinette, Mount Bayley and Tanquary Formation.

The Antoinette, Mount Bayley and Tanquary Formations are included in the marginal clastic and carbonate belt of test-figure 3, and are distributed coextensively over a rather limited area of western Ellesmere Island, extending from the south side of Cañon Fiord to territory around the junction of Tanquary and Greely Fiords (see also Eureka Sound North, Cañon Fiord, Greely Fiord West, Greely Fiord East). The Antoinette and Tanquary Formations exist by virtue of evaporitic rocks of the Mount Bayley that effects a tripartite division in dominantly carbonate beds included elsewhere on Ellesmere Island in the Belcher Channel Formation.

To the northwest, the Mount Bayley grades laterally into limestone of the Nansen Formation (see Text-fig. 3). This facies relation is evident in the mountainous, thrust faulted terrain on the west side of Tanquary Fiord and southwest of McKinley Bay, where units of anhydrite and anhydritic limestone, too thin and sporadic in distribution to constitute a mappable unit, have been observed in about the middle of the Nansen Formation. Similarly, remnants of the Mount Bayley can be recognized by thin units of anhydrite and anhydritic limestone that occur in about the middle of the Belcher Channel Formation, a few miles north of the type section of the Mount Bayley. In both instances described above, the Mount Bayley seems to disappear through intertonguing and intergrading. While strata correlative with the Mount Bayley in the Belcher Channel Formation cannot be demonstrated with certainty on Hamilton Peninsula, a soft weathering interval consisting mainly of calcareous siltstone and sandstone which is persistently developed within the Belcher Channel in this region appears to constitute strata most likely correlative with evaporitic rocks of the Mount Bayley, based mainly on the suggested ages of fusulinaceans below and above this interval (see section 73 and 74 on Fig. 3). Thus with the facies change of the Mount Bayley to limestone in a northwesterly direction, the Antoinette and Tanquary Formations merge laterally with the Nansen Formation. Similarly, with the disappearance of the Mount Bayley in northeasterly and southeasterly directions, the Antoinette and Tanquary Formations merge laterally with the Belcher Channel Formation.

Lithology.

The general character of the Mount Bayley, aside from variations in thickness, does not vary greatly in different portions of the region. The formation is composed mainly of anhydrite and as such resembles more closely in lithology the Otto Fiord Formation (see p. 00) than any other within the report area. That interbeds in the anhydrite of the Mount Bayley are mainly quartzose siltstone and quartzose sandstone, whereas interbeds in the Otto Fiord are chiefly limestone, constitute the principal differences in these formations. Four sections described below serve to elucidate the lithologic characters of the Mount Bayley in widely separated localities.

1. The type section of the formation in Greely Fiord is illustrated graphically in section 80 on figure 4. It is 500 feet thick, and consists mainly of anhydrite, that is thin to thick bedded with subordinate interbeds of medium grey, calcareous quartzose siltstone and silty limestone.

2. A section of the Mount Bayley measured north of the Tchernyschew River, near the geographic centre of Hamilton Peninsula is 820 feet thick, and represents the thickest known section of the formation (see locality 164, Greely Fiord West). The section is described below.

Unit No.	Lithologic Character	Thickness in Feet
	Overlying strata, Tanquary Formation	
5	Anhydrite, thin to mainly thick bedded	525
4	Anhydrite, sandstone and siltstone, interbedded; anhydrite, thin to thick bedded; fine grained, sandstone and siltstone, mainly medium light grey and variably anhydritic	95
3	Limestone, shale and sandstone, interbedded; limestone, variably silty, medium dark grey and thin bedded; shale, variably silty, medium dark grey; sandstone, medium light grey, thin-bedded, fine grained, soft	65
2	Anhydrite, medium bedded	15
1	Sandstone, subordinate anhydrite, interbedded; sandstone, light to medium grey, fine grained, thin to medium bedded, soft, anhydritic in upper beds; anhydrite, thin to medium bedded	120
	Total thickness of Mount Bayley Formation	820
	Underlying strata, Antoinette Formation	

3. Another section of the Mount Bayley measured on Hamilton Peninsula is illustrated graphically in section 71 on figure 3, and shown on plate XXIV. It is 250 feet thick and is made up almost entirely of thin- to medium-bedded anhydrite.

4. A section of the formation near the foot of Mount Bridgman, south of Canon Fiord is 190 feet thick. It is illustrated graphically in section 56 on figure 1, and shown on plate XXV. This section consists mainly of medium-bedded anhydrite with minor interbeds of quartzose siltstone, that is variably argillaceous and gypsiferous.

Age.

Evidence as to the age of the Mount Bayley is not entirely satisfactory. The formation is unquestionably Early Permian in age, and it is judged to be approximately Asselian on the basis of the occurrence of the fusulinacean, Paraschwagerina sp., collected in the upper beds of the Antoinette Formation, and Schwagerina krotowi (Schellwien) found in the lower portion of the Tanquary Formation (see section 56, Fig. 1).

Tanquary Formation

Definition and Distribution.

The Tanquary Formation is here proposed for a unit of carbonate and clastic strata that overlies evaporitic rocks of the Mount Bayley Formation. The formation is named for Tanquary Fiord in northwestern Ellesmere Island, and is typically developed along the north side of Greely Fiord, some three miles east of the junction of Tanquary and Greely Fiords (see Pl. XXI).

Outcrops of the Tanquary form a rather narrow, northeasterly trending belt in western Ellesmere Island, extending from Vesle Fiord to the environs of Tanquary and Greely Fiord. The most extensive exposures of the Tanquary are on Elmerson and Hamilton Peninsulas. Distribution of the formation is shown in text-figure 3 and on geologic maps, Eureka Sound North, Canon Fiord, Greely Fiord West, and Greely Fiord East.

Contact Relations.

Both the lower and upper contacts of the Tanquary are sharp, yet conformable. While there is no evidence that the contact of the Tanquary with the underlying Mount Bayley Formation marks a break in sedimentation, the top of the Tanquary is unquestionably an erosional surface, and in different regions different formation, such as the Sabine Bay, Assistance and Trold Fiord Formations, and the Triassic, Bjorne Formation overlie Tanquary rocks. It is therefore somewhat surprising, that although the upper surface of the Tanquary may in places represent the coincidence of as many as four disconformities, the formation probably has not been extensively eroded as judged from the common occurrence of *Schwagerina hyperborea* (Salter) in uppermost beds of the Tanquary. Moreover, the varying thicknesses (700 to 2,740 feet) of measured sections of the Tanquary may be regarded, for all practical purposes, to involve more or less contemporaneous beds. Laterally equivalent strata of the Tanquary have been dealt with under the heading of the Mount Bayley Formation (*see* p. 00).

Lithology, Thickness and Age.

The Tanquary is made up principally of sandstone and limestone, and lesser amounts of siltstone. The sandstone is ordinarily calcareous, fine grained, variably hard and soft, and well bedded; crossbedding is rare. The proportion of clastic sediments varies considerably, generally increasing in prominence to the southwest, and decreasing to the northeast and northwest. The limestone is commonly quartzose, aphanitic to coarse grained and bioclastic. Dominant weathering and fresh surface colours of both carbonate and clastic rocks are various shades of grey and yellow. The formation is commonly distinguished on aerial photographs by its strong ledges (*see* Pls. XXI, XXIV, XXV).

Four complete sections of the Tanquary described below will serve to illustrate regional variations in lithology.

1. The type section of the Tanquary is illustrated graphically in section 80 on figure 4, and shown on Plate XXI. It is 700 feet thick, and almost entirely exposed. It consists of nearly equal parts of limestone, and siltstone and sandstone. The limestone is represented by seven prominent units varying from 15 to 90 feet in thickness, that alternate with units of less resistant calcareous siltstone and sandstone. The limestone is predominantly medium light grey to greyish pink, fine to coarse grained and biogenic, and medium to thick bedded and massive. Limestone that is variably silty and sandy occurs in the upper portion of the section. Fossils abound in the limestone; certain beds are made up almost entirely of fusulinaceans, while others are composed mainly of large, solitary corals. The sandstone and siltstone are generally medium light grey, thin to medium bedded, generally soft and variably porous. The sandstone is generally fine grained.

2. A section of the Tanquary measured north of Tschernyschew River in the northern part of Hamilton Peninsula (see locality 164, Greely Fiord West) is described below.

Unit No.	Lithologic Character	Thickness in Feet
	Overlying strata, Sabine Bay Formation	
10	Limestone, variably quartzose, white, coarse grained, massive, rubbly weathering, and weathering white and yellow	40
9	Limestone, slightly quartzose, greyish red purple to dark reddish brown, coarse grained, medium to generally thick bedded; contains medium dark grey calcareous siltstone partings; Schwagerina hyperborea (Sa ter) occurs abundantly 40 feet below top	60
8	Limestone, quartzose, medium light grey, fine to medium grained, medium to thick bedded into underlying and overlying units	70

Unit No.	Lithologic Character	Thickness in Feet
7	Siltstone, sandstone and lesser amounts of limestone, interbedded; all rocks are medium grey to medium light grey, and medium to thick bedded; sandstone, calcareous, fine grained; limestone, variably quartzose, and coarse to generally fine grained......	100
6	Siltstone and sandstone, alternating; both rock types calcareous, medium grey to medium light grey, medium to thick bedded, variably hard and soft, sandstone, fine grained; <u>Zoophycos</u> occurs throughout	180
5	Limestone, variably quartzose and bioclastic; medium light grey to greyish pink, generally fine grained, but including medium and coarse grained beds; upper portion thin bedded, lower portion medium to thick bedded; minor amounts of siltstone, calcareous sandstone, and lenticular chert interbedded throughout	100
4	Limestone, pale pink, coarse grained, massive..........	20
3	Siltstone, dark grey, thin to medium bedded; minor interbeds of argillaceous limestone..................	125
2	Limestone, pale pink, coarse grained, thick bedded, weathers greyish orange and light brown	35
1	Limestone, medium light grey, ordinarily fine grained, irregular medium beds, minor chert nodules and silicified corals; minor amounts of medium light grey calcareous sandstone, siltstone and shale partings	455
	Covered interval	100
	Total thickness of Tanquary Formation..................	1,285
	Underlying strata, Mount Bayley Formation	

3. A section, 2,170 feet thick, measured in southern Hamilton Peninsula is illustrated graphically in section 71 on figure 3, and shown on Plate XXIV. There the dominant lithology is calcareous sandstone. The section is divisible into three broad units of local extent: a lower unit, about 750 feet thick, consisting mainly of limestone, variably quartzose and biogenic, medium light grey to dark grey, thin to medium bedded, with minor interbeds of sandstone; a middle unit, about 1,050 feet made up of calcareous sandstone, mainly light grey, fine grained, variably hard and soft, in part porous, and weathering to light gold and reddish yellow; Zoophycos occurs throughout; an upper member about 370 feet thick, comprising limestone, light grey, fine grained to aphanitic and thin to thick bedded. The occurrence of Schwagerina krotowi (Schellwien) in basal beds of this section is of interest in indicating an Asselian age.

4. The greatest thickness of Tanquary strata measured in the report area, 2,740 feet, occurs on the east slope of Mount Bridgman on the south side of Canon Fiord. This section is represented graphically in section 56 on figure 1, and shown on Plate XXV. The section is characterized by several covered intervals, but exposures indicate that the prevailing lithology is calcareous sandstone, variably hard and soft, and porous, and lesser amounts of siltstone and resistant limestone ledges. The section is particularly noteworthy for providing the best evidence as to the age of the upper part of the Tanquary. A fauna of fusulinaceans from the lower beds of the section, identified as Pseudoschwagerina sp. and Eoparafusulina sp. A, indicate correlation with the late Wolfcampian (= Sakmarian) of the United States, while Schwagerina cf. S. hyperborea (Salter) collected near the top of the formation suggest an early Artinskian age.

3. Lower Permian (Artinskian) Nonmarine Sequence

Sabine Bay Formation

Definition and Distribution.

The Sabine Bay Formation was named by Tozer and Thorsteinsson (1964, p. 101) for light coloured, nonmarine, quartzose sandstone of Early Permian age that disconformably overlies the Belcher Channel Formation on Sabine Peninsula, Melville Island. These authors describe the sandstone as generally pale orange, medium grained, thin to thick bedded, commonly crossbedded, and as containing layers of coal up to two inches thick. Thin beds of chert-pebble conglomerate form minor constituents. The principal weathering colour is pale reddish brown. The Sabine Bay on Sabine Peninsula was subsequently studied by Nassichuk (1965, p. 10; 1970), who determined the range in thickness of the formation as 20 to 400 feet. Moverover, he was the first to demonstrate that the Assistance Formation was present in Melville Island and that it lay disconformably on the Sabine Bay.

A body of quartzose sandstone and subordinate conglomerate that crops out in the environs of Cañon Fiord and Greely Fiord in western Ellesmere, is provisionally referred to the Sabine Bay Formation (Cañon Fiord and Greely Fiord West). As in the case of the type section, the lower and upper boundaries of the Sabine Bay on Ellesmere Island are represented by disconformities, and are well-marked, both on the ground and on aerial photographs. The formations rests either on Tanquary Formation or equivalent strata of the Belcher Channel Formation. It is overlain throughout most of its areal extent, by the Assistance Formation, but on north side of Greely Fiord where Assistance strata are missing, the Sabine Bay is succeeded by the Trold Fiord Formation (see section 79 on Fig. 4). The Sabine Bay has no known equivalents in axial regions of the Sverdrup

Basin. Occurrences of this formation on Melville Island and Ellesmere Island are tentatively considered to represent remnants of a once continuous body of sediments that were laid down along the southern and southeastern margin of the basin.

Lithology.

The formation consists mainly of quartzose sandstone, and lesser amounts of quartz and chert pebble conglomerate. The sandstone is mainly fine to medium textured, less commonly coarse textured. It is thin to medium bedded in places, but commonly thick bedded to massive. It is generally noncalcareous, and limonitic specks characterize many beds; crossbedding, though not common, is locally conspicuous. Unweathered surfaces are mainly white to light grey; less common colours include soft shades of red, brown and yellow. The dominant weathering colours are light grey, pale yellowish orange, and pale reddish brown. As on Melville Island, Sabine Bay strata are generally porous and for the most part, poorly consolidated. Nevertheless the topographic expression of the formation is dominated by the harder, massive units of sandstone which tend to form low ledges and ridges. This property and the relatively light weathering characteristics of the formation are useful in differentiating Sabine Bay Formation on aerial photographs (see Pls. XXI, XXIV and XXV). Carbonaceous remains were noted throughout several feet of the formation in section 71 (see Fig. 3) on Hamilton Peninsula. At this locality also, a bed of porous sandstone contained bituminous residues.

Thickness.

The formation ranges from zero to a maximum thickness of 635 feet. Five sections measured in Greely Fiord West are tabulated below:

Locality		Thickness feet
71	Hamilton Peninsula	635
73	" "	390
164	" "	260
165	" "	255
79	north side, Greely Fiord	91

Age.

No fossils were observed in the Sabine Bay on Ellesmere Island, and its correlation with typical rocks of the formation on Melville Island is based on physical stratigraphy only. The age of the formation is fairly accurately dated as early Artinskian on the basis of its stratigraphic position above the Belcher Channel Formation and below the Assistance Formation. Nassichuk (1970, p. 79) has collected from basal beds of the Sabine Bay on Melville Island, specimens of a single genus of ammonoids which he identified as Sverdrupites sp., and dates as Artinskian. These fossils indicate that the Sabine Bay is, at least in part marine.

Esayoo Formation

The name Esayoo is here applied to dark coloured, basaltic volcanic flows and agglomerate that locally overlie the Nansen Formation in northwestern Ellesmere Island and northern Axel Heiberg Island. The Esayoo Formation is named for Esayoo Bay, an arm of Borup Fiord in northern Ellesmere Island (Greely Fiord West). The type section is located about two miles northeast of the head of Esayoo Bay. Outcrops of the Esayoo are limited to five, widely separated localities. The thicknesses of the Esayoo and the names of formations that overlie the Esayoo at these localities are tabulated below:

Locality	Thickness in feet	Overlying Formation
Type locality Greely Fiord West	250	Trold Fiord
Locality 78 Krieger Mountains; Greely Fiord West	975	Degerbols
Locality 68 Head of Hare Fiord; Otto Fiord	240	Trold Fiord
Locality 65 North coast, Axel Heiberg Island Cape Stallworthy	120	van Hauen
Locality 166 northeastern Axel Heiberg Island Bukken Fiord	150	Degerböls

The rocks herein referred to the Esayoo Formation were discovered by Per Schei (1904, 461) on the north coast of Axel Heiberg Island, and reported on by Bugge (1910).

The age of the Esayoo is Artinskian, and very probably early Artinskian, as judged from its stratigraphic position above the Nansen Formation and below the van Hauen Formation. But whether the Esayoo is older or younger than the Sabine Bay Formation cannot be determined on the basis of available evidence. For matters of convenience in table 1 the formation is shown as older than the Sabine Bay.

4. Lower Permian (Artinskian) Marine Sequence

Assistance Formation

Definition and Distribution.

The Assistance Formation was named and defined by Harker and Thorsteinsson (1960, p. 9; see also Thorsteinsson, 1963, p. 255), for a succession of predominantly unconsolidated clastic sediments that overlies the Belcher Channel Formation, near the northern extremity of Grinnell Peninsula, Devon Island. The type section is composed mainly of alternating units of fine-grained sand, and subordinate silt and clay. These rocks are mainly medium bedded, and variably calcareous and glauconitic. The predominant fresh surface colour is medium grey; weathering colours include yellowish orange and medium greyish green. Dusky red ironstone and calcareous sandstone concretions that are rich in fossils, occur in the upper part of the formation.

The type section is about 200 feet thick. Although no definitely recognized formation is known to overlie the Assistance on Grinnell Peninsula, there is a possibility that the uppermost 12 feet of beds in the type section may in fact represent basal beds of the Trold Fiord Formation. These upper beds consist of sand which weathers to a distinctive green colour, and resemble closely the Trold Fiord Formation that commonly overlies the Assistance in other parts of the Canadian Arctic Archipelago.

Nassichuk (1965; 1970) has shown that the Assistance crops out in Melville Island where it is unusually thin, varying from 50 to 100 feet in thickness. The Assistance Formation crops out along the west side of Ellesmere Island where it forms a narrow belt that extends from Bjorne Peninsula northeastward to Hamilton Peninsula (Baumann Fiord, Cañon Fiord, and Greely Fiord East). The distribution of the Assistance, and that of the correlative van Hauen Formation are shown in text-figure 4. The Assistance and van Hauen are considered to represent near-shore and basinal deposits, respectively.

Throughout its areal extent the lower and upper boundaries of the Assistance are represented by disconformities, and different formations, in different areas underlie and overlie Assistance beds. It should be noted however, that the actual contact of the Assistance and overlying Degerböls Formation on Bjorne Peninsula has not been observed.

Lithology and Thickness.

The Assistance on Ellesmere Island is composed mainly of soft weathering, quartzose sandstone and lesser amounts of siltstone. The formation thins to a feather edge, and the greatest thickness observed is 1,330 feet, on Bjorne Peninsula. Three sections described below will serve to give an idea of the lithologic variability of the formation.

1. A section measured on the east side of East Cape River, on Hamilton Peninsula is illustrated graphically as section 73 in figure 3, and shown in plate XXI. The Assistance in this area, overlies the Sabine Bay Formation and is in turn, overlain by the Trold Fiord Formation. It is 410 feet thick and consist mainly of grey sandstone, that is soft and friable, thin to medium bedded, and variably calcareous and glauconitic. The dominant weathering colour of this section is yellowish brown. A bed of chert pebble conglomerate about 3 feet thick occurs at the base of the formation. Interbedded with the sandstone are harder units of calcareous sandstone which stand out in the topography.

It is of interest to note here, that the lithology of Assistance rocks described above bears closer resemblance to the type section of the formation on Grinnell Peninsula than does that of any other section assigned to the Assistance on Ellesmere Island. Moreover, as will be discussed on a later page, this is the only section of the Assistance on Ellesmere Island that has yielded a fauna that is correlative with the fauna in the type section.

2. Another section of the Assistance was measured on Hamilton Peninsula about three miles northwest of section 73, described above, and across a major thrust fault. This section is illustrated graphically as section 71 on figure 3 (see also Pl. XXIV). The section is 570 feet thick. It is made up principally of quartzose sandstone that is generally fine grained, thin to medium bedded, and variably calcareous to noncalcareous. The predominant fresh surface colours are yellowish brown and greyish orange; the weathering colours are a distinctive dark yellowish orange and greyish yellow. Most of the sandstone is porous, irregularly bedded, and impregnated with limonite. Puzzling features in many of the sandstone are highly irregular, black filaments and tube-like structures, presumably composed of carbonaceous material, that cut indiscriminately across bedding planes.

Sparse fragments of brachiopods occur throughout the section. The sandstones are weakly consolidated and weather generally to smooth, rounded slopes. Thin interbeds of medium grey calcareous sandstone and quartzose limestone, replete with fragmented brachiopods and bryozoans represent minor constituents. The Assistance in this section, underlies the Trold Fiord Formation, and overlies the Sabine Bay Formation.

A noteworthy feature in virtually all outcrops of the Assistance, expecting those on Bjorne Peninsula, is the problematical fossil, Zoophycos. These fossils, occur sparingly in the Canyon Fiord and Sabine Bay Formations; they are fairly common also in the Trold Fiord Formation, but they occur in prodigious numbers in the Assistance.

3. The Assistance crops out extensively in southeastern regions of Bjorne Peninsula, and grades northwestward into the van Hauen Formation. A moderately well exposed section of the Assistance measured on Bjorne Peninsula is illustrated graphically as section 52 on figure 1 (see also Pl. XXVII). A broad, twofold lithologic division of the formation is differentiated in this section. The lower 400 feet or more consists largely of alternating hard and soft units of fine-grained sandstone and siltstone, which are light grey to medium grey, medium to generally thin bedded, and variably calcareous and argillaceous. Rocks of this interval are poorly exposed in this section, but are very well exposed some miles to the southwest at locality 114 on the north shore of Eids Fiord. The remaining 930 feet of the formation is composed mainly of resistant siltstone that is light grey to medium grey, thin to medium bedded, and variably argillaceous, calcareous and cherty, and lesser interbeds of bioclastic limestone. The Assistance, on Bjorne Peninsula, overlies the Belcher Channel Formation, and is overlain by the Degerböls Formation.

Age and Correlation.

Collectively the faunas of the Assistance from Grinnell Peninsula, Melville Island and Ellesmere Island indicate an early to late Artinskian age. However, as will be pointed out in the following discussion, the formation does not include strata of earliest Artinskian age.

In a systematic study of Permian ammonoids from the Canadian Arctic, Nassichuk, Furnish and Glenister (1965), described and figured an ammonoid fauna that was collected 915 feet above the base of the Assistance in section 52 (see Fig. 1), on Bjorne Peninsula. The fauna included:

Locality 52; GSC Cat. No. 57719

Neoshumardites cf. *N. Sakmarae* (Ruzhencev)
Paragastrioceras aff. *P. jossae* (de Verneuil)
Uraloceras burtiense (Voinova)
Uraloceras involutum (Voinova)
Metalegoceras crenatum n. sp.

Nassichuk et al. (op. cit., p. 9), stated that the fauna by itself, would indicate either a late Sakmarian age (i.e. Sterlitamakian substage), or early Artinskian age (i.e. Aktastinian substage), but in view of the early Artinskian age indicated by the youngest fusulinaceans in the underlying Belcher Channel Formation these authors favoured the early Artinskian alternative. Moreover, Nassichuk *et al*. regarded the fauna as appreciably older than the fauna described by Harker (in Harker and Thorsteinsson, 1960) from the type section of the Assistance.

Brachiopods associated with ammonoids discussed above have been submitted to J.B. Waterhouse whose list of identifications and remarks are as follows:

Locality 52; GSC Cat. No. 57719

Orthotetacean
Echinoconchid, possibly *Bathymyonia* sp.
Kutorginella sp.
Linoproductus simensis (Tschernyschew)

Yakovlevia sp.
Septacamera mutabilis Tschernyschew
Camerisma sp. aff. C. pentameroides (Tschernyschew)
Orulgania sp., or Pseudosyrinx sp.
Spiriferella polaris (Wiman)
Martinia sp.

The fauna belongs to brachiopod fauna E in the northern Yukon, and probably to the Jakutoproductus zone, although the key genus is absent. This zone is considered to be Aktastinian in the Urals, and correlative with the Skinner Ranch Formation in the Glass Mountains, on brachiopods and other faunal evidence. The fauna differs considerably from the type Assistance fauna.

The oldest fossils in the Assistance on Bjorne Peninsula is a fauna of brachiopods collected about 100 feet stratigraphically above the base of the formation at locality 114 (see Baumann Fiord) on the north side of Eids Fiord. The fauna is listed below:

Locality 114; GSC Cat. No. 57724

Fragment of Fimbriara sp., or Jakutoproductus sp.
Anemonaria sp.
Linoproductus sp.
Stenoscisma sp.
Cleiothyridina sp.
Neospirifer sp. or Septospirifer sp.
Spiriferella sp.

Identifications are by J.B. Waterhouse who suggests that the fauna represents the Jakutoproductus zone, and is therefore about the same age as the ammonoid and brachiopod faunas obtained at locality 52 (see above).

The fauna from locality 114 is of interest for three reasons: (1) Because the fauna occurs near the base of the Assistance, it seems probable that no part of the Assistance on Bjorne Peninsula is older than early Artinskian (i.e. Aktastinian). (2) The suggested age of this fauna conflicts in no way with writers opinion that the fusulinaceans in the underlying Belcher Channel Formation range upwards into the early

Artinskian (see p. 00). (3) If the age limits of the Belcher Channel and Assistance given above are correct, it follows that the widespread disconformity represented by the contact between these two formations is of no great time significance.

An especially interesting feature of the type locality of the Assistance is the abundant and well preserved fauna consisting mostly of brachiopods, but including a few ammonoids, pelecypods, scaphopods and gastropods. This fauna which occurs in the upper part of the formation, was described by Harker (in Harker and Thorsteinsson, 1960). Harker correlated this fauna with the Svalbardinian, a series erected by Stepanow (1957), as a marine equivalent of the Kungurian, and typified by the Spiriferenkalk of Spitsbergen. A correlation chart produced by Harker (op. cit., p. 14), shows the Assistance as equivalent to the upper part of the Baigendzhinian Subseries of the Artinskian, and upper part of the Leonardian and lower Wordian. The age of the Assistance has been the subject of considerable discussion in recent years, and although Harker's opinion that the Assistance and Foldvik Creek Formation of East Greenland are of similar age has been generally rejected, his age assignment of the Assistance has been generally accepted. In this connection it should be noted that since the publication of Harker's (op. cit.) study, basal beds of the type Word Formation have been included in the Leonardian Series of the Lower Permian (Cooper and Grant, 1966).

Representatives of the fauna that occurs in the type section of the Assistance have been found on Ellesmere Island, in section 73, on Hamilton Peninsula. There, as in the type section, the fossils are concentrated in the upper part of the formation. Peter Harker collected the following fauna approximately 350 feet above the base of the formation. Determinations are by J.B. Waterhouse.

Locality 73, GSC Cat. No. 58968

Rhipidomella sp.
Orthotetacean cf. Arctitreta sp.
Waagenoconcha sp. or Aulosteges sp.
Stenoscisma sp.
?Cleiothyridina sp.
Spiriferella sp.
Neospirifer sp. cf. N. marcoui (Waagen)
Phricodthyris sp.

In the same section of the Assistance, but 370 feet above the base of the formation, Harker collected the following forms which are identified by J.B. Waterhouse:

Locality 73; GSC Cat. No. 58973

?Waagenoconcha sp.
Aneomcnaria sp.
Linoproductus sp.
Yakovlevia sp.
Horridonia sp.
Stenoscisma sp.
Spiriferella sp.
Neospirifer sp.
Phricodothyris sp.

According to Waterhouse the two faunas listed above are similar to the brachiopod fauna described by Harker (in Harker and Thorsteinsson, 1960) from the type section of the Assistance which he regards as Ufimian in age. (Ufimian is a Russian series, inserted variously between the Artinskian and Kazanian, or between the Kungurian and Kazanian (Waterhouse 1969a, 1969b).

The ammonoids in the upper part of the Assistance which seem to constitute one faunal assemblage, provide additional information on the upper age limit of the formation. Nassichuk et al. (1965) includes a study of two ammonoids, Pseudogastrioceras fortieri Harker, and Spirolegoceras harkeri Ruzhencev, that were obtained by Thorsteinsson from the type section of the Assistance. According to Nassichuk et al. (op. cit.), these ammonoids indicated correlation of the Assistance with the Road Canyon Formation of west

Texas, equivalent formations in other parts of U.S.A., Soviet Union and Australia, which these authors (following Cooper and Grant, 1966) assign to the uppermost Lower Permian. Moreover, Nassichuk et al. (op. cit.) regarded these formations as probably younger than the type Baigendzhinian Subseries of the Artinskian. A further systematic study of "late" Assistance ammonoid fauna has been given by Nassichuk (1970), on the basis of collections made largely by himself from: (1) an interval 150 to 170 feet above the base of the type section; (2) exposures in the general vicinity of the type section of the Assistance on Grinnell Peninsula; and (3) the Assistance on Melville Island. The fauna includes the following:

> Daubichites (= Pseudogastrioceras) fortieri (Harker)
> Sverdrupites (= Spirolegoceras) harkeri (Rushendev)
> Sverdrupites sp.
> Popanoceras cf. P. sobolewskyanum (Verneuil)
> Sverdrupites amundseni n. sp.
> Snyartinskia belcheri n. sp.
> Medlicottia aff. M. orbignyana (verneuil)

Nassichuk's opinion on the correlation of this fauna differs from that previously expressed by Nassichuk et al. (op. cit), only insofar as it concerns correlation with the Russian standard of the Permian. According to Nassichuk, new forms in the fauna indicated affinities with ammonoid species from upper Artinskian strata (Baigendzhinian) of the Ural Mountains. Thus Nassichuk regarded the ammonoids as both latest Early Permian and latest Artinskian (Baigendzhinian) in age.

Although correlation of strata assigned to the Assistance in the environs of Cañon Fiord with the type section of the formation on Grinnell Peninsula has been established beyond reasonable doubt, there is some uncertainty concerning the identity of the Assistance on Bjorne Peninsula. The basis of the problem posed here are as follows: 1. There is no paleontological evidence to indicate the presence of strata older than late Artinskian (Baigendzhinian) in the Assistance on Grinnell Peninsula, Melville Island and in the environs of Cañon Fiord. Moreover, because the late Artinskian ammonoid fauna occurs throughout much of the thin development of the Assistance on Melville Island (see Nassichuk, 1970), it appears improbable that these strata could also include the early Artinskian (Aktistanian) faunas represented on Bjorne Peninsula. 2. There is no paleontological evidence to indicate the presence of strata younger than early Artinskian in the strata assigned to the Assistance on Bjorne Peninsula. Nevertheless, in section 52 shown on figure 1, about 450 feet of unfossiliferous strata overlie the youngest early Artinskian fossils, and it is possible that these upper beds are at least, in part late Artinskian in age. 3. The van Hauen Formation has nowhere yielded diagnostic fossils. Strata assigned to the Assistance on Bjorne Peninsula are equated with the van Hauen with reasonable certainty there on the basis of lateral continuity. The Assistance on Grinnell Peninsula, Melville Island and around Cañon Fiord have not been observed to grade basinward into the van Hauen. The opinion that these outcrops of the Assistance and the van Hauen are correlative is based partly on similar stratigraphic positions, and partly on the assumption that the Assistance in these areas equates with strata classed as Assistance on Bjorne Peninsula.

The relations just summarized suggest, two alternative classifications of the various rock units: 1. The strata in question on Bjorne Peninsula are incorrectly assigned to the Assistance. These strata represent a new formation that is older than the Assistance Formation. Moreover, equivalents of the Assistance in deeper parts of the Sverdrup Basin, if present at all, are unknown. 2. The strata on Bjorne Peninsula are correctly assigned to the Assistance, and represents a comparatively thick section deposited in deeper parts of the Sverdrup Basin where it ranges from early to late Artinskian. The formation thins rapidly in southerly and southeasterly directions, mainly by overstep of lower beds onto pre-Assistance rocks, with the result that sections in Melville Island, Grinnell Peninsula and in the environs of Cañon Fiord preserve strata of late Artinskian age only. Exposures of the Assistance on Bjorne Peninsula are situated further basinward than the three above mentioned areas which accounts for the presence of strata of early Artinskinian, and probably also Baigendzhinian ages.

No clear choice of the two alternatives set forth above can be made without further stratigraphic and paleontological work. Nevertheless, in the writer's opinion the second alternative seems to provide the simplest explanation of available facts, and represents the working hypothesis adopted in this report.

Van Hauen Formation

Definition, Distribution and Thickness.

The van Hauen Formation is here named for a sequence of rocks represented principally by dark coloured shale, and well-bedded siltstone and chert that are bounded below and above by regional disconformities. Throughout much of its areal extent the van Hauen lies either on the Nansen Formation or equivalent beds of the Hare Fiord Formation. It is generally overlain, either by the Degerböls Formation or its assumed facies equivalent, the Trold Fiord Formation. Locally other formations come to underlie and overlie van Hauen strata. The formation is named for the van Hauen Pass, a low valley that forms a short overland route between Hare and Otto Fiords in northwestern Ellesmere Island. The type section is about one mile northeast of this pass (*see* Pl. IV).

Contact relations and thicknesses of 12 measured sections of the van Hauen Formation are summarized in table 2. These sections are illustrated graphically in figures 1, 2 and 3. The areal distribution of the van Hauen, and location of measured sections of the formation are shown in text-figure 4 (*see* also *Baumann Fiord*, *Eureka Sound South*, *Eureka Sound North*, *Greely Fiord west*, *Otto Fiord*, and *Bukken Fiord*).

van Hauen strata were described for the first time by E.T. Tozer in his field studies on Bjorne Peninsula and around the head of Blind Fiord in southwestern Ellesmere Island (Tozer, 1963a, 1963b). Tozer applied the informal term, 'dark beds' to these rocks.

The thickness of the van Hauen is highly variable, and ranges from a trace to 2,240 feet. The formation generally attains its greatest thickness in the eastern part of its area of distribution. There also van Hauen strata are commonly divisible into distinctive lower and upper members. In general the formation thins in a northwesterly direction, and progressively thinner sections preserve proportionally smaller thickness of the upper member. In several localities including those indicated by measured sections in extreme western and northern regions of the area of study, the upper member is generally absent (see Fig. 2). That the van Hauen originally exhibited regional differences in total thickness of sediments can be demonstrated by markedly different thicknesses of the lower member in sections measured on Bjorne Peninsula and west of Blind Fiord in southwestern Ellesmere Island (these two sections are described later). Nevertheless, no clear understanding of such variations is now possible because at least one, and in some cases two periods of erosion have affected the van Hauen. Where van Hauen strata are overlain by the Trold Fiord Formation or correlative rocks of the Degerböls Formation one period of erosion is indicated by the disconformity that separates these formations. Where van Hauen rocks are succeeded by the Lower Triassic, Bjorne Formation or correlative rocks of the Blind Fiord Formation it is reasonable to assume that sub-Triassic erosion has removed the Trold Fiord (or Degerböls) Formation and then subjected the van Hauen to a second period of erosion.

Lithology.

Two members are differentiated in thicker, and therefore presumably more complete sections of the van Hauen. They are here informally designated, in upward sequence, as members A and B. The contact between these members is fairly sharp and generally only a few feet of beds are not readily assigned to either member. Member A is recessive-weathering and commonly occupies topographic lows, in marked contrast to the resistant and ridge-forming upper member (see Pls. IV and XI).

Member A, as typically developed, consists largely of interbedded shale and siltstone with lesser amounts of chert and sandstone, and rare bioclastic limestone. In some sections shale predominates, in others siltstone. The shale is dark grey to black, and commonly fissile and sooty. Small rounded ironstone concretions characterize some outcrops. In fresh exposures the shale commonly lacks bedding and may therefore, be described best as mudstone. The siltstone is also dark grey to black and thin to generally medium bedded, and thick bedded, it is variably shaly, commonly siliceous and very resistant. The member is on the whole noncalcareous, poor in fossils and not markedly bituminous. What fossils occur are represented mainly by fragmentary brachiopods and bryozoans.

Member B is a remarkably uniform succession of chert and subordinate siltstone that in places appear to intergrade, and it is commonly a difficult matter to distinguish these lithic types in the field. Both the chert and siltstone are generally dark grey to black, exceedingly resistant, sharp and brittle. They are thin to thick bedded, but generally medium bedded. Medium bluish grey chert is common. Shale and shale siltstone may occur as bedding plane partings. Thin sections have revealed that some of the chert is composed of spicules, presumably those of sponges. The siltstone is variably siliceous. Although the principal weathering colours are dark grey to black, some exposures weather to various shades of red, brown and yellow.

The foregoing lithologic characterization typifies the van Hauen as represented throughout the greater part of its areal extent. However, strata assigned to this formation in western and northern regions of Axel Heiberg Island, and north of Otto Fiord in northwestern Ellesmere Island appear to represent somewhat atypical developments of the formation, especially in having proportionally greater carbonate content. The van Hauen Formation in western and northern regions are therefore regarded as facies variations of the formation which are exposed in eastern and southeastern regions.

Probably the most characteristic features of the van Hauen as a whole are its prevailing, nearly black, fresh surface and weathering colours, and the sharp, brittle talus derived from these unusual rocks, that produces a crunching sound underfoot.

The type section of the van Hauen is shown on Plate IV. It is represented as section 69 on figure 3. The following is a description of this section.

Unit No.	Lithologic Character	Thickness in Feet
	Overlying strata, Degerbols Formation	
	Member B	
4	Chert and subordinate siltstone, interbedded; both lithic types are dark grey to black, thin to medium bedded, very hard and brittle; regularly bedded; many bedding plains exhibit pock-marked surfaces; many chert beds characterized by medium bluish grey colour; subordinate inter-leaves of dark grey shaly siltstone	595
	Member A	
3	Siltstone, quartzose, siliceous, noncalcareous, medium grey, thick bedded, very hard	60
2	Sandstone, quartzose, noncalcareous, medium grey, fine to medium textured, thick bedded, hard	50

Unit No.	Lithologic Character	Thickness in Feet
1	Shale and siltstone, interbedded, noncalcareous; shale, dark gryy to black, fissile, soft, constitutes about 2/3 of the thickness of unit; siltstone, quartzose, dark grey to black	630
	Total thickness of van Hauen Formation	1,335
	Underlying strata, Hare Fiord Formation	

The van Hauen, and for that matter the upper part of the Hare Fiord Formation, have not yielded diagnostic fossils. Consequently physical stratigraphy is as yet, the only means of distinguishing these formations.

The contact of the type section of the van Hauen and the underlying Hare Fiord Formation is not especially well marked insofar as it has been drawn within rocks that are dark coloured and lithologically similar in certain other respects. Nevertheless the contact does separate soft-weathering, predominantly noncalcareous strata from underlying, partly calcareous rocks, even though the placement of a few feet of beds at the contact remains in doubt. That this contact is more or less correct is indicated by the lithologic similarities of the type section of the van Hauen to strata assigned to this formation in nearby localities where the underlying rocks are those of the Nansen or Belcher Formations with which van Hauen rocks are lithologically sharply contrasted.

The most southerly exposures of the van Hauen occur in north-central regions of Bjorne Peninsula of southwestern Ellesmere Island, where excellent exposures occur on the west flank of the Schei Point anticline. The van Hauen on Bjorne Peninsula is especially interesting for three reasons: (1) van Hauen strata grade into light coloured sandstone and siltstone of the Assistance Formation a few miles to south and southeast of the Schei Point anticline. This provides the principal basis for correlating these two formations and dating van Hauen strata as Artinskian. (2) Exposures of the van Hauen on Bjorne Peninsula are located some 250 miles south of the type section of the formation which occurs near the northern limit of these rocks within the area of study. Nevertheless the thicknesses and lithologies of van Hauen strata in these two regions are more closely comparable to one another than to other developments of this formation in other localities. The significance of this if any is uncertain. (3) With the exception of the van Hauen, all other late Paleozoic and Mesozoic formations on Bjorne Peninsula are represented by near shore deposits. The occurrence in this region of the van Hauen Formation which is interpreted as a basinal deposit, suggest that the shoreline of the Sverdrup Basin was probably situated farther to the southeast of Bjorne Peninsula during van Hauen time than at any other time in the sedimentary history of the basin.

A section of the van Hauen measured on the west side of the Schei Point anticline (illustrated as section 53, figure 1), is described below.

Unit No.	Lithologic Character	Thickness in Feet
	Overlying strata, Bjorne Formation, Lower Triassic	
	Member B	
3	Chert and subordinate siltstone, interbedded; chert, dark grey to black, and bluish grey, thin to mainly medium bedded, and variably silty; siltstone, dark grey to black, thin to mainly medium bedded; both of the above lithic types, very hard and brittle; but commonly separated by soft, bedding plane partings of dark grey shaly siltstone. A 3-foot bed of bioclastic limestone occurs 30 feet from top of unit.....................	480
	Member A	
2	Shale, dark grey to black, partly silty, with ironstone bands and subrounded concretions; recessive-weathering	640

Unit No.	Lithologic Character	Thickness in Feet
1	Siltstone and subordinate shale, interbedded; siltstone, medium dark grey, thin bedded and very shaly; shale dark grey and variably silty; relatively resistant unit....................................	180
	Total thickness of van Hauen Formation	1,300
	Underlying strata, Belcher Channel Formation	

Excellent exposures of the van Hauen occur on the west side of Blind Fiord in southwestern Ellesmere Island. There the formation overlies the Nansen Formation, and is overlain for the most part by the Lower Triassic, Blind Fiord Formation, or by thin selvage wedge of the Trold Fiord Formation. Both lower and upper contacts are remarkably sharp on aerial photographs (see Pl. XI) and on the ground. van Hauen exposures west of Blind Fiord are situated more or less along a north-south line that includes the type section of the formation to the north, and outcrops of the formation on Bjorne Peninsula to the south. These exposures represent the greatest known thickness of the formation, and are of further interest in exhibiting lithologic characters by which they resemble closely rocks of this formation in the type section and on Bjorne Peninsula.

The van Hauen was studied some 4.5 miles southwest of the head of Blind Fiord. The section is described below.

Unit No.	Lithologic Character	Thickness in Feet
	Overlying strata, Trold Fiord Formation, Upper Permian	
	Member B	
3	Chert, dark grey to black, and medium bluish grey, thin to mainly medium bedded, very hard and brittle, ridge-forming; thin units of dark grey, bioclastic limestone are interbedded in upper part of member	800

Unit No.	Lithologic Character	Thickness in Feet
	Member A	
2	Shale and subordinate siltstone, interbedded, noncalcareous; shale, variably silty, dark grey to black, fissile; siltstone, quartzose, variably shaly, dark grey to black, mainly thin bedded, relatively recessive-weathering unit..	720
1	Siltstone and subordinate shale, interbedded, lithologic character as above; relatively resistant unit	740
	Total thickness of van Hauen Formation..................	2,240
	Underlying strata, Nansen Formation	

A sequence of strata classified as Member A of the van Hauen are intercalated between the Hare Fiord Formation and Lower Triassic, Blind Fiord Formation in two sections of Carboniferous and Permian rocks studied in eastern Axel Heiberg Island. One section includes a thickness of 1,075 feet of van Hauen strata and is situated south of the head of Mokka Fiord (Section 59, Fig. 2); the other section occurs north of Whitsunday Bay and there the van Hauen is 710 feet thick (Section 60, Fig. 2). The contact between Hare Fiord and van Hauen strata at these localities has been placed - by much the same criteria employed for this purpose in the type section of the van Hauen Formation - between a lower sequence represented by siltstone that is mainly thick-bedded, resistant and variably calcareous, and an upper sequence made up of alternating units of soft-weathering, non-calcareous, shale and thin-bedded siltstone. The absence in these sections of the distinctive chert beds of Member B of the van Hauen Formation increases the uncertainty of identifying Member A, especially in view of the fact that soft-weathering units of shale and siltstone may occur within sequences of the Hare Fiord Formation (e.g. Section 69, Fig. 3). Consequently the assignment of strata to the van Hauen Formation in these sections must be regarded as questionable.

The Lower Triassic, Blind Fiord Formation that overlies van Hauen strata at these localities is made up of siltstone and shale. Thus the Permian-Triassic boundary lies within rocks of rather similar lithologies. Although the van Hauen - Blind Fiord contact is not readily apparent on aerial photographs it is recognized easily on the ground by subtle lithologic differences, such as the generally less resistant nature, and lighter weathering colours of the Blind Fiord Formation.

western Axel Heiberg Island

Two sections of strata assigned to the van Hauen that occur south of Bunde Fiord in western regions of Axel Heiberg Island are illustrated geographically as Sections 57 and 58 in figure 2. The most westerly section, about one mile southwest of Arthaber Creek, consists of a uniform sequence of dark grey, thin-bedded calcareous siltstone that is very brittle and 225 feet thick. The other section is about 4 miles south of the mouth of Camp Five Creek. It comprises an alternating succession of argillaceous limestone and limestone that is very dark grey, finely textured, thin-bedded and 300 feet thick. The two sections are about 16 miles apart and occur in separate thrust sheets. Both sections are intercalated between the underlying Nansen Formation and overlying Degerbols Formation. The relationship of these sections to typical developments of the van Hauen in areas to the east is not entirely certain, but they are provisionally regarded as a calcareous facies of Member A.

Svartevaeg Cliffs, Northern Axel Heiberg Island

About 700 feet of strata that are tentatively referred to the van Hauen crop out near the southeastern limit of the spectacular sea cliffs known as Svartevaeg Cliffs, along the north coast of Axel Heiberg Island (Section 65, Fig. 3). In this region the van Hauen Formation overlies the volcanic formation, Esayoo, and underlies the Lower Triassic, Blind Fiord Formation. The formation is here made up of three principal assemblages. (1) The basal 80 feet or so consists largely of dark grey shale. (2) The succeeding, approximately 560 feet of strata is poorly exposed. It comprises an alternating succession of quartzose siltstone and sandstone, that are mainly medium light grey, thin to medium bedded, and variably calcareous and glauconitic; limestone that is medium grey, fine grained, thin to medium bedded and variably silty; and thin beds of dark grey chert. (3) The upper unit is made up mainly of chert that is light to dark grey, and thin-bedded, and subordinate interbeds of calcareous quartzose siltstone. It is about 60 feet thick.

Attempts to relate the above described strata to typical rocks of the van Hauen Formation are beset with difficulties, especially in view of the lack of faunal evidence and the isolated nature of the exposures at Svartevaeg Cliffs. A distance of some 40 miles separate the van Hauen at Svartevaeg Cliffs and the nearest known exposures of the formation. Nevertheless, it may be suggested that the upper 60 feet of chert and subordinate siltstone is correlative with Member B, while the remaining, and lower 640 feet of strata represent a facies variant of Member A.

North of Otto Fiord, Northwestern Ellesmere Island

Some 10 miles west of the head of Otto Fiord a thin representative of the van Hauen is intercalated above the Nansen Formation and below the Degerbols Formation (Section 67, Fig. 3). In this region van Hauen strata are divisible into three lithologic units. (1) The lower 65 feet of beds consist of bioclastic limestone that is medium dark grey, thin- to medium-bedded and variably silty, and associated thin interleaves of dark grey siltstone. Fossils occur throughout and include fragmentary brachiopods, bryozoans and crinoid debris. (2) The middle unit is 60 feet thick and is made up of dark grey, thin-bedded shaly quartzose siltstone and interbeds of dark grey, thin-bedded silty limestone.

(3) The upper part of the formation consists of dark grey, thin-bedded chert and siltstone beds, that total 30 feet in thickness. The relationship of the above described rocks to typical developments of the formation is uncertain, but it may be suggested that the lower two units are correlative with Member A, while the upper member is correlative with Member B.

Age and Correlation. The van Hauen has yielded a few small collections of generally poorly preserved brachiopods and bryozoans. These have not been studied critically. The formation is nevertheless dated as about early to late Artinskian on the basis of its presumed correlation with the Assistance Formation.

There is a good possibility that the van Hauen Formation is correlative with the Fantasque Formation on the Canadian mainland on the basis of similar lithologic characters and stratigraphic positions. The Fantasque Formation was described originally by Harker (1963, p. 23) for Permian rocks consisting largely of chert in southwestern District of Mackenzie. In addition to the latter region, the Fantasque Formation is now known t be distributed widely in the Yukon Territory and northern British Columbia (Bamber, Taylor, Procter, 1968). Moreover, the name Fantasque has been applied to rocks as far south as the Croswnest Pass in southern Alberta and British Columbia (Norris, 1965, p. 13). The following description of the Fantasque Formation in northeastern British Columbia by Bamber, Taylor and Procter (1967, p. 71) serves to illustrate the remarkable lithologic similarity between this formation and the van Hauen Formation. "The thickness of the formation decreases from 150 feet in the north to approximately 40 feet in the south, near Halfway River. In southern La Biche Range, and in the eastern and central foothills between Toad and Halfway Rivers, the Fantasque Formation is composed of irregularly bedded, medium to dark grey chert, which is pyritic in part and contains abundant sponge spicules. North of Tuchodi River the chert beds in the lower 10-15 feet of the unit are separated by laminae and thin beds of dark grey shale, as in the lower 22 feet of the type section. At the western edge of the foothills, near South Tetsa River, there are laminae and beds of shale throughout the formation, and the chert is interbedded with siliceous mudstone and siltstone". The Fantasque Formation, where preserved, represents the youngest Permian deposits. It is bounded above by a regional disconformity and underlies Lower Triassic rocks. It overlies strata which cannot be more precisely dated than Permian. In some places at least, the lower contact is a disconformity. The Fantasque Formation is poor in fossils, but it has yielded Helicoprion sp., and poorly preserved brachiopods. In this connection it is noteworthy that the Assistance Formation which is considered to equate with the van Hauen has also yielded Helicoprion sp. (Nassichuk, personal communication).

5. Upper Permian (Guadalupian) Marine Sequence

Trold Fiord Formation

Definition and Distribution.

The name Trold Fiord is here proposed for a formation that consists chiefly of sandstone, and subordinate biogenic limestone, pebble conglomerate and chert. The type locality is on a small, unnamed tributary of East Cape River which issues into the northeast side of Canon Fiord on the west coast of Ellesmere Island (see Pl. XXIV). There the formation overlies the Assistance Formation and is in turn overlain by the Lower Triassic, Bjorne Formation. The Trold Fiord Formation is named for a prominent fiord on the west coast of Ellesmere Island, some 100 miles south of the type locality. Excellent exposures of the formation occur also in the environs of Trold Fiord (see Pl. XII).

The Trold Fiord is confined to near-shore regions of the Sverdrup Basin, and besides Ellesmere Island it crops out on two other islands in the Canadian Arctic Archipelago: it forms a narrow east-west trending belt of outcrop across northern Melville Island[1]; and across southern Camberon Island[2]. On Ellesmere Island Trold Fiord strata

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1 Tozer (1963c), on the basis of field studies in 1955, was the first to establish the presence of Carboniferous and Permian rocks on Sabine Peninsula, Melville Island. His sequence of formations comprising rocks of these ages may be summarized briefly in ascending stratigraphic order, as follows: Canyon Fiord Formation; unnamed formation of quartzose limestone; unnamed formation of sandstone; and Assistance Formation. Of special interest here are the strata that Tozer referred to the Assistance Formation. They were described as 1,600 feet thick and consisting essentially of calcareous quartz sandstone.
In 1958, Tozer and Thorsteinsson (1964, pp. 93-111, 229) restudied the Carboniferous and Permian rocks of Sabine Peninsula. They also recognized four formations in rocks of these ages and these formations corresponded to those recognized earlier by Tozer (op. cit.), but with some important changes in terminology. The formations recognized by Tozer and Thorsteinsson are summarized briefly from oldest to youngest, as follows: Canyon Fiord Formation; Belcher Channel Formation; Sabine Bay Formation - a new name for Tozer's (op. cit.) unnamed formation of sandstone - and an unnamed formation. According to these authors the Assistance Formation was absent on Melville Island and most if not all of the 1,600 feet of strata referred earlier to that formation by Tozer (op. cit.) was in fact, a new formation; the Trold Fiord as defined in the present report.
In 1964, Nassichuk (1965) conducted detailed stratigraphic and faunal studies of the Carboniferous and Permian rocks of Sabine Peninsula. His stratigraphic conclusions regarding rocks included in the Canyon Fiord, Belcher Channel and Sabine Bay Formations are in essential agreement with those of Tozer and Thorsteinsson (op. cit.). On the other hand, Nassichuk's research produced a new and interesting interpretation of the strata assigned previously to the Assistance Formation by Tozer (op. cit.) and later regarded as a new formation by Tozer and Thorsteinsson (op. cit.). In these strata Nassichuk recognized three distinctive formations, all of which are apparently bounded below and above by disconformities. The three formations are summarized in ascending stratigraphic order as follows: 1. Assistance Formation, overlying the Sabine Bay Formation, and consisting of unconsolidated grey sand and ironstone concretionary bands, and varying in thickness from less than 85 to 100 feet; 2. Unite A, made up chiefly of bioclastic limestone and 465 feet in thickness; and 3. Unit B, consisting of green glauconitic sandstone, black chert and minor limestone, and attaining a maximum thickness of 800 feet. Unit B is the Trold Fiord Formation as defined in this report.

2 Rocks classified asthe Assistance Formation in southern regions of Cameron Island by Greiner (1963, p. 636) are undoudtedly misidentified. They are here referred to the Trold Fiord Formation.

trace a narrow belt that extends from the environs of Trold and Blind Fiords in the south to territory between Tanquary Fiord and the head of Hare Fiord in the north. (see Text-fig. 5; also Baumann Fiord, Eureka Sound South, Eureka Sound North, Greely Fiord West, Greely Fiord East, Otto Fiord and Tanquary Fiord).

Stratigraphic relations and Thickness.

The Trold Fiord Formation and its assumed correlative, the Degerbols Formation represent the youngest Permian deposits in the Sverdrup Basin. Both formations are delimited below and above by regional disconformities and they are invariably overlain, either by the Lower Triassic Bjorne Formation, or its facies equivalent, the Blind Fiord Formation.

The Trold Fiord Formation varies in thickness from a trace to over 900 feet, and thicknesses may be highly variable over short distances (see Table 3). This is owing in part at least, to post-Permian erosion of upper beds and in part to overstep of lower beds towards the southeastern margin of the Sverdrup Basin. That the Trold Fiord represents a transgressive deposit is suggested by the fact that it comes to overlie progressively older Permian and Carboniferous formations when traced from northwest to southeast (see Table 3). Both lower and upper contacts of the formation are well marked on the ground and on aerial photographs.

Lithology.

The formation consists mainly of quartzose sandstone that is grey, green or brown, fine to coarse textured, thin to thick bedded and massive, variably calcareous and glauconitic[1], and resistant to mainly friable and soft-weathering. The sandstone is

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1 The term glauconite is used here in the broad sense of including the clay minerals chlorite, montmorillonite, and kaolinite (Triplehorn, 1966).

predominantly fine grained and medium bedded. Interbedded at various intervals with the sandstone are subordinate units of fossil fragmental limestone and coquinoid limestone, pebble conglomerate and less commonly, beds of grey or blue chert. The limestone is grey, pink or brown, generally irregularly and medium bedded, and variably quartzose and glauconitic. The conglomerate is made up of granules and pebbles in a groundmass of calcareous quartzose sandstone. The clasts are subrounded to subangular and consist mainly of red jaspers, limestone, sandstone and quartz. The conglomerate and limestone units are generally resistant and form topographically prominent ridges and low cliffs.

Two outstanding characteristics of the Trold Fiord are its remarkable profusion of fossils and almost startling green weathering colour by which this formation is readily identified. Although green as a fresh surface colour is secondary to various shades of grey, green glauconite as an uniquitous weathering product tends to coat most Trold Fiord outcrops and colours the soft slopes that commonly develop on parts of this formation. Nevertheless, dusky red and moderate red weathering colours characterize certain beds in most exposures of the formation, particularly in the territory between Borup Fiord and the head of Hare Fiord in northwestern Ellesmere Island where these colours are dominant.

The following is a detailed description section of the Trold Fiord at the type locality northeast of Canyon Fiord (<u>see</u> also section 72, Fig. 3).

<u>Unit No.</u>	<u>Lithologic Character</u>	<u>Thickness in Feet</u>
	Overlying strata, Bjorne Formation, Lower Triassic, quartzose sandstone	
3	Sandstone, quartzose, glauconitic, mainly light grey and dark greenish grey, fine to medium grained, thin to thick bedded, generally medium bedded, commonly irregularly bedded, alternating hard and very soft units, variably calcareous; sparse brachiopods and <u>zoophycos</u> throughout	240

Unit No.	Lithologic Character	Thickness in Feet
2	Sandstone, quartzose, glauconitic, coquinoidal calcareous, dark greenish grey, fine to coarse grained, thin to mainly thick bedded, highly fossiliferous; alternates with limestone, quartzose, glauconitic, medium light grey, mainly coarse grained, thin to medium bedded; hard, resistant unit greenish and brownish weathering colours.............	62
1	Sandstone, quartzose, glauconitic, dark greenish grey, fine-grained, thin bedded, soft weathering. A three-foot bed of chert pebble conglomerate occurs 13 inches above base of unit; consists of rounded to subrounded, multicoloured chert in a calcareous quartzose sandstone cement; sparse brachiopods throughout	48
	Total thickness of Trold Fiord Formation	350

Age and Correlation.

Most exposures of the Trold Fiord in the report area are abundantly fossiliferous, but the fossils are commonly not as well-preserved as on Melville Island, nor are they as easy to collect. The most characteristic fossils are brachiopods and bryozoans, and rare gastropods, pelecypods and horn corals. Many of the brachiopods and bryozoans are uncommonly large.

Three collections of brachiopods were examined by J.B. Waterhouse who reports:

Locality 72; GSC Cat. No. 57687, obtained 60 feet above base of type section

Thamnosia (Thuleproductus) n. sp. A
Spiriferella sp.

Locality 72; GSC Cat. No. 57688, 100 feet above base of type section

?Kuvelousia sphiva Waterhouse
Neospirifer cf. N. striatoparadoxus (Toula)

Locality 73; GSC Cat. No. 58951, collected in lower part of the formation about 4 miles northeast of locality 71

giant Waagenoconcha - W. purdoni not Waagen of Wiman from Productuskalk of Spitzbergen and Bear Island
Horridonia granulifera
Thamnosia sp.
Yakovlevia
?Stenoscisma
Neospirifer aff. N. striatoparodoxus (Toula)

According to Waterhouse the faunas indicate a Kazanian (Wordian Substage) age.

Corals associated with the fauna from locality 73 have been identified as Sochkineophyllum sp., by E.W. Bamber who reports: that the genus occurs mainly in the Lower Permian, but is also known from the Carboniferous. According to Bamber the species of Sochkineophyllum represented at locality 73, occurs also in the Degerböls Formation on Bjorne Peninsula (locality 52), and in talus at the base of the Trold Fiord Formation on Melville Island (GSC Cat. No. C-484). Bamber regards these corals as similar Sochkineophyllum artiense (Soshkina) from the Artinskian on Lytva River, central Urals, U.S.S.R.

A single specimen of an ammonoid collected by A.H. MacNair from the Trold Fiord on Cameron Island has been described as Neogeoceras macnari by Nassichuk, Furnish and Glenister (1965). According to these authors species of Neogeoceras are confined to rocks of Guadalupian age.

Several collections of brachiopods made by W.W. Nassichuk from the Trold Formation on Melville Island have been identified by R.E. Grant who suggests that the brachiopods are Guadalupian in age. He also regards these faunas as probably correlative with the Wordian Substage, and the brachiopods described by Dunbar (1955) from the Foldvik Creek Formation of central East Greenland (Nassichuk,personal communication).

It would seem very unlikely that the Trold Fiord is older than Guadalupian because of its stratigraphic position above the Assistance Formation which is considered to include strata of latest Artinskian age. A Guadalupian age is accepted for the Trold Fiord Formation in this report.

Degerböls Formation

Definition, Distribution and Stratigraphic Relations.

The Degerböls Formation is a relatively thin, resistant carbonate unit which commonly forms prominent dip slopes in the mountains of northwestern Ellesmere Island.

It is here named for Degerböls Island, a small island located near the head of Otto Fiord in northwestern Ellesmere Island. The type section is less than a mile east of van Hauen Pass, and about 12 miles east of Degerböls Island (see Pl. IV). It is illustrated graphically in section 69, figure 3. The type section is completely exposed and exhibits both bottom and top contacts. As a point of interest, a nearly complete section of the formation crops out on Degerböls Island.

The Degerböls is distributed in southwestern and northwestern Ellesmere Island, and northern Axel Heiberg Island (Baumann Fiord, Greely Fiord West, Otto Fiord, Cape Stallworthy, and Bukken Fiord). Distribution of the Degerböls and its preseumed equivalent, the Trold Fiord Formation are shown in text-figure 5. The Degerböls and Trold Fiord are regarded as basinal and near-shore facies, respectively.

Like the Trold Fiord Formation, the Degerböls constitute the top of the Permian, and is separated from overlying Lower Triassic strata by a widespread erosion surface. Throughout most of its areal extent, the Degerböls lies disconformably on the van Hauen Formation. However, in some places, for example on Svartefjeld Peninsula (Greely Fiord West, and Bukken Fiord), the van Hauen Formation has been removed by erosion and Degerböls strata which rest directly on the Nansen Formation. On Bjorne Peninsula the Degerböls lies with structural conformity on the Assistance Formation, but there the actual contact of the two formations has not been observed.

Lithology and Thickness

The type section of the Degerböls consists mainly of alternating units of biogenic limestone and lesser amounts of aphanitic to fine-grained limestone. These rocks are light to medium grey, and thick- to generally medium-bedded. The dominant weathering colours are various shades of grey and yellow. Grey and blue chert is rather common throughout the section, and occurs principally as irregular nodules, and as individual beds, or more rarely as fossil replacements. The biogenic limestone is characteristically medium to coarse grained, medium grey and commonly contains fragments of fossils that are recognizable as brachiopods, bryozoans and crinoid columnals. Except for absence of fusulinaceans, rocks of the Degerböls resemble closely those of typical developments of the Nansen Formation.

The thickness of the Degerböls is highly variable, a character that reflects differential erosion by sub-Triassic erosion; at several places, the entire formation has been removed. The type section is 600 feet thick. The thickest known section is south of Bunde Fiord in western Axel Heiberg Island, where a thickness of 1,270 was obtained (section 57, Fig. 2). In this area the Degerböls is somewhat atypical in that it consists of nearly equal parts limestone and chert.

An unusual section of the Degerböls that crops out in the Krieger Mountains of northern Ellesmere Island was studied by D. Morris and T.A. Frisch (see section 78, Fig. 4). There the formation is 920 feet thick and consists mostly of thin-bedded, light grey to bluish grey chert, and minor amounts of cherty limestone.

Rocks assigned to the Degerböls on Bjorne Peninsula in southwestern Ellesmere Island include two relatively small areas of limestone exposures where partial sections were measured (sections 49 and 52, Fig. 1; Pl. XXVII). The present-day erosion surface forms the top of the formation in both areas. The Degerbols on Bjorne Peninsula conforms more or less to the lithologic characterisation of typical rocks given above. Although the lower part of the formation there contains small amounts of interbedded siltstone and shale, this is not unusual. The best outcrops of the Degerböls are found at Great Bear Cape where 465 feet of strata are exposed.

Age and Correlation.

It was from the limestone at Great Bear Cape that Per Schei (1904), geologist on the "Second Norwegian Expedition in the Fram, 1898-1902", under the command of Otto Sverdrup (1904), collected most of the Permian fossils described by Tschernyschew and Stepanow (1916). The fossils included a sponge, corals, bryozoans, brachiopods and pelecypods, and the report by Tschernyschew and Stepanow made Great Bear Cape one of the best known geological localities in the Canadian Arctic Archipelago. Nevertheless, the age of the Great Bear Cape fauna is still a matter of considerable disagreement among paleontologists. Troelsen (1950, p. 72) reviewed the problem of the age of the Great Bear Cape fauna and concluded that, "Although some of Tschernyschew's identifications may need revision, the present writer is inclined to agree with Tschernyschew and Stepanow (1916) that the Great Bear Cape sequence should be referred to the zone of Pseudoschwagerina". (Pseudoschwagerina is regarded as an index fossil of the Wolfcampain Series). Dunbar (1955, p. 59), in his monographic study of the Permian brachiopods of central East Greenland, expressed the opinion that the Great Bear Cape fauna is Lower Permian in age, and distinctly older than the brachiopod faunas of central East Greenland which he regarded as Late Permian (Zeckstein) in age. Gobbet (1963, p. 191), in a comprehensive study of Carboniferous and Permian brachiopods of Svalbard, stated that the brachiopods in the Great Bear Cape fauna, as described by Tschernyschew and Stepanow (1916) compare with the Early Permian elements in the Svalbardian fauna but that Late Permian forms are absent. In 1960, Minato described Ipciphyllum tschernyschewi as a new species of coral based on materials from the Great Bear Cape fauna which had been originally referred to Lithostrotion borealis Stuckenberg by Tschernyschew and Stepanow (op. cit). Partly on the basis of other occurrences of the genus Ipciphyllum, and partly on the basis of a re-evaluation of the brachiopods from Great Bear Cape, Minato argued convincingly for correlating the Great Bear Cape fauna with the upper part of the Parafusulina zone of Thompson (1948). Thus, Minato dates the Great Bear Cape (= Degerböls) fauna as Guadalupian, or early Late Permian.

Minato's age assignment of the Degerböls is followed in the present report. It is the most readily acceptable age on the bases of: (1) the latest Early Permian age assignment of the Assistance Formation that immediately underlies the Degerböls; (2) presumed correlation of the Degerböls and Trold Fiord Formations; and (3) age determinations of a few small fossil collections obtained by the writer from the Degerböls.

Fossils are plentiful in the Degerböls at Great Bear Cape, but the outcrops generally form steep ledges that are not easily collected. Fossils are most easily obtained in the talus apron at the foot of the cape, and it seems reasonable that Per Schei, who collected under conditions of snow cover at Great Bear Cape, obtained most of his excellent materials from this source. The following forms were obtained about 360 feet stratigraphically above the base of exposures by the writer at Great Bear Cape. They have been identified by R.E. Grant who comments:

"Locality 49 (GSC Cat. No. 67265)

Kochiproductus? sp.
Linoproductus dorotheevi (Fredericks)
Neophricadothyris asiatica (Chao)
"Productus" arcticus Whitfield
Spiriferella keilhavi (Boch)
Waagenoconcha payeri (Toula)
Yakolevia sp.

Spirifella keilhavi is too loosely defined to be of value in detailed correlation; "Productus" arcticus provides a link with some Word and Guadalupe correlatives in Alaska and Western Canada; Yakolevia and Kochiproductus suggest correlation with the Central East Greenland fauna. The age would seem to be "Svalbardian", but whether early or late is uncertain.

Comparison of this list with the list from the Assistance Formation (Harker and Thorsteinsson, 1960, p. 11) shows very little in common: only the questioned (by them) species of Waagenoconcha, and the specifically indeterminate and generically doubtful Kochiproductus from Bjorne Peninsula".

Brachiopods obtained from the type section of the Degerböls, about 475 feet above the base of the formation, as tabulated below:

(Locality 69; GSC Cat. No. 47846)

Waagenoconcha sp.
Anemonaria sp.
alate Pterospirifer n. sp.
Spiriferinaella sp.
Choristies sp.

Identifications are by J. B. Waterhouse who suggested an early Kazanian age (= early Guadalupian) for the collection.

PERMIAN-TRIASSIC BOUNDARY

Basal Mesozoic deposits in the Sverdrup Basin are represented by two, correlative Lower Triassic rock units: the Bjorne Formation, a marginal facies consisting mainly of red quartzose sandstone that traces a northeasterly path in western Ellesmere Island from Bjorne Peninsula to and beyond the environs of Tanquary Fiord; and the Blind Fiord Formation, a basinal facies made up chiefly of dark coloured siltstone, shale and fine-grained sandstone. The Blind Fiord is widely distributed throughout Axel Heiberg Island, and western and northwestern regions of Ellesmere Island. Tozer (1967, p. 13) correlates the Otoceras concavum Zone at the base of the Blind Fiord Formation with the Otoceras woodwardi Zone of the Himalayas. The latter zone is generally accepted as constituting the base of the Triassic. Moreover, according to Tozer (pers. com.), basal beds of the Bjorne and Blind Fiord Formations may be regarded for all practical purposes as synchronous. Throughout much of their areal extent, the Bjorne and Blind Fiord Formations overlie rocks of Permian age. However, in western regions of Ellesmere Island, Permian rocks are locally bevelled out by erosion and Triassic rocks lie on Carboniferous rocks (see Pl. XXVI).

The Trold Fiord Formation (green glauconitic sandstone) and its facies equivalent the Degerböls Formation (limestone), both of Guadalupian age, constitute the youngest Permian deposits in the Sverdrup Basin. As there is no paleontological evidence to indicate the presence of the Djhulfian Stage (latest Permian) in this region, the break between Permian and Triassic rocks denotes a considerable hiatus in the sedimentary record. Furthermore, as the Bjorne and Blind Fiord Formations include the oldest known Triassic rocks it is apparent that the hiatus represents Permian time only.

Actual exposure of the Permian-Triassic contact has been observed at many widely separated localities on Axel Heiberg and Ellesmere Islands, and in all instances the contact is represented as a sharp surface of separation between structurally conformable formations. Basal conglomeratic beds are rarely present in the Bjorne Formation, and have not been observed in the Blind Fiord Formation. In general the upper surface of Permian rocks beneath the sub-Triassic disconformity shows little or no evidence of erosion. However, the upper 20 feet or more of beds in the type section of the Degerböls Formation in northwestern Ellesmere Island (see p. 00) consists of vuggy limestone infilled with iron oxide, indicating that the formation was probably leached prior to deposition of the Blind Fiord Formation.

The regional relationships of Permian and Triassic rocks leave no doubt that the two systems are separated by a regional disconformity, involving not only withdrawal of marine waters from the Sverdrup Basin, but also differential uplift and widespread erosion. Late Permian tectonic adjustments in the basin are indicated clearly in figures 1 to 4 by the different formations that underlie Triassic rocks in different regions. Moreover, the absence of both the Trold Fiord and Degerböls Formations over large areas of eastern and northeastern Axel Heiberg Island, and neighbouring regions of Ellesmere Island as shown in text-figure 5, seems most reasonably attributed to broad, differential uplift along the axis of the Sverdrup Basin in latest Permian time.

DIAPIRS

History of Study

B.W. Waugh, in the course of indexing trimetrogon aerial photographs of the Canadian Arctic Archipelago taken by the R.C.A.F. in 1950, noticed on Melville and Ellef Ringnes Islands several distinctly circular landforms which he brought to the attention of the Geological Survey where the photographs were studied by I.C. Brown (1951). Brown recognized that these landforms were very probably structurally controlled, and after proposing several alternate hypotheses to explain their origin, he concluded that they probably represented igneous intrusions.

In 1952 and 1953, W.W. Heywood (1955, 1957), using the Isachsen weather station as his base of operation and travelling by foot, carried out the first geologic studies on Ellef Ringnes Island. In 1953, Heywood walked from Isachsen to the nearest circular structure, a distance of some 30 miles, where he made the startling discovery that the core work in what he referred to as the Isachsen Dome (= Isachsen Diapir in this report) was highly deformed anhydrite and its alteration product gypsum, with minor interbeds of limestone, and inclusions of limestone, diabase, basalt and gabbro. Equally surprising was Heywood's discovery that the anhydrite was not cap rock but of primary sedimentary origin and that it constituted the mobile rock in the diapir.

Following Heywood's (op. cit.) studies, the diapirs of the Sverdrup Basin attracted a great deal of attention, not only for their intrinsic interest but also because of the association of petroleum and diapirs in various parts of the world. Although a great deal of information has been added to our knowledge of these interesting structures since Heywood's pioneer work, the outstanding general features of the Isachsen Diapir that he determined after his arduous walk from the weather station have been found to characterize the scores of diapirs now known to occur in Sverdrup Basin.

In 1955, members of Operation Franklin established the fact that large numbers of diapirs occurred in the Sverdrup Basin, particularly on Axel Heiberg Island. Their report (Fortier, et al., 1963) contains descriptions of several diapirs (Roots, 1963a, 1963b, 1963c).

In 1956, Thorsteinsson and Tozer (1957) discovered a formation of bedded anhydrite and gypsum - the Otto Fiord Formation of the present report - in normal stratigraphic position in the vicinity of Hare Fiord in northwestern Ellesmere Island, and determined its age as Pennsylvanian or Permian. Moreover, in the same general region, these authors traced this formation laterally into a large diapir (Hare Fiord Diapir) and concluded that the formation probably represented the same rocks that gave rise to the anhydrite and gypsum diapirs in other parts of Sverdrup Basin.

In 1957, Fortier (p. 431) suggested that the development of diapirs in the Sverdrup Basin was related to the Tertiary orogeny that affected a major part of the Sverdrup Basin. This concept was accepted by Thorsteinsson and Tozer (1960).

E.H. Kranck (1961), on the basis of field work carried out in 1959 in western Axel Heiberg Island, noted that the Strand Fiord region was characterized by mainly broad, open synclines and tightly folded anticlines, and that the latter were commonly pierced by diapirs. Kranck attributed this style of folding to compressional and isostatic forces acting at the same time on thick Mesozoic sediments - rendered competent by a unit of volcanic flows and numerous basic igneous sills - overlying incompetent late Paleozoic anhydrite and gypsum. Kranck visualized the evaporitic rocks as having moved upwards under the influence of compressional and isostatic forces to pierce anticlines and form elongated diapirs. Moreover, Kranck recognized a second type of diapir in this region: large circular domal structures, typified by the South Fiord

Diapir. The latter Kranck (p. 440) regarded as probably having formed " . . . more or less in step with sedimentation", and mainly as a result of " . . . load pressure", but he offered no evidence for this assertion.

During the field seasons of 1960, 1961 and 1962, the Dominion Observatory in conjunction with the Polar Continental Shelf Project, conducted a program of reconnaissance gravity surveys over a large area of the Queen Elizabeth Islands. On the basis of the first two years work, Sobczak (1963) published a Bouguer anomaly map of Ellef Ringnes and Amund Ringnes Islands, and a report in which he interpreted negative gravity anomalies over Isachsen Diapir and Dumbbell Diapir (Ellef Ringnes) as indicating intrusive gypsum, while a pronounced gravity high over North Cornwall Diapir (Amund Ringnes) is regarded as indicating a basement arch and basic intrusions. Sobczak et al., (1963) summarized the three-year program with a report and four Bouguer anomaly maps covering much of the Sverdrup Islands group and Parry Islands group. In the report these authors stated, "The local negative anomalies on Ellef Ringnes Island coincide with gypsum intrusions that in turn may be underlain by masses of salt".

In the field season of 1960, Hoen (1964) carried out a detailed study of ten representative diapirs in western Axel Heiberg Island. He rejected the possibility that the anhydrite in core rocks represents residual cap rock that resulted from upward migrating meteoric water. He also discounted the possibility that the anhydrite cores originated as a bedded unit of evaporite that originally overlay bedded halite and rose passively upwards above rising columns of salt. Instead, Hoen concluded that the Axel Heiberg diapirs are structurally similar to, and originated in the same manner as halite diapirs.

Hoen)op. cit.) stated that certain of the larger diapirs in western Axel Heiberg Island developed under static conditions prior to the Tertiary orogeny. He accepted the hypothesis which attributes diapirs to the isostatic rise of materials having greater plasticities and lesser specific gravities than those of superincumbent rocks. He regarded the specific gravity and strength of anhydrite as too great to permit diapirism, and therefore suggested that the anhydrite cores originated as bedded gypsum which burial to depths of about 2,000 m, commenced to rise isostatically. Hoen believed that dehydration did not commence until the sedimentary cover reached thicknesses of about 5,000 m, and that isostatic rise of the core ceased when mixed gypsum and anhydrite achieved a specific gravity comparable, or somewhat greater than the country rocks. The smaller anticlinal, and fault diapirs, Hoen regarded as having been induced by orogenic forces.

Schwerdtner and Clark (1967) devoted the field season of 1963 to detailed studies and mapping of two diapirs on Axel Heiberg Island. South Fiord Diapir (studied also by Hoen, 1964), and Mokka Fiord Diapir. These authors are at one with previous workers in regarding the role of anhydrite in these diapirs as active, rather than passive. While accepting the possibility that halite may underlie the anhydrite at depth in normal stratigraphic position, Schwerdtner and Clark did not regard halite as essential to the development of diapirs. These authors differed from Hoen (op. cit.) in regarding anhydrite and not gypsum as the original source material, and they considered that differences in plastici between source rocks and overburden can induce diapirism under suitable stress conditions, regardless of differences in specific gravity. Moreover, they pointed out that the viscosity of anhydrite is comparable to that of halite.

According to Schwerdtner and Clark (op. cit.), the South Fiord Diapir is composed of three subcores, whereas the Mokka Fiord Diapir represents a single core. Furthermore, they stated that the two diapirs were emplaced prior to the Tertiary orogeny, but their reasons for this belief are not clear.

Diapirism in the Sverdrup Basin is the subject of a paper by Gould and de Mille (1964), based on extensive photogeologic studies and field investigations conducted in 1960 on Ellef Ringnes, Amund Ringnes and Axel Heiberg Islands. These authors distinguished two major categories of diapirs: 1, Large, domal structures that intrude weakly deformed sediment in western regions of the Sverdrup Basin, as for example on Ellef Ringnes and Melville Island. These diapirs are regarded as essentially halite diapirs consisting of, " . . . halite cores beneath the exposed gypsum and anhydrite"; 2, Generally smaller, elongate diapirs that are associated with faults or anticlinal axes, and which occur in the highly deformed regions of the Sverdrup Basin on Axel Heiberg and Ellesmere Islands. According to Gould and de Mille (op. cit.), such diapirs probably did not involve halite but have resulted from the tectonic squeezing of anhydrite. (The paper by Gould and de Mille, as well as that of Hoen (1964) contains many excellent illustrations of diapirs in the Sverdrup Basin).

The thinning of the Cretaceous Hassel Formation in the direction of the Isachsen Diapir is cited by Gould and de Mille (op. cit.) as evidence that some movement of this diapir took place as early as Cretaceous time. Furthermore, these authors state that locally, Cretaceous sediments along the periphery of the Isachsen Diapir appear to lie unconformably on core rocks. Stott (1969), who carried out regional stratigraphic and structural studies on Ellef Ringnes Island in 1967, has produced considerable stratigraphic evidence to support the opinion that certain diapirs in this island were rising as early as Late Jurassic time. Moreover, he suggested that movement of the core rocks may have occurred continually since then. According to Stott (op. cit., p. 38) ". . . the Tertiary orogeny was at most a secondary influence rather than the primary cause of the development of diapirs on Ellef Ringnes Island."

Spector and Hornal (1970) interpreted negative gravity anomalies over Cape Calquhoun Diapir (Melville Island), Isachsen Diapir (Ellef Ringnes Island), and South Fiord Diapir (Axel Heiberg Island), in order to estimate heights of the evaporite stocks. Each stock was assumed to represent a right-vertical cylinder consisting of two homogeneous parts, high density anhydrite overlying low density gypsum and/or salt. Each stock was assumed to represent a right-vertical cylinder consisting of two homogeneous parts, high density anhydrite overlying low density gypsum and/or salt. Each stock was assumed to be surrounded by country rock of uniform density. On the basis of these assumptions depth calculations indicated maximum depth of 700 to 2,800 m for Cape Colquhoun Diapir, 3,500 to 4,500 m for Isachsen Diapir, and 800 to 2,000 m for South Fiord Diapir. Spector and Hornal (op. cit.) stressed that these depth destimates are gravity minima because of the following possibilities: "(a) the existence of a transition zone in which a gradation occurs between the low density (gypsum/rock salt) and high density (anhydrite) zone; (b) the cross-sectional area of the dome decreases with depth, i.e., it has a tear-shaped cross section; (c) the density contrast of the low-density region is less in magnitude than 0.1 gm/cm^3 with respect to the surrounding medium".

Observations and Remarks on Diapirs

Anhydrite diapirs are common in Axel Heiberg Island and northwestern Ellesmere Island, particularly along the axis of the Sverdrup Basin (see Text-fig. 6). The diapirs vary in size from bodies a few square feet in area to prominent topographic features such as the South Fiord Diapir which is about 5 miles in diameter and towers some 1,500 feet above the surrounding countryside. While it is impossible to offer a meaningful estimate of the total number of diapirs of all sizes on the two islands, 98 diapirs are of sufficient size to be shown on the geologic maps accompanying this report. These diapirs are distributed among the following map-areas: Haig-Thomas Island, Glacier Fiord, Middle Fiord, Strand Fiord, Eureka Sound North, Bukken Fiord, Greely Fiord West, Cape Stallworthy and Otto Fiord. The largest concentration of diapirs is in the environs of Strand Fiord in western Axel Heiberg Island. A total of 40 diapirs are shown on the Strand Fiord map-area alone, but some of these are probably connected at depth.

Scores of small diapirs are represented simply as low mounds or topographic lows of tumbled and disordered blocks of gypsum and lesser amounts of selenite. Large diapirs are commonly intricately dissected by streams, a feature which combined with the extreme tectonic disturbance of core rocks presents the appearance of chaotic landscapes. Gypsum is the most common rock observed in the cores but fresh surface exposures are generally found to be anhydrite. Selenite is common also in most large diapirs, and occurs as inclusions, veins and individual beds. Inclusions of limestone, diabase, gabbro and basalt are also common, particularly in extremely contorted and sheared parts of the core. Partial sections up to 300 feet or more in thickness of the anhydritic formation that fave rise to these diapirs can be found in many of the larger diapirs, particularly in peripheral regions where the strike of the anhydrite generally conforms to the edge of the core.

Three principal kinds of diapirs may be differentiated in the report area on the basis of regional setting: (1) Diapiric dome. This diapir is generally large and rounded in plan. It occurs in regions of gently inclinded to flay-lying sediments, and is common in western regions of the Sverdrup Basin such as Ellef Ringnes and Melville Islands. The South Fiord Diapir, Cape Levvel Diapir and Sand Bay Diapir in western Axel Heiberg Island (Middle Fiord) are probably the only representatives of this type of diapir in the report area. (2) Diapiric anticline. This diapir is found in axial region of anticlines. It is generally elongate and its principal axis coincides more or less with the axis of anticlines. It is well exemplified by the Kanguk Diapir in western Axel Heiberg Island (Middle Fiord). (3) Fault diapir. This diapir is associated with both gravity and thrust faults. The anticlinal diapir and fault diapir are comparable in size and shape; both are generally smaller than the diapiric dome, and occur in the more highly deformed terrains of Axel Heiberg Island and northwestern Ellesmere Island. It is not always possible to distinguish diapiric anticlines and fault diapirs. Several examples of fault diapirs occur along the Stolz thrust in eastern Axel Heiberg Island (Eureka Sound North). A special type of fault diapir may be recognized in anhydrite dykes that intrude certain gravity faults. An excellent example of this kind of a diapir occurs along the east side of Hare Fiord in northwestern Ellesmere, some 15 miles northeast of the junction of Hare Fiord and Greely Fiord (Greely Fiord West).

The reasons for regarding the Otto Fiord Formation as having provided the source materials for diapirs, not only on Axel Heiberg and Ellesmere Island, but for the entire Sverdrup Basin are as follows: (1) Correlation of the Otto Fiord Formation and diapirs is suggested by the Bashkirian age of that formation based on its stratigraphic position within normal stratigraphic successions around Hare Fiord in northwestern Ellesmere Island, and the Bashkirian age of ammonoids found in core rocks of the South Fiord Diapir (western Axel Heiberg Island) and Barrow Diapir (Melville Island, see p. 00). (2) Partial sections of anhydrite, generally including minor interbeds of limestone that have been studied in several of the large diapirs in the Sverdrup Basin, bear closer lithologic similarity to the Otto Fiord Formation than to any of several other anhydritic formations in the Archipelago. (3) Diapirs of moderate size at two widely separated localities, namely Hare Fiord Diapir some 10 miles northeast of the mouth of Hare Fiord in northwestern Ellesmere Island (Greely Fiord West), and Whitsunday Bay

Diapir in eastern Axel Heiberg Island (Eureka Sound North), are continuous with outcrops of the Otto Fiord Formation in normal stratigraphic position along major thrust faults. (4) Fossils older than Carboniferous have not been found in any diapir in the Sverdrup Basin. On the basis of available evidence the Otto Fiord Formation represents the only possible source of diapirs in the Sverdrup Basin.

Gould and de Mille (1964, p. 725) and Stott (1969, p. 38) have suggested that evaporites of lower Paleozoic age may be involved in diapirs of the Sverdrup Basin. Of particular interest in this connection are the Baumann Fiord and Bay Fiord Formations, both of Ordovician age. These formations are distributed widely in the Franklinian miogeosyncline of southeastern and southern Ellesmere Island (Kerr, 1968). One or both formations are exposed in the Franklinian miogeosyncline on Devon Island, Cornwallis Island and Bathurst Island (Kerr, 1967a). However, neither the Baumann Fiord or Bay Fiord, nor any other evaporitic formation is known to occur in the Franklinian eugeosyncline of northern Axel Heiberg and northern Ellesmere Islands (Trettin, 1969a, 1969b). Moreover, as the Sverdrup Basin appears to lie mainly on rocks of the Franklinian eugeosyncline (Thorsteinsson and Tozer, 1960) there would seem to be little possibility that evaporites of pre-Carboniferous age are present beneath the basin.

There is an interesting relationship in northwestern Ellesmere Island and neighbouring parts of Axel Heiberg Island between the occurrence and character of anhydrite diapirs, and the regional distribution of the Otto Fiord, Hare Fiord and Nansen Formations. It is apparent in this region that diapirs of moderate and large size occur only where the Otto Fiord Formation is overlain by relatively incompetent siltstone and shale beds of the Hare Fiord Formation; where the Otto Fiord Formation is overlain by relatively competent carbonate rocks of the Nansen Formation, diapirs are few in number and generally very small. On the basis of this relationship it seems reasonable to suggest that the Otto Fiord and Hare Fiord Formations are distributed more or less coextensively in the subsurface throughout parts of the Sverdrup Basin characterized by diapirs of large and moderate size, but in which Carboniferous and Permian formations in normal stratigraphic sequence are hidden beneath younger sediments (see Text-fig. 6).

In connection with the above discussion the geologic settings of three other anhydrite formations are: Baumann Fiord (Kerr, 1967a), Lower Ordovician; Bay Fiord (Kerr, op. cit.), Middle Ordovician; and Mount Bayley (see p. 00), Lower Permian. The Baumann Fiord and Bay Fiord Formations crop out extensively in southeastern and southern Ellesmere Island, whereas the Mount Bayley Formation is distributed in the environs of Cañon Fiord and Greely Fiord in western Ellesmere Island. All three formations are more or less comparable to the Otto Fiord Formation in thickness and lithology, and like the Otto Fiord the three formations occur in folded and thrust faulted terrains. All are overlain everywhere by relatively thick, competent carbonate formations, and none gives rise to diapirs.

Hoen (1964, p. 78) stated that the South Fiord Diapir, Expedition Diapir and Strand Diapir in western Axel Heiberg Island have had a long history of growth, and that they were emplaced prior to the Tertiary orogeny. His assertion is based mainly on the character, and contact relations of basic dykes and sills in certain of these diapirs. Hoen (op. cit.) accepted the opinion that dykes and sills of Sverdrup Basin are Late cretaceous in age, and he interpreted the presence of long, unbroken sills, and cross-cutting dykes in the anhydrite of South Fiord Diapir as having been intruded after diapirism. It is the writer's opinion that the sills in question are coextensive with at least equally long and unbroken, partial sections of anhydrite beds within the diapir, and it is therefore just as reasonable to regard the sills as having been emplaced before as after diapirism. With regard to Expedition Diapir and Strand Diapir, Hoen (op. cit.) cited the presence of diabase sills in peripheral regions of the core rocks as evidence that the sills were intruded after diapirism. The writer has examined the sills in question, and concludes that nowhere are the contacts of the sills and diapiric cores sufficiently well-exposed to determine whether they are in fault or intrusive contact with the cores.

There are, nevertheless, geological circumstances other than those offered by Hoen (1964, p. 78) that suggest that emplacement of certain diapirs in western Axel Heiberg Island may have occurred over a long period of time which predates the mid-Cenozoic orogeny. The structural setting of such large diapirs as South Fiord and Cape Levvel which pierce weakly deformed sediments is similar to that of diapirs on Ellef Ringnes Island, which Gould and de Mille (1964), and Stott (1969) consider to have risen progressively with sedimentation. Moreover, in size and configuration, South Fiord Diapir and Cape Levvel Diapir resemble more closely diapirs on Ellef Ringnes Island than those in other parts of Axel Heiberg Island and Ellesmere Island.

With the possible exception of certain large diapirs in western Axel Heiberg Island discussed above, there can be little doubt that the great majority of diapirs on Axel Heiberg and Ellesmere Islands were induced by the mid-Cenozoic orogeny. Not only are most diapirs clearly related to anticlines and faults effected by this orogeny, but some are known to even intrude the Tertiary Eureka Sound Formation (<u>Eureka Sound North</u>) There is evidence to suggest that this may be the case with all diapirs on these two islands: (1) There is no evidence that formations thin in the direction of any diapir. (2) All exposed contacts of diapirs and country rock that were examined are represented by faults or zones of intense shearing; none is represented by an unconformity. (3) Inclusions of basic rocks, ostensibly representing fragments of dykes and sills are common in many diapirs. They are particularly common in large diapirs such as South Fiord Diapir, Sand Bay Diapir and Cape Levvel Diapir. The inclusions represent evidence that considerable movement of diapirs occurred after the intrusion of the dykes and sills. Consideration of the time of emplacement of the dykes and sills is therefore pertinent to the time of emplacement of the diapirs. Basic dykes and sills are common in rocks of the Sverdrup Basin, and are known to intrude virtually all formations older than, and including volcanic rocks of the Upper Cretaceous Strand Fiord Formation which crops out in western Axel Heiberg Island. Dykes and sills are not known to intrude the Upper Cretaceous Kanguk Formation or the Tertiary Eureka Sound Formation. Although extrusive rocks occur in the Lower Cretaceous Isachsen and Christopher Formations on Axel Heiberg Island (Bukken Fiord), and are represented by the Carboniferous Audhild Formation in Ellesmere Island (p. 00), and by the Permian Esayoo Formation in Axel Heiberg and Ellesmere Islands, no dykes are demonstrably correlative with any of these volcanics. On the ~~bases~~ basis of the above circumstances the time of emplacement of dykes and sills in the Sverdrup Basin is generally regarded as Late Cretaceous, an event that was probably correlative with the extrusion of the Strand Fiord Formation. (4) Despite the prevalence of dykes, none is known to cut the boundary of any diapir and its country rock on Axel Heiberg and Ellesmere Islands, or for that matter any diapir in the Sverdrup Basin.

Hoen (1964, p. 76) has argued convincingly against the possibility that halite played a significant role in the development of the diapirs which he studied in western Axel Heiberg Island. Hoen (op. cit.) found no evidence of rock salt in any of the diapirs, and he suggests that if salt were responsible for these structures it should have reached the surface where it would be preserved today because of the unusually low annual precipitation - about 15 cm - in Axel Heiberg Island. (In fact, Hoen's arguments against the presence of halite apply equally to all diapirs in the Sverdrup Basin). Moreover, the writer has not observed halite or any indication that halite was present in any diapir or outcrop of the Otto Fiord Formation on Axel Heiberg or Ellesmere Islands. In addition, compelling evidence that halite is not essential to the development of diapirs is provided by Hare Fiord Diapir and Whitsunday Bay Diapir (discussed earlier) which are continuous with outcrops of the Otto Fiord Formation in normal stratigraphic position.

The Hare Fiord and Whitsunday Bay Diapirs are of considerable significance to the central problem of diapirism. There are today two divergent hypotheses that purport to explain the cause of diapirism, given the necessary pressure environment: (1) bouyancy of light source material beneath an overburden of higher density; or (2) differences in plasticity between source material and overburden, regardless of differences in density. In this connection the geologic setting of the Hare Fiord and Whitsunday Bay Daipirs favours the latter hypothesis.

Negative gravity anomalies over certain diapirs in western regions of the Sverdrup Basin obtained by reconnaissance surveys during the early part of the last decade (Sobczak, 1963; Sobczak et al., 1964), provide reasonable indication that halite is involved in these diapirs. These anomalies are the bases for Gould and de Mille's (1964, p. 745) suggestion that these diapirs are principally halite diapirs consisting of cores of halite beneath exposed masses of anhydrite, and the analogous suggestion by Spector and Hornal (1970), that the diapirs consist of exposed anhydrite and subsurface halite and/or gypsum[1]. As the structure of the anhydrite in these western diapirs indicates

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1 In the light of MacDonald's (1953) study of anhydrite-gypsum equilibrium relations, it seems most improbable that gypsum can exist at depths greater than about 2,000 feet. Moreover, a leading authority on marine evaporites, Frederick H. Stewart (1963, p. 40Y), states that, "Gypsum is practically absent in nature except in near-surface deposits". Depths to the source beds of the evaporites involved in the three diapirs discussed by Spector and Hornal (op. cit.) may be estimated as in the order of 15,000 to 22,000 feet. These figures are based on the cumulative thicknesses of formations (mainly Mesozoic) exposed around these diapirs, and formations (mainly Carboniferous and Permian) exposed only in northern Axel

clearly that the anhydrite behaved as active source material, it is reasonable to suppose that halite, if present, originally consituted a considerable thickness of beds underlying a considerable thickness of anhydrite, and that both units of rock were intruded concomitantly to form bipartite diapirs. There is, however, one disconcerting element in this bipartite concept; and that is the barely credible coincidence that the present day erosion surface transects in all instances, the anhydrite portion and not the halite portion of these western diapirs.

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1 (cont'd)
Heiberg and Ellesmere Islands, but which may be reasonably assumed to occur in the subsurface in the environs of these diapirs. Consequently, if negative gravity anomalies in western regions of the Sverdrup Basin do in fact, indicate a subsurface deposit of an evaporitic mineral of relatively low specific gravity, the mineral is probable halite and certainly not gypsum.

Furthermore, MacDonald's)op. cit.) study renders improbable Hoen's (1964, p. 79) suggestion that certain large diapirs in western Axel Heiberg Island originated as bedded gypsum which commenced to rise isostatically upon burial to depths of about 2,000 m.

Plate I. Vertical aerial photograph of Kleybolte Peninsula that forms the northwestern extremity of Ellesmere Island. The type sections of Emma Fiord Formation and Audhild Formation are indicated by solid stars. Dotted and dashed line marks angular unconformity between basal beds of the Sverdrup Basin and rocks of the underlying Franklinian Geosyncline. Geology by R. Thorsteinsson and H.P. Trettin. bc, Bourne Complex, slaty siltstone, shale, tuffaceous (?) green phyllite, volcanic flows, and hornfels of uncertain age, but probably pre-Silurian. The complex is cut by numerous diabase intrusions of unknown age; lPhl, thermally metamorphosed shale, siltstone, sandstone and limestone with dioritic intrusions, probably Middle or Late Devonian age; Ce, Emma Fiord Formation; Cb, Borup Fiord Formation; Ca, Audhild Formation; and CPn, Nansen Formation.

Plate II. Vertical aerial photograph of thrust faulted, mountains north of head of Hare Fiord in northwestern Ellesmere Island showing type section of Nansen Formation. Crossed hammers are located at approximate centre of traverse along which stratigraphic column 68 in figure 3 was measured. Dotted and dashed line marks angular unconformity between basal beds of Sverdrup Basin and rocks of underlying Franklinian geosyncline. Geology by R. Thorsteinsson and H.P. Trettin. Ꞓg, Grant Land Formation, Early Ordovician and/or Cambrian age; Cb, Borup Fiord Formation; CPn, Nansen Formation; Pe, Esayoo Formation; Ptf, Trold Fiord Formation; and TRh, Heiberg Formation, Upper Triassic.

Plate III. Type sections of Otto Fiord Formation (Co) and Hare Fiord Formation (CPh) about three miles east of van Hauen Pass in northwestern Ellesmere Island. The view is west towards the pass. The Otto Fiord is composed mainly of anhydrite and gypsum and is characteristically light coloured. It also contains interbeds of limestone that stand out as dark layers. The Otto Fiord thrust over the Middle and Upper Triassic, Blaa Mountain Formation (TRba). The Hare Fiord comprises dark coloured, impure limestone, siltstone and shale and is typically dark weathering.

Plate IV. Aerial view of type sections of the formations, Otto Fiord (Co), Hare Fiord (CPh), van Hauen (Pv), and Degerböls (Pd), which are represented graphically as section 69, in figure 3. The view is to the east from above van Hauen Pass. The formations dip steeply to north. The arrow points to a prominent ravine shown above dog sledge in photograph reproduced above as plate III. TRbl, Blind Fiord Formation, Lower Triassic.

Plate V. Basal strata of the Canyon Fiord Formation (Cc) lying with angular unconformity on the Cornwallis Group (Co) on the west side of Trold Fiord, western Ellesmere Island (see locality 137, Eureka Sound South). Cc - a, basal unit of conglomerate and redbeds, 45 feet thick; Cc - b, anhydrite and gypsum, 200 feet thick; and Cc - c, limestone containing Moscovian fusulinaceans. The latter unit clearly belongs to the Canyon Fiord, but units Cc - a and Cc - b, are only tentatively assigned to that formation. These two units may in fact, represent the Lower and Upper Carboniferous Otto Fiord Formation that crops out extensively in eastern Axel Heiberg Island and northwestern Ellesmere Island.

Plate VI. View looking west from valley bottom at head of Hare Fiord in northwestern Ellesmere Island. The type section of Nansen Formation (CPn), a uniform sequence of light weathering limestone, was measured on ravine seen in right foreground. Dotted and dashed line marks angular unconformity between Borup Fiord Formation (Cb), and Ꞓg, Grant Land Formation, Early Ordovician and/or Cambrian age. This figure supplements photograph reproduced as plate II.

Plate VII. Characteristic exposures of anhydrite and gypsum of the Otto Fiord Formation (Co), overlain by dark grey to black shale, siltstone and impure limestone of Hare Fiord Formation (CPh). Arrow points to small bioherm in basal Hare Fiord beds from which R.L. Christie and W.W. Nassichuk collected an ammonoid fauna of early Moscovian age (see Nassichuk and Furnish, 1965). View is to west from delta of Stepanow Creek. About 24 miles separate this locality and the locality shown in plate VI. The Otto Fiord Formation and Hare Fiord Formation are correlative with the Nansen Formation.

Plate VIII. Aerial view looking southeastward over spectacular limestone masses in basal part of Hare Fiord Formation (CPh), that is thrust over Lower Triassic Blind Fiord Formation (TRbl), in Blue Mountains between Hare Fiord and Greely Fiord in northwestern Ellesmere Island. Crossed hammers are positioned on locality that yielded the Lower Permian ammonoid, *Paragastrioceras* n. sp., described by Nassichuk, Furnish and Glenister (1965, p. 18). Section 70b in figure 3, was measured in ravine to right of crossed hammers. Arrow points to prominent cuesta developed in van Hauen Formation (Pv), the upper surface of which marks Permian and Triassic boundary.

Plate IX. Aerial view looking east and supplementing photograph reproduced in plate VIII. The x on this plate and that of plate VIII mark corresponding localities.

Plate X. Aerial view looking east along fiord wall that rises to an elevation of 2,900 feet above sea level on south side of Otto Fiord in northwestern Ellesmere Island. Standing in this imposing line of cliffs are the formations; Nansen (CPn), van Hauen (Pv), and Degerböls overlain on backslope by Lower Triassic Blind Fiord Formation (TRbl). Dark layers in Nansen limestone are interbeds of shale and siltstone that reflect proximity to region of facies change with the predominantly clastic, Hare Fiord Formation that occurs a few miles to south.

Plate XI. Aerial view of Nansen Formation (CPn), van Hauen Formation (Pv) and Lower Triassic, Blind Fiord Formation (Ŧbl), on west side of Blind Fiord in western Ellesmere Island. View is to north and along the strike of the van Hauen. All three formations dip fairly steeply to the west. Note the contrasted topographic expressions of the lower shale and siltstone member and the upper chert member of the van Hauen.

Plate XII. Green beds of the Trold Fiord Formation (Ptf) lying on redbeds of the Canyon Fiord Formation (Cc), and overlain by redbeds of the Lower Triassic, Bjorne Formation (Ŧb). This locality is about 1 mile west of Trold Fiord in west-central regions of Ellesmere Island, and some 4 miles south of the head of the fiord. View is to south and across the ravine in which was measured stratigraphic column 64 in figure 2. Note the angular relations of the Canyon Fiord-Trold Fiord contact.

Plate XIII. Aerial view of the same territory shown above in plate XI. The arrow here and in plate XI point to one and the same reefoid mass of Permian age. In this region the Nansen Formation is characterized by alternating hard units of limestone and softer units of mainly calcareous siltstone which impart a pronounced banded appearance to the formation, especially when viewed from a distance.

Plate XIV. Vertical aerial photograph showing type section of Canyon Fiord Formation on northeast side of Cañon Fiord in western Ellesmere Island. The three dotted lines indicate traverse line along which composite section 75 on figure 3 was measured. Dotted and dashed line marks angular unconformity between rocks of Sverdrup Basin and Franklinian geosyncline. Arrow points to ravine designated by J. C. Troelsen (1950) as the type locality of the Canyon Fiord Formation and illustrated as figure 9 in his report. Geology by J.W. Kerr and R. Thorsteinsson. Oc, Cornwallis Group, Middle Ordovician; OSar, undivided Allen Bay - Read Bay Formations, Upper Ordovician to Upper Silurian; SDcp, Cape Phillips Formation, Upper Silurian and Lower Devonian; Dc, unnamed Devonian clastic sediments; and CPc, Canyon Fiord Formation. In this part of Ellesmere the Canyon Fiord includes both Carboniferous and Permian rocks.

Plate XV. Exposures of Canyon Fiord Formation (CPc) overlain by Trold Fiord Formation (Ptf), on south side of Cañon Fiord, western region of Ellesmere Island. These exposures are depicted as column 76 of figure 3. In this part of Ellesmere Island the Canyon Fiord includes strata of both Carboniferous and Permian ages.

Plate XVI. Angular unconformity between Canyon Fiord Formation (Cc) and the Middle Ordovician Cornwallis Group (Oc), at locality described below under plate XVII. Hammer rests on unconformity. Basal 4.5 feet of the Canyon Fiord is composed of interbedded, light coloured limestone, pebble conglomerate and quartzose sandstone. Strata in upper half of photograph consist of mainly thick-bedded conglomerate that normally characterizes base of formation. Crossed hammers are located on limestone that has yielded foraminifera dated as early Bashkirian.

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Plate XVII. Canyon Fiord Formation (Cc) unconformably overlying Cornwallis Group (Oc) at headwater of Tschernyschew River, Hamilton Peninsula in western Ellesmere Island. View to north. Icefield of Albert and Victoria Mountains barely visible to right of photograph. Arrow points to outcrops (just off photograph) shown above in plate XVI, and which constitute basal beds of measured section shown as section 74 in figure 3.

Plate XVIII. Vertical aerial photograph of territory northeast of head of Vesle Fiord in western regions of Ellesmere Island. Dotted and dashed line marks angular unconformity between basal strata of Sverdrup Basin and rocks of the underlying Franklinian geosyncline. The territory shown here is of particular interest in depicting the complex structural relationships that characterize formations in near-shore regions of the Sverdrup Basin. Note pinch out of Bjorne Formation and Canyon Fiord Formation owing mainly to transgressive nature of the Isachsen Formation. Geology by J.W. Kerr, R. Thorsteinsson and E.T. Tozer. Oe, Eleanor River Formation; Lower Ordovician; Oc, Cornwallis Group, Middle Ordovician; OSa, Allen Bay Formation, Lower Ordovician and Lower Silurian; SDcp, Cape Phillips Formation, Middle Silurian to Lower Devonian; De, Eids Formation, Lower and Middle Devonian; Dbl, Blue Fiord Formation, Middle Devonian; Dob, Okse Bay Formation, Upper Devonian; Cc, Canyon Fiord Formation; TRb, Bjorne Formation, Lower Triassic; Ki, Isachsen, Lower Cretaceous; Kc, Christopher Formation, Lower Cretaceous; Kh, Hassel Formation, Upper Cretaceous; Kk, Kanguk Formation, Upper Cretaceous; and Te, Eureka Sound Formation, Tertiary.

Plate XIX. Vertical aerial photograph of environs of Eids Fiord, southwestern Ellesmere Island. Dotted and dashed line marks angular unconformity between basal strata of Sverdrup Basin and underlying Franklinian geosyncline. Crossed hammers are located at approximate centre of traverse along which was measured section 50 in figure 1. Bedded character of Canyon Fiord Formation results from alternating soft and harder units of quartzose sandstone; that of Belcher Channel Formation is the result of resistant units of limestone that alternate with softer units of quartzose sandstone. Geology south of Eids Fiord by J. W. Kerr. Geology north of Eids Fiord by R. Thorsteinsson. De, Eids Formation, Lower and Middle Devonian; Dbl, Blue Fiord Formation, Middle Devonian; Cc, Canyon Fiord Formation; CPbc, Belcher Channel Formation; Pa, Assistance Formation; and Ki, Isachsen Formation, Early Cretaceous.

Plate XX. Vertical aerial photograph of Hamilton Peninsula in western Ellesmere Island. Dotted and dashed line marks angular unconformity between basal strata of Sverdrup Basin and rocks of underlying Franklinian geosyncline. Note weathering characteristics and topographic expressions of various Carboniferous and Permian Formations. Note also overstep of Trold Fiord Formation from northwest to southeast. Crossed hammers mark approximate centre of traverse along which was measured section 74 in figure 3, Pl , undivided lower Paleozoic rocks; Cc, Canyon Fiord Formation; CPbc, Belcher Channel Formation; CPan, Antoinette Formation; Ps, Sabine Bay Formation; Pa, Assistance Formation; Ptf, Trold Fiord Formation; and ꞦTb, Bjorne Formation, Lower Triassic.

Plate XXI. Vertical aerial photograph of unnamed peninsula formed by junction of Tanquary Fiord and Greely Fiord in northern Ellesmere Island. Crossed hammers are located immediately below cliffs that expose type sections of Mount Bayley Formation and Tanquary Formation which are shown as section 80 in figure 4. Solid star is positioned on Canyon Fiord Formation and immediately below type section of Antoinette Formation that is illustrated as section 81 in figure 4. Note characteristic light colour of anhydrite and gypsum represented by Mount Bayley Formation; also the distinctively bedded nature of Tanquary Formation owing to alternating units of resistant limestone and softer units of siltstone and sandstone. Cc, Canyon Fiord Formation. CPa, Antoinette Formation; Pmb, Mount Bayley Formation; Pt, Tanquary Formation; and ₧b, Bjorne Formation, Lower Triassic.

Plate XXII. Svartevaeg Cliffs near northern extremity of Axel Heiberg Island. View looking northwest from the ice of Nansen Sound and towards Arctic Ocean. The cliffs seen here rise to over 1,000 feet above sea level. They consist of nearly flat-lying limestone and lesser amounts of chert that are assigned to the Nansen Formation (CPn). The prominent cleft in cliffs that is visible in centre background may be seen in centre background of a photograph of Svartevaeg Cliffs that is reproduced opposite page 196 in Dr. Frederick A. Cook's narrative, My Attainment of the Pole.

Plate XXIII. Southeastern extremity of Svartevaeg Cliffs showing volcanic rocks of Esayoo Formation (Pe) overlying Nansen Formation (CPn). Arrow points to location of cliffs shown above in plate XXII. The volcanic rocks shown here were discovered by Per Schei (1904, p. 461).

Plate XXIV. Vertical aerial photograph of East Cape and vicinity on the northeast side of Canon Fiord in western Ellesmere Island. Photograph illustrates well the weathering characteristics and topographic expressions of various Carboniferous and Permian Formations. Dark coloured units of rock in Tanquary Formation and Sabine Bay Formation are sills. A dike that cuts Assistance Formation may be seen near centre of photograph. Crossed hammers mark approximate centre of traverse along which was measured section 71 in figure 3. Solid star is positioned on Bjorne Formation immediately to left of type section of Trold Fiord Formation which is illustrated as section 72 in figure 3. Geology by R. Thorsteinsson and E.T. Tozer. CPa, Antoinette Formation; Pmb, Mount Bayley Formation; Pt, Tanquary Formation; Ps, Sabine Bay Formation; Pa, Assistance Formation; Ptf, Trold Fiord Formation; Tb, Bjorne Formation, Lower Triassic; Ts, Schei Point Formation; Middle and Upper Triassic; Th, Heiberg Formation, Upper Triassic; and Q, Quaternary.

Plate XXV. Vertical aerial photograph of environs of Mount Bridgman in Sawtooth Range, western Ellesmere Island. Crossed hammers are positioned in approximate centre of traverse along which was measured section 56 in figure 1. Geology by R. Thorsteinsson and E. T. Tozer. CPan, Antoinette Formation; Pmb, Mount Bayley Formation; Pt, Tanquary Formation; Ps, Sabine Bay Formation; Pa, Assistance Formation; Ptf, Trold Fiord Formation; TRb, Bjorne Formation, Lower Triassic; TRs, Schei Point Formation, Middle and Upper Triassic, TRh, Heiberg Formation, Upper Triassic, J, undivided, Borden Island Formation, Lower Jurassic, Savik Formation, Lower to Upper Jurassic, and Awingak Formation, Upper Jurassic; Ki, Isachsen Formation, Lower Cretaceous; Kc, Christopher Formation, Lower Cretaceous; Kh, Hassel Formation, Upper Cretaceous; Kk, Kanguk Formation, Upper Cretaceous; and Te, Eureka Sound Formation, Tertiary.

Plate XXVI. Vertical aerial photograph of thrust-faulted mountains in environs of McKinley Bay and Tanquary Fiord in northern Ellesmere Island. Note the distinctly bedded character of Nansen Formation that results from alternating units of hard limestone, and softer units of quartzose sandstone and siltstone. The clastic rocks reflect proximity of this region to the shoreline of the Sverdrup Basin. Note also pinch-out of Trold Fiord Formation in southeastern part of region. Arrow points to locality where Schwagerina hyperborea (Salter) was collected in upper 20 feet of Nansen Formation. Geology by R. Thorsteinsson and E. T. Tozer. CPn, Nansen Formation; Ptf, Trold Fiord Formation; Ŧb, Bjorne Formation, Lower Triassic; Schei Point Formation, Upper Triassic; Ŧh, Heiberg Formation, Upper Triassic; and J, undivided Jurassic strata. The significance of the uncommonly thin Schei Point section in this region is discussed by Tozer (1963, p. 6).

Plate XXVII. Vertical aerial photograph of much faulted area on the coast of Bjorne Peninsula in southwestern Ellesmere Island. Crossed hammers mark locality of a Lower Permian, ammonoid fauna collected in the Assistance Formation and described by Nassichuk, Furnish and Glenister (1965, p. 8). The crossed hammers are also located near centre of traverse along which was measured section 52 of figure 1. Cc, Canyon Fiord Formation; CPbc, Belcher Channel Formation; Pa, Assistance Formation; and Pd, Degerböls Formation.

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