68-16

GEOLOGICAL SURVEY OF CANADA

PAPER 68-16

DEPARTMENT OF ENERGY, MINES AND RESOURCES

ELLEF RINGNES ISLAND, CANADIAN ARCTIC ARCHIPELAGO

(Report and map 4-1968)

D. F. Stott

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1969

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CONTENTS

Illustrations

ABSTRACT

Ellef Ringnes Island, located in the northwestern region of the Canadian Arctic Archipelago and bordering the Arctic Ocean, is centred about latitude 78° 40' north and longitude 102° 00' west. It comprises an area of little more than 5,000 square miles. The bedrock geology of the island is shown at a scale of one inch to 4 miles.

Ellef Ringnes Island is characterized by broad lowlands and locally, by dissected uplands which reflect the diversity of structure and lithologic characters of the bedrock formations. The island is rimmed by low, shelving coastal areas. Domal structures with cores of diapiric anhydrite and secondary gypsum constitute striking features of the landscape.

Two major, structural provinces of the Arctic Archipelago are represented; the Sverdrup basin which includes the greater part of the island and preponderant thickness of sediments; and the Arctic Coastal Plain, an area of about 800 square miles at the northwestern extremity of the island.

The formations of the Sverdrup basin are, in ascending stratigraphic order, as follows: (1) an unnamed formation of Early Carboniferous age, composed of intensely deformed anhydrite and gypsum, and occurring in cores of diapirs; (2) an unnamed formation of Middle Carboniferous age, composed mainly of dark coloured, marine limestone generally associated with evaporites in diapirs, and locally overlain unconformably by Deer Bay shale and Isachsen sandstone; (3) the Borden Island Formation of Early Jurassic age, consisting of more than 200 feet of marine sandstone and siltstone with no base exposed; (4) the Savik Formation of Early and Middle Jurassic age, consisting of 250 feet of marine mudstone and sandstone; (5) the Jaeger Formation of Late Jurassic age, composed of 150 to 200 feet of glauconitic sandstone; (6) the Deer Bay Formation consisting of 1,000 feet of marine shale of Late Jurassic and Early Cretaceous ages; (7) the Isachsen Formation of Early Cretaceous age, composed of 3,000 feet of mainly non-marine sandstone; (8) the Christopher Formation of Early Cretaceous age, composed of 1,500 feet of marine shale; (9) the Hassel Formation of Early and/or Late Cretaceous ages, which consists of between 300 and 1,800 feet of non-marine sandstone; (10) the Kanguk Formation, a marine shale 650-700 feet thick, and of Late Cretaceous age; (11) the Eureka Sound Formation of Late Cretaceous to Early Tertiary age, consisting of more than 200 feet of non-marine sandstone and sand. The Jurassic to early Tertiary sediments constitute an essentially conformable succession.

The formations described above are deformed into broad, shallow folds having northwesterly to northerly trends. Diapirs occur at the culminations of major anticlines. A system of northeasterly trending normal faults is best developed in the northern part of the island. In this region also, the Deer Bay Formation is intruded extensively by dykes and sills of diabase, basalt, and gabbro. Similar rocks intrude the Isachsen, Christopher, and Hassel Formations but on a smaller scale.

The Arctic Coastal Plain is underlain by non-marine, clastic sediments of the Beaufort Formation that dip gently toward the northwest and lie unconformably on the deformed rocks of the Sverdrup Basin. The Beaufort Formation is about 300 feet thick.

The diapiric structures, emplaced through intermittent growth throughout a considerable span of geological time, have exerted an important influence on the local stratigraphy and structure. The possibility of there being accumulations of oil and gas on the island is considered excellent and this fact is also related to the presence of the diapirs.

ELLEF RINGNES ISLAND, CANADIAN ARCTIC ARCHIPELAGO

INTRODUCTION

Ellef Ringnes Island, one of the Queen Elizabeth Islands of the Canadian Arctic Archipelago, is the westernmost of the Sverdrup Islands and borders the Arctic Ocean. It comprises over 5,000 square miles, being about 125 miles at its greatest length and 75 miles at its maximum width. The only settlement, Isachsen, is located at latitude 78° 47' N, longitude 103° 32' W.

Original plans for the geological investigation of the Ringnes Islands called for detailed stratigraphic studies and mapping of the islands on the scale of 1 inch to 4 miles. This report, based on field work undertaken in 1967, is concerned mainly with the bedrock geology of Ellef Ringnes Island. The completion of the mapping, including Amund Ringnes and King Christian Islands, as well as more detailed stratigraphic investigations will require an additional field season.

ACCESSIBILITY AND FACILITIES

Ellef Ringnes Island is most conveniently reached from Resolute on Cornwallis Island, the terminal for regularly scheduled commercial flights from Montreal and many charter flights from Edmonton. That settlement serves as one of the main distribution centres of the Arctic sea-lift and accomodation, fuel supplies, and charter aircraft can be obtained there from various commercial companies.

The only airstrip on Ellef Ringnes Island is maintained by the staff of the Joint Air Weather Station. Throughout most of the year, the strip may be used by small aircraft and such commercial aircraft as a DC4. In some years, however, the strip is unusable for short periods between June and August because of its muddy condition. Planes such as Beaver or Otter equipped with oversize tires can land at many places on the island although areas of shales should be avoided.

The most satisfactory method of travel during the summer is by helicopter, although small tracked vehicles have been used on the island by various groups, such as the Polar Continental Shelf Project. The sea-ice does not always break up around the island during the summer and wide leads commonly develop along the coastline, hindering direct travel across the ice. Overland travel on foot can be very slow and exhausting as a deep layer of saturated mud develops from the combined effects of permafrost and meltwater.

Isachsen, the only settlement, is a weather station established in 1948 and operated jointly by the governments of Canada and United States of America. Only eight or nine persons are permanently employed there but, during the summer, their numbers increase to about fifteen as additional personnel are required for the construction of the airstrip and other maintenance jobs around the base. No supplies are available to the general public at Isachsen and only very limited services can be provided. Persons planning on operating out of Isachsen are advised to consult with the Meteorological Branch of the Department of Transport before arriving there.

Isachsen is not the most favourable place to base a camp although the air-strip does provide a number of advantages. The region around the base is one of the wettest and muddiest places on the island. Furthermore, the summer fogs commonly linger on the high ridges which surround the base, and prevent travel out of the area while other parts of the island may have relatively good flying conditions. Several gravelled areas in the central and southern part of the island are more suitable for a large camp.

CLIMATE, FLORA AND FAUNA

Ellef Ringnes Island has an Arctic maritime climate. Precipitation is low, averaging about 3.8 inches per year. Plant growth is inhibited by the arid conditions and the generally low summer temperatures. Furthermore, certain formations, such as the Isachsen and Beaufort, are composed of relatively clean sand which is not conducive to the production of good soils. Many parts of the island are completely barren of vegetation while the most luxuriant growth comprises only lichens, low mosses, some grasses, and a few flowers such as saxifrage and Arctic poppy.

Despite the general arid conditions, much of the surface of Ellef Ringnes Island becomes saturated with water in June and early July during the spring run-off and, at this time, large areas of the island are difficult to negotiate on foot. This is especially true of areas of shale outcrops or of valley bottoms that have derived sediments from shale terranes, because those deposits tend to retain moisture for longer periods of time than, for instance, sand or sandstone terranes. Another important factor in these high latitudes is the relatively small thickness of the active layer. This is commonly a few inches to a foot above the permafrost layer which prevents rapid downward percolation of meltwater. Most of the precipitation occurs as snow from late August to early June. The amount of rain, most abundant in July, is usually less than one inch but totalled almost 1.6 inches in 1967. Lingering snow drifts on high ridges and slopes are a source of meltwater until late July in normal years; after this date many of the rivers become almost completely dry. Geological field work is limited to less than two and a half months because snow cover remains well into June and returns in late August or early September. During 1967, a considerable amount of snow remained throughout the summer.

In a recent report on the climate of the Canadian Arctic, Thompson (1967) points out that "in June, July and August, low-lying stratus clouds and coastal fogs are notorious features of the climate......The water-logged lands and cold, partially ice-covered waterways influence the climate by adding sufficient moisture to create extensive low-lying clouds and fog banks, while holding air temperatures to within a few degrees of the melting point".

Although the 1967 temperatures were only a few degrees different than the long-term average, they were sufficiently lower and close enough to the freezing point to result in a very late season and the incomplete removal of the snow cover. Average temperatures and precipitation during the spring, summer, and autumn seasons of 1967 are compared with those of a ten-year average in the following table that is based on information obtained from the Meteorological Branch.

	Mean daily		Mean of daily maximum (Fahrenheit)		Mean of daily minimum		Precipitation (in inches)	
	1951-60	1967	1951-60	1967	1951-60	1967	1951-60	1967
June	31.6	27.5	35.4	30.8	27.7	24.2	.1	.22
July	38.6	34.6	43.0	38.0	34.2	31.1	.71	1.58
August	34.0	31.6	38.6	35.2	30.5	27.9	.73	0.94

Animals were scarce during 1967. Cariboo, most numerous on Reindeer Peninsula, probably number about 150 to 200 on the whole island. Three muskoxen were reported on Ellef Ringnes in 1960 but, in 1967, no living animals were seen although two weathered skeletons were found. The almost complete absence of lemmings and Arctic hare was reflected in the very small population of wolves and foxes. Seals are present in the bays and one polar bear was seen on the ice. Long-tailed jaegers and glaucous gulls were present in the vicinity of Isachsen and ptarmigan, snow bunting, and Brant geese were observed at various localities on the island.

HISTORICAL REVIEW

Ellef Ringnes Island was discovered in 1901 by a sledging party consisting of Gunerius Isachsen and Sverre Hassel, members of the Second Norwegian Arctic Expedition of 1898-1902, which was under the command of Otto Sverdrup. The island was named to honour Ellef Ringnes, a Norwegian brewer and one of the principal patrons of Sverdrup's expedition. At the time of the discovery of Ellef Ringnes Island, the Norwegian expedition was based at Goose Fiord on the south coast of Ellesmere Island. Isachsen and Hassel made their initial sighting of Ellef Ringnes Island on April 23 as they rounded the southwest corner of Amund Ringnes Island, an island they had discovered and partly explored the previous year, and named for Ellef's brother. The following day Isachsen and Hassel travelled across Hassel Sound making a landfall at the southern extremity of their newly discovered island. In the course of the following 20 days or so, the two Norwegians succeeded in circumnavigating Ellef Ringnes Island. Their resulting map and notes on geological specimens are published in Otto Sverdrup's narrative, New Land (1904).

The second visit to Ellef Ringnes Island was made by a sledging pa·ty headed by the American explorer Donald B. MacMillan (1918), commander of the Croker Land Expedition of 1913-1917, with headquarters at Etah, Greenland. In the spring of 1916, MacMillan set out from Etah with the object of exploring King Christian Island which had been sighted, but not visited by Isachsen and Hassel. MacMillan reached King Christian Island on April 19, but adverse weather and a shortage of dog food caused him to abandon his exploration of that island. On his return to Etah, MacMillan stopped briefly at Cape Nathorst,which forms the southern extremity of Ellef Ringnes Island, where he built a cairn and deposited a note dated April 23, 1916.

On May 31, 1916, V. Stefansson, commander of the Canadian Arctic Expedition of 1913-1918, landed at Cape Isachsen which constitutes the northwestern extremity of Ellef Ringnes Island. Stefansson's party was also travelling by dog sledge. He had left his wintering quarters at Cape Kellett on Banks Island in early March and proceeded north. After charting the coast lines of Brock, Borden and Mackenzie King Island which he had discovered the previous year, Stefansson set out in a northeasterly direction in search of new land. From Cape Isachsen, Stefansson went on to discover Meighen Island from where he travelled southwest. After passing through Hassel Sound Stefansson touched on Cape Nathorst where he collected MacMillan's note on July 20. A facsimile of this note is reproduced opposite page 529 in Stefansson (1921). The following year Stefansson travelled south for a short distance along the west coast of Ellef Ringnes Island on his return from explorations in the Arctic Ocean north of Borden Island.

The south coast of Ellef Ringnes was touched on briefly by Inspector A.H. Joy (R.C.M.P.) during his epic journey in 1929 from Dundas Harbour to Melville Island and thence north to Lougheed and Ellef Ringnes Islands (Fetherstonhaugh, 1938). From Ellef Ringnes Island, Joy proceeded east to Bache Peninsula on the east coast of Ellesmere Island.

Geological interest in Ellef Ringnes Islands was aroused when aerial photographs taken by the United States Air Force in 1946 and 1947 revealed the presence there of spectacular elliptical and domal structures. In 1951, I.C. Brown published an account of these structures, based on his studies of the aerial photographs, and suggested several possible explanations for their origin. The first geological reconnaissance of the island was made by W.W. Heywood of the Geological Survey in the summers of 1952 and 1953 (Heywood, 1955, 1957). Heywood's pioneering work not only demonstrated that anhydrite and secondary gypsum constituted the mobile rock in the core of the diapiric structures, but also established the basic stratigraphic framework of Ellef Ringnes Island. He is the originator of the names of the Deer Bay, Isachsen, Christopher, and Hassel formations which are now known to be distributed widely throughout the Sverdrup basin. Additional studies of the domal structures were made in 1955 by R.G. Blackadar (1963), D.J. McLaren (1963), and H.R. Greiner (1963) during regional geological investigation of the Arctic Islands (Fortier et al., 1963). Y.O. Fortier and E.F. Roots made additional observations on the island that were incorporated in that report. A summary of Mesozoic stratigraphy of the Arctic Archipelago, including data from Ellef Ringnes Island, was incorporated in reports by Tozer (1960, 1961).

In 1948, the federal Department of Transport and the United States Weather Bureau jointly established a meteorological station at Isachsen (Rae, 1951). The station has been in constant operation since that time.

Isachsen served as a base of the Polar Continental Shelf Project from 1959 to 1963, during which time research was carried out in various fields related to oceanography. Studies of Ellef Ringnes Island by Denis St. Onge resulted in a detailed report on its geomorphology (St. Onge, 1965). In addition, a seismic survey (Hobson, 1962; Hobson and Overton, 1962) and a gravity study (Weber and Sobczak, 1962; Sobczak, 1963; Sobczak et al., 1963) were made across part of Ellef Ringnes Island.

The emplacement of the anhydrite diapirs of this island was investigated as part of more regional studies by W. Schwerdtner (1963), Schwerdtner and A.R. Clark (1967), and by D.B. Gould and G. de Mille (1964).

ACKNOWLEDGMENTS

The writer is indebted to the Meteorological Branch of the Department of Transport and the United States Weather Bureau for services provided at Isachsen, a Joint Air Weather Station. He wishes to thank, particularly, D. Banman, Canadian Officer-in-charge and D. Black, American Executive Officer, for their cooperation and is deeply grateful for the assistance and encouragement provided by the radio operators, strip mechanics, and other staff members.

Able assistance in the field was given by R.M. Robinson, L.A. Burgess, and L.S. Eliuk. J. Abelseth, radio operator, and R. Ballard, cook, provided admirable support in camp.

Transportation in the field was provided by a 47G2 helicopter supplied by Niagara Helicopters Limited of Niagara Falls; by Beaver, Piper Cub, and Otter aircraft supplied by Bradley Air Service, Ottawa; and by DC4 aircraft supplied by Nordair Limited, Montreal. The writer extends his appreciation to these companies and their crews for their support; he particularly thanks F.V. Grover and R. Murphy, the helicopter crew.

The writer is indebted to colleagues of the Geological Survey whose previous experiences in the Arctic proved of invaluable assistance. Preliminary plans were greatly aided by the advice of R. Thorsteinsson of the Arctic Island Section who also discussed many of the regional problems and critically reviewed this report.

PHYSIOGRAPHY AND GLACIATION

PHYSICAL FEATURES

Ellef Ringnes Island lies within two main physiographic provinces, the Arctic Coastal Plain and the Sverdrup-Parry physiographic region as defined by Fortier (1957, p. 405). Its physiography has been discussed by Roots (1963, p. 526) and St. Onge (1965).

The northwestern two-thirds of Isachsen Peninsula lies within the Arctic Coastal Plain, a low-lying region bordering the Arctic Ocean from Banks Island to Meighen Island. The plain is developed on and is coextensive with the Beaufort Formation, a succesion of late Tertiary to Pleistocene sands and gravels that dip seaward and lie unconformably on rocks of various older structural provinces. It is a monotonous, flat and almost featureless area with long and nearly parallel drainage patterns. Large parts of the area consist of braided river channels containing reworked sands and gravels of the Beaufort Formation. The remainder of the area is a slightly dissected lowland. The maximum elevation of the Arctic Coastal Plain on Ellef Ringnes Island is about 200 feet above sea-level.

The remainder of Ellef Ringnes, included in the Sverdrup-Parry physiographic province, can be subdivided into two main physiographic units; the dissected plateau north of Isachsen, and the broad lowlands of the main part of the island.

The dissected plateau, bordering the southeastern edge of the Arctic Coastal Plain, occupies the southeastern third of Isachsen Peninsula and extends northeasterly from Gabbro Peninsula across the northern tip of Christopher Peninsula. The dissected plateau comprises numerous, irregular mesas and curved ridges controlled by resistant masses of diabase, gabbro sills and dykes, and soft flat-lying sediments. The main ridges, formed of the igneous rocks, rise steeply from relatively flat valleys or abruptly from the coast, forming fiord-like bays. The maximum elevation of this region is about 725 feet above sea-level.

The central and southern parts of Ellef Ringnes Island consist of broad lowlands with local uplands. This physiographic unit includes the highest topographic feature of the island, the Isachsen dome, a diapir that rises to an elevation of over 800 feet above sea-level in the central region. The low coastal areas, and overlain by flat-lying sediments, are formed in part by coalesced river flood plains. Most of the lowland is a gently undulating plain with shallow valleys and low interstream areas. Broad belts, underlain by shales and finely dissected by numerous small streams, generally have very low relief. However, two prominent escarpments in shale are present, one lying east of Isachsen dome and the other extending east-west across the island south of Contour dome[1]. Resistant sandstones, dipping gently eastward, form badland topography with large hoodoos and a great series of cuestas trending northeasterly from Noice Peninsula to Louise Fiord.

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[1] The two large piercement structures lying in the center of the island were originally called Dumbbells dome because of their combined shape. Subsequently, the name was applied by the Canadian Permanent Committee on Geographical Names to only the western dome. It is convenient for reference purposes to distinguish each diapir separately and the southeasterly one is here named Contour dome.

For purposes of this report, all piercement structures on Ellef Ringnes Island are referred to as domes although "diapir" may be more correct. The term "dome" has been formally applied to some features in a geographic sense and it is undesirable to cause any confusion.

Local uplands are formed by several piercement structures. Of these, Dumbbells and Contour domes, lying in the central part of the island and Isachsen Dome to the southwest, are surrounded by cuestas of up-turned sandstone. Hoodoo Dome in the southern part, has less prominent cuestas and only a very small central core of anhydrite and secondary gypsum. The summits of the domes have a uniform, even-topped appearance from a distance but the cores are maturely dissected, forming the most rugged topography on the island. The domes, having elevations in the order of from 600 to 800 feet, stand several hundred feet above the surrounding areas and have a maximum local relief in the order of 300 to 400 feet. Several large streams have been superimposed on these structures, notably tributaries of Dumbbell, Contour, and Hoodoo Rivers.

Many of the smaller relief features of Ellef Ringnes Island were described and explained in considerable detail in a recent report by St. Onge (1965). He indicated that all the relief features evolved by processes characteristic of a periglacial region with deep permafrost. Frost-splitting, frost-heaving, solifluction, and nivation were shown to be major factors in the disaggregation of the rocks. Furthermore, fluvial action was also shown to be active in erosion and transportation of material, despite the semi-arid climatic conditions.

GLACIATION

Some earlier reports (i.e. Schei, 1903) suggested that Ellef Ringnes Island was not glaciated. A northern boundary of continental glaciation was drawn south of the islands of the Canadian Arctic Archipelago by Hobbs (1945) and Jenness (1952). Heywood (1957), basing his conclusions on an apparent absence of typical glacial features, suggested that an active ice mass was never present. Later, Savile (1961) concluded from botanical evidence that the island must have been covered by a thin ice-cap. At the same time, St. Onge (1961) identified a gravel ridge as an esker. In his later report (1965), St. Onge described erratics and raised beaches and suggested that the island was covered by an ice mass whose principal axes of flow followed channels along the present straits.

Blocks of pink and red granite, pegmatitic granite, gneiss, quartzitic sandstone and jasper conglomerate are found at scattered localities throughout the island and on some of the higher ridges. None of those rock types is indigenous to the island and the nearest sources are several hundred miles distant on such islands as Prince of Wales, Devon, and Ellesmere. Gravel ridges and hills containing these large boulders are more numerous than St. Onge originally indicated, and are found from south of Hoodoo Dome to Dumbbells Dome. A similar deposit was seen lying on the Beaufort Formation in the northwestern corner of Isachsen Peninsula.

The thickness of the ice-cap postulated by St. Onge was based on the assumption that the isostatic rebound of the island was in the order of only 40 metres. However, during the course of present investigations, Pleistocene marine shells were found at elevations as high as 250 feet. The weight of the ice mass must, therefore, have been considerably larger. Emerged strandlines are developed along the coast in many parts of the region. They occur in the vicinity of Deer Bay and Noice Peninsula, and are prominent along the western and southern margins of Meteorologist Peninsula.

TABLE OF FORMATIONS

Era	Period or Epoch	Formation and thickness (feet)	Lithology
Cenozoic	Quaternary		Residual soil, river deposits, raised beaches, clay, sand, and gravel
		unconformity	
		Boulder gravels	Gravels, sand; boulders of quartzite, granite, diabase
		unconformity	
		Beaufort 250-300	Sand, gravel, silt; unaltered wood
	Tertiary	unconformity	
		Eureka Sound 200+	Sandstone, sand; carbonized logs, coal seams (non-marine)
Mesozoic	Upper Cretaceous	Kanguk 650-700	Black marine shale; reddish weathering sideritic concretions (marine)
		Hassel 300-1,800	Sandstone, mudstone, coal (non-marine)
	Lower Cretaceous	Christopher 1,500+	Black marine shale; yellow and red concretions; platy sandstone (marine)
		Isachsen 3,000+	Sandstone and sand, fine- to coarse-grained, conglomeratic in part; some mudstone; coal (non-marine)

TABLE OF FORMATIONS (Cont'd)

Era	Period or Epoch	Formation and thickness (feet)	Lithology
Mesozoic	Lower Cretaceous	Deer Bay 1,000-	Shale, black to grey; yellow to reddish concretions; calcite rosettes (marine)
	Jurassic	Jaeger 200	Sandstone, ferruginous, highly glauconitic; fine-grained; concretionary (marine)
		Savik 250	Mudstone, grey, brown, and green, soft; some silty glauconitic sandstone; abundantly fossiliferous (marine)
		Borden Island	Sandstone, fine-grained, well-sorted; quartzose; yellow siltstone; reddish ferruginous concretionary beds (marine)
Diapiric or unconformable contact[1]			
Paleozoic	Middle Carboniferous to Lower Permian		Limestone, grey; breccia; conglomerate; in part bituminous
	Lower Carboniferous		Anhydrite, gypsum

[1] Paleozoic beds are commonly in diapiric contact with surrounding Mesozoic beds but locally, Paleozoic limestones are unconformably overlain by either Deer Bay shales or Isachsen sandstones. The lower boundary of the Borden Island Formation is not exposed and those Jurassic beds may lie above Triassic and/or Permian strata.

STRATIGRAPHY

GENERAL STATEMENT

Two major structural provinces of the Arctic Archipelago are represented by sedimentary rocks exposed on Ellef Ringnes Island. The first is the Sverdrup basin which includes the greater part of the island's area and by far the greater thickness of sediments. The second is the Arctic Coastal Plain which is underlain by the Beaufort Formation that lies unconformably on rocks of the Sverdrup basin. The latter formation is confined to Isachsen Peninsula of northwestern Ellef Ringnes Island.

Throughout most of its areal extent, the Sverdrup basin includes a conformable sequence of rocks representing the Carboniferous, Permian, Triassic, Jurassic, Cretaceous, and Cenozoic (Paleocene and Eocene) systems. The situation on Ellef Ringnes Island is somewhat anomalous, mainly because diapirism of the Carboniferous evaporitic formation has resulted in disruption of the lower part of the succession.

Lower Carboniferous (Namurian) evaporitic rocks associated with Middle Carboniferous (Moscovian) carbonate sediments represent two unnamed formations respectively, which occur in normal stratigraphic succession on northern Ellesmere Island. (R. Thorsteinsson, personal communication). These formations on Ellef Ringnes Island are exposed principally in piercement structures and intrude the overlying Early Jurassic to early Tertiary succession. The Carboniferous formations are intensely deformed and their thicknesses can be estimated only as being in the order of several hundreds of feet. There can be no doubt that these rocks are essentially emplacement bodies that are strikingly similar to certain salt domes of the Gulf basin of the southeastern United States. Nevertheless, there is evidence to indicate that, locally, the unnamed limestone formation is in sedimentary contact with one, and probably two formations of Early Jurassic and Cretaceous ages; moreover, that such contacts represent unconformities.

No rocks of Permian or Triassic age were discovered on Ellef Ringnes during the present study although they may be present at depth[1]. Permian rocks, several hundred to two thousand feet thick, are known to occur around the eastern and southern margins of the Sverdrup basin, extending from Ellesmere Island across Devon Island to Melville Island (Tozer and Thorsteinsson, 1964). Similarly, a thick succession of Triassic rocks is exposed on western Ellesmere Island and Axel Heiberg Island (Tozer, 1963), and on nearby Cornwall Island (Greiner, 1963, p. 534) although the Triassic sequence is thin to absent to the southwest on Melville, Brock and Borden Islands (Tozer and Thorsteinsson, 1964). It seems likely that strata equivalent to those Permian and Triassic formations would extend into the central part of the Sverdrup basin and that they may occur at depth between the known Carboniferous and Jurassic rocks of Ellef Ringnes Island.

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[1] In a brief summary, the writer (1968) tentatively assigned some sandstones to the Triassic but recent identification of their fossils by H. Frebold indicates that the beds are of Early Jurassic age.

The preponderance of bedrock exposed on Ellef Ringnes Island consists of a conformable succession of nine, marine and non-marine, clastic formations, that range in age from Early Jurassic to early Tertiary. The maximum total thickness of that succession is in the order of 9,500 feet.

Jurassic rocks are represented by four marine formations. They are, in ascending stratigraphic order, the Borden Island, Savik, Jaeger, and Deer Bay. The Deer Bay includes sediments of both Late Jurassic to earliest Cretaceous ages. The intersystemic boundary lies, therefore, within this formation, but it is not represented by a physical break in sedimentation. Three major transgressions are recorded by the formations mentioned above (Tozer and Thorsteinsson, 1964, p. 121). The earliest transgression, of Sinemurian (Early Jurassic) age, is marked by the base of the Borden Island Formation. The Pliensbachian stage is unrepresented in the Sverdrup basin, and the Savik shales record a Toarcian (Early Jurassic) incursion. A Late Jurassic transgression is indicated by the basal beds of the Deer Bay Formation which are probably of upper Kimmeridgian to lower Volgian age (Frebold, 1961, p. 30).

The Cretaceous beds are subdivided into five formations and are, in ascending order, Isachsen, Christopher, Hassel, Kanguk, and Eureka Sound. The latter may include some strata of Tertiary age. Two major marine transgressions are recorded, one in Early Cretaceous, represented by the Christopher shales, and one in Late Cretaceous, represented by the Kanguk shales.

Unconsolidated sands containing unaltered fossil wood were noted at several localities on the western side of Meteorologist Peninsula. The most conspicuous occurrence was found at the southeastern end of Christopher syncline where the sands lie within a river valley carved in beds of the Eureka Sound Formation. That deposit resembles the Beaufort Formation although it is separated by considerable distance from the latter. No attempt was made to separate those sediments from the mantle of Recent sands and they have been mapped together.

The Beaufort Formation represents the youngest bedrock formation on the island. It consists of unconsolidated, non-marine sands and gravel of late Tertiary to Pleistocene age, that lie unconformably on various older Mesozoic formations. The Beaufort occupies the northwesternmost part of the island and dips gently toward the Arctic Ocean. The present erosion surface marks the upper limit of the Beaufort Formation and the thickness of the formation, as represented on Ellef Ringnes Island, probably does not exceed 300 feet.

CARBONIFEROUS AND PERMIAN ROCKS

It is considered important at this time to present a comprehensive review of the stratigraphy of Carboniferous and Permian rocks in the Sverdrup basin in order that the reader may understand better the sequence found in the diapirs of Ellef Ringnes Island, and realize the significance of those rocks in the appraisal of the petroleum potential of the region. The following outline of Carboniferous and Permian rocks of the Sverdrup basin is based on information provided by R. Thorsteinsson who has just completed and intensive investigation of that succession.

Carboniferous and Permian rocks in the Sverdrup basin constitute a natural grouping of structurally conformably formations. Although rocks of the two systems are separated by an unconformity at some places along the margins of the basin, the intersystemic boundary is not represented by a physical break throughout the principal part of the basin. Carboniferous rocks represent the oldest deposits in the Sverdrup basin and they lie with angular unconformity on rocks of the Franklinian geosyncline. The upper boundary of the Permian rocks is invariably a disconformity.

Carboniferous and Permian rocks crop out in three, somewhat arbitrarily defined, regions of the Sverdrup basin. (1) They occur in a relatively narrow, marginal belt along the southern and southeastern edges of the basin. This belt can be traced in a east-west direction across the northern region of Melville Island, Cameron Island, and northern Grinnell Peninsula, from where it turns northeasterly and crosses Ellesmere Island diagonally from southwest to northeast. The formations in the marginal belt are represented mainly by clastic and carbonate sediments, and the sequence of formations varies from place to place owing to disconformities and to onlap and offlap relationships. (2) In the central region of the Sverdrup basin, intensely deformed Carboniferous and Permian evaporite and carbonate rocks are exposed in the cores of numerous spectacular diapiric structures. The area that encompasses these structures includes northern Sabine Peninsula, Melville Island, central and southern parts of Ellef Ringnes Island, Amund Ringnes Island, much of Axel Heiberg Island, and a limited part of northwestern Ellesmere Island in the environs of Hare Fiord. (3) In the main part of the Sverdrup basin, Carboniferous and Permian rocks are exhibited in excellent exposures in eastern and northern Axel Heiberg Island and northwestern Ellesmere Island. (The stratigraphy of Carboniferous and Permian rocks in those regions will be described in a forthcoming report by Thorsteinsson). It is, therefore, from the succession in eastern and northern Axel Heiberg Island and northwestern Ellesmere Island, where both diapiric structures and normal successions occur, that the stratigraphy of the source beds of the diapiric structures of southwestern Axel Heiberg, Sabine Peninsula, Ellef Ringnes and Amund Ringnes Island must be inferred. Rocks of those systems are characterized by diverse facies and complex stratigraphic relations which cannot be treated adequately here. In general, the main body of Carboniferous and Permian rocks is divisible into four principal facies belts that parallel the northeasterly trending axis of the Sverdrup basin. From southeast to northwest, those belts are as follows: (a) a marginal facies belt characterized by clastic and carbonate rocks, as described above; (b) a shelf facies belt characterized mainly by light coloured carbonate rocks; (c) a basinal facies belt that consists mainly of dark coloured shale, siltstone, and limestone, underlain by a unit of anhydrite; and (d) a shelf facies belt consisting mainly of light coloured limestone and underlain by a unit of anhydrite.

It is the basinal facies belt of Carboniferous and Permian rocks that is clearly related to areas of the Sverdrup basin that are characterized by diapirs. A typical development of this belt is found in the upper reaches of Hare Fiord in northwestern Ellesmere Island. There, the Carboniferous and Permian successions are divided by Thorsteinsson into five, as yet unnamed, formations that are described briefly below in descending stratigraphic order. Formations 2 and 3 in this succession constitute the basinal facies referred to in the foregoing discussion.

Formation 5: Limestone, medium grey and medium dark grey, mainly medium-bedded, to lesser extent thick-bedded, mainly bioclastic, in part aphanitic, weathers greyish yellow and yellowish grey; subordinate chert and cherty limestone; 600 feet thick; Guadalupian (Late Permian) in age; overlain disconformably by rocks of Early Triassic and underlain disconformably by Formation 4.

Formation 4: Upper unit of chert and subordinate siltstone, both lithic types dark grey to black, thin- to medium-bedded, 595 feet thick; lower unit of shale and siltstone, dark grey to black, minor sandstone, 740 feet thick; total thickness, 1,335 feet; presumed Artinskian age (late Early Permian); underlain disconformably by Formation 3.

Formation 3: Upper unit of siltstone, subordinate shale and limestone; all three lithic types dark grey to black, 1,240 feet thick; lower unit of limestone, argillaceous, dark grey to black, thin- to mainly medium-bedded with minor interbeds of black, sooty shale and chert; biohermal development common in this unit, 1,240 feet thick; total thickness, 2,480 feet; Moscovian (Early Carboniferous) to Artinskian (Early Permian) in age.

Formation 2: Anhydrite and secondary gypsum; thick-bedded to massive; minor interbeds of dark grey limestone; 1,000 feet thick; has not yielded diagnostic fossils.

Formation 1: Sandstone, quartzose, alternating with conglomerate, both units are dusky red and thin- to mainly thick-bedded; minor interbeds of siltstone, shale, and bioclastic limestone; 540 feet thick; lies with angular unconformity on rocks of lower Paleozoic age.

Formations 2 to 5 inclusive were measured by Thorsteinsson two miles northeast of Van Hauen Pass, a low valley that forms a short overland route between Hare Fiord in northwest Ellesmere Island (UTM zone 16, 9000200N, 525150E). A photograph of Formations 2 and 3 at that locality is shown as Figure 3 in Thorsteinsson and Tozer (1957). Formation 1 was measured some 22 miles northeast of Van Hauen Pass (UTM zone 17, 900425ON, 540600E).

Non-marine rocks of Visean age (Early Carboniferous) that were described originally by Kerr and Trettin (1962) are absent at the above described localities. Those rocks are present in northern Axel Heiberg and northwesternmost Ellesmere Island where they disconformably underlie Formation 1.

Formation 1, according to Thorsteinsson, is dated as early Namurian (Early Carboniferous) on the basis of a rich foraminiferal fauna identified by B.F. Mamet.

The oldest fossils in Formation 3 occur 50 to 75 feet above the base of the formation and consist of ammonoids that W.W. Nassichuk (1967) has dated as Moscovian (Middle Carboniferous). At other localities in the environs of Hare Fiord, Formation 3 has yielded also Late Carboniferous and Early Permian ammonoids (Nassichuk, personal communication).

Formation 2, consisting mainly of anhydrite, has yielded no fossils where it occurs in normal stratigraphic successions, such as the one described above northeast of Van Hauen Pass. Nevertheless, the age of the formation is Namurian (Early Carboniferous) and/or Bashkirian (Late Carboniferous) on the basis of its stratigraphic position between Formations 1 and 3. In this connection, ammonoid faunas collected from two widely separated anhydrite diapirs are of special interest. Ernst W. Hoen (1964, p. 8) collected ammonoids from limestone beds in an anhydrite diapir on the west coast of Axel Heiberg Island which W.M. Furnish and B.F. Glenister date as Namurian. W.W. Nassichuk has made large collections of ammonoids from intercalated limestone beds in the Barrow Dome on Sabine Peninsula which he has dated as Namurian and possibly also Bashkirian in age.

It seems reasonable to conclude, therefore, that the source beds of the anhydrite diapirs in the Sverdrup basin represent a single formation of Namurian and possibly also Bashkirian age, and are identical with Formation 2 described above. Similarly, the limestones within the diapirs probably represent some part of the overlying Middle Carboniferous to Early Permian formations.

Unnamed Formation of Anhydrite

Anhydrite constitutes the predominant rock type in the cores of Dumbbells, Contour, Isachsen, and Mallock Domes, and is well represented in the smaller Haakon and Helicopter Domes. Only a relatively small area of gypsum is exposed at the centre of Hoodoo Dome although two small bodies occur along the eastern flank, suggesting that a larger mass underlies the main anticlinal structure.

At the surface, the anhydrite formation consists largely of the alteration product gypsum, but fresh surface exposures are generally found to be anhydrite. The anhydrite is finely grained and varies in colour from light to dark grey. Selenite is present in all the diapirs, in a few places forming a major part of the rock. Large crystals are not uncommon. The selenite occurs in irregular masses, as layers within the bedded evaporites, and as irregular veins.

The anhydrite and gypsum are, in part, banded and bedded and it is these bands and beds that reveal the extreme tectonic disturbance of the evaporites. Intricate folds are clearly visible along the sides of stream valleys and complex patterns are apparent on the upper surfaces of the diapirs. The strike of beds near the periphery of some of the diapirs commonly conforms to the outer contact of the diapirs.

Inclusions of diabase, basalt, and gabbro are present in all the diapirs with the exception of Hoodoo Dome, and these occurrences are described in a following section. The intrusive rocks are not well dated; they may represent a late Paleozoic phase of basic igneous activity or they may be related to the later phase in which Mesozoic rocks were intruded.

No fossils were obtained from the anhydrite formation. However, as stated previously, it is reasonable to infer that the evaporites are closely related to the Early Carboniferous Formation 2 of Thorsteinsson.

Unnamed Formation of Limestone

Isolated blocks and, in some cases, large masses of limestone occur within the main piercement structures. Some of these may represent original beds of limestone intercalated within the anhydrite sequence. Others, particularly the thicker sequences, such as the occurrence at Haakon Dome, probably belong to one of the limestone formations that overlie the anhydrite formation.

Heywood (1957, p. 8) reported that the largest limestone block within Isachsen Dome is 50 feet wide, 100 feet long, and more than 10 feet thick. In a more recent report, Gould and de Mille (1964, p. 728) reported that "outcrops of buff, unfossiliferous limestone....locally appears to be in unconformable contact with the overlying Cretaceous sediments. This suggests that a structure of considerable magnitude, exposing Paleozoic sediments, may have been present at the onset of Lower Cretaceous sedimentation."

Blackadar (1963b, p. 561) noted that "limestone, limestone breccia, and conglomerate, in part separate the gypsum from the intruded strata of the Isachsen Formation" at the north end of the Dumbbells dome. The conglomerate, containing quartz pebbles and shale fragments, was described as lying below the limestone, the maximum observed thickness of the total succession being about 375 feet.

Greiner (1963, p. 566) reported some 300 feet of siltstone, dolomitic siltstone, dolomite, and limestone within Malloch Dome. The limestone was described as light coloured and crystalline, or dark grey and fine-grained.

At the west end of Contour dome, a relatively large area contains numerous outcrops of limestone. The bedding attitude of the stratigraphically highest beds is approximately the same as that of the overlying Deer Bay and Isachsen Formations. There is no evidence of contorted or disrupted bedding to indicate any faults between those beds. As far as could be determined, the beds are in depositional contact, although the contact does represent a major unconformity. The upper four feet of the succession is limestone breccia which might represent a basal Mesozoic conglomerate but it appears to be more closely related to the underlying beds. Some boulders are as much as 2 feet in diameter but clasts are generally less than 2 inches. The rock is grey to very light pinkish grey and poorly bedded. It is underlain by grey, very bituminous limestone, No fossils were discovered at this locality.

No large masses of carbonate rock appear to be present in Hoodoo Dome although McLaren (1963, p. 554) described some blocks of dark grey, fetid, medium-grained, calcareous dolomite. Loose boulders of black, cherty limestone yielded brachiopods and coral.

At the northern end of Helicopter Dome, both limestone breccia and bedded limestones were observed. The limestone is dark grey, aphanitic to finely crystalline, somewhat fractured, with calcite veins. Other limestone is sandy, grading into calcareous fine-grained sandstone. Some of the limestone is slightly metamorphosed, probably as a result of the diabase intrusions that occur within the dome.

Haakon Dome differs from the others in the relatively great abundance of limestone exposed in proportion to gypsum. The succession is not readily determined, the rocks being disrupted by intrusions of anhydrite, gypsum, and diabase. Black, finely crystalline limestone and brownish grey limestone breccia and bioclastic limestone are present. Abundant brachiopods, representing several species, were collected at the top of the dome.

The following fauna (GSC loc. C-12), obtained from Haakon Dome was identified by J.B. Waterhouse.

Krotovia sp.
Avonia sp.
Plicatifera sp. (or echinoconchid)
Linoproductus sp. (or *Ovatia* sp.)
Coledium cf. *C. erugatum* Grant
poorly preserved buxtoniid, dictyoclostid,
dielasmatid and leioproductid brachiopods
Parallelodon sp.

Waterhouse comments as follows:

> Preservation is extremely poor, with virtually no spinosity left on the Productacea, rendering generic determination very difficult. Some of the forms present show slight similarity to species assigned to the Mississippian by Nelson (1961). The fauna from GSC loc. 56430, from Hare Fiord, Ellesmere Island, has buxtoniid, ?echinoconchid, and linoproductid brachiopods somewhat similar to those from GSC loc. C-12. The age of the fauna from GSC loc. 56430 has been established as Moscovian (middle Pennsylvanian) on the basis of associated ammonoids. A Moscovian age is likely for GSC loc. C-12, but no definite age determination is possible because of the poor preservation.

JURASSIC ROCKS

Borden Island Formation

A series of glauconitic sands and red ferruginous sandstone, about 200 feet thick, and occurring on Borden Island, was designated as the Borden Island Formation by Tozer and Thorsteinsson (1964, p. 121). The formation was shown to be present at various localities around Sverdrup basin as follows: it is represented by a thin succession in northwestern Melville Island (op. cit); locally present on Prince Patrick Island (H. Frebold, pers. comm.); and occurs on northern Ellesmere Island and throughout much or all of eastern Axel Heiberg Island (Tozer, 1963, p. 16).

On Ellef Ringnes Island, sandstones were discovered lying below the Jurassic Savik shales at the north end of Reindeer Peninsula. A series of normal faults with only small displacement has broken the area into angular blocks, thereby inhibiting the determination of the correct succession. Although the base of the formation is nowhere exposed, the total thickness appears to be over 200 feet.

The lowest beds apparently are located on the northeastern side of the peninsula. They consist of brown to brownish grey, flaggy to thin-bedded, quartzose sandstone with much interbedded, dark red- to maroon-weathering, ferruginous concretionary siltstone. Brown to yellowish grey, platy sandstone and silty, flaky shale containing much finely comminuted carbonaceous material occurs on the west coast. Those beds are overlain by thick-bedded to massive quartzose sandstones. Farther inland, similar beds are exposed on low hills lying immediately south of the Arctic Coastal Plain. There, the sandstones are fine-grained, light grey to white, thick-bedded to massive, light brown- to grey-weathering and quartzose. They are very well sorted, show some slight lamination and are porous. This succession was not encountered elsewhere on the island and no similar rocks were noted on the flanks of any of the domes.

The type Borden Island Formation was dated, in part, by its stratigraphic position between the Heiberg Formation (Norian and ?younger) and Wilkie Point beds (Toarcian). A fossil from talus, identified by Frebold as Arietites and dated almost certainly as of Lower Sinumurian age, was assumed to be derived from Borden Island beds because the basal Wilkie Point strata had yielded Toarcian ammonites.

Fossils collected by the writer from Borden Island beds on Reindeer Peninsula (GSC loc. 80753) were identified and dated by Hans Frebold. He reported Coroniceras (Primarietites) sp. indet. of the subfamily Arietitinae Hyatt and Charmasseiceras sp. indet. of the family Schlotheimiidae Spath. He stated that this fauna is new for the Canadian Arctic and assigned it to the bucklandi zone of early Sinemurian age. He suggested that it is probably about the same age as the Lower Sinemurian beds of Melville and Borden islands and of the Richardson Mountains (see Frebold, 1960, p. 26 and Table I).

Savik Formation

The Savik Formation was originally defined on Axel Heiberg Island (Souther, 1963, p. 435) as including about 300 feet of white-weathering, black, pyritic shale. Although the colour of the shales differ on Ellef Ringnes, it seems desirable to maintain the name for the similar marine succession.

A complete section of the formation, exposed on north-central Reindeer Peninsula, was found to be 250 feet thick. Although mud and weathered rubble covers much of the surface, an approximate description was obtained:

Section 67-1. Savik and Jaeger Formations, north-central Reindeer Peninsula, Ellef Ringnes Island, NWT., 78° 57' N, 104° 32' W.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Top of ridge		
	JAEGER FORMATION		
1	Sandstone, fine-grained, silty, glauconitic, green to olive-brown, ferruginous; green- to brown-weathering. Estimated	50	50
	SAVIK FORMATION		
7	Mudstone, silty, green to olive-green; much maroon and dark reddish brown-weathering concretionary material; grades into overlying beds GSC loc. 80766 *Cranocephalites* sp. group of *C. vulgaris* Spath and *C. pompeckj* (Madsen) Age: Early Bathonian, *pompeckj* zone	70	250
6	Mudstone, sandy, olive-brown; sandstone, very silty, olive-brown to olive-grey	25	180
5	Mudstone, very silty and sandy, very glauconitic, green to greenish brown; interbedded sandstone, calcareous, grey, silty, glauconitic; dark maroon-weathering concretionary masses; abundant pelecypods GSC loc. 80740 *Leioceras opalinum* (Reinecke) *Gresslya* sp. *Inoceramus* sp. *Oxytoma septentrionalis* (Haughton) *Pecten* sp. Age: Early Bajocian	10	155
4	Mudstone, greyish brown; thin reddish brown-weathering sideritic plates; some calcareous siltstone; poorly exposed GSC loc. 80764 *Catacoeloceras* sp. *Pseudolioceras* sp. Belemnoidea Age: Late Toarcian	30	145

Unit	Lithology	Thickness (feet)	Height above base (feet)
3	Mudstone, soft, flaky, greenish grey; reddish brown-weathering concretions	30	115
2	Mudstone, grey, soft, very calcareous; thin concretionary plates and some fragments of light grey siltstone; some belemnites	35	85
1	Shale to mudstone, grey, soft; small concretionary plates and small yellowish concretions; grades into interbedded shale and sandstone, platy, concretionary, brown; abundant belemnites GSC loc. 80734 Dactylioceras spp. Pelecypod fragments Age: Early Toarcian, falciferum zone	50	50
	contact not exposed		
	BORDEN ISLAND FORMATION		
1	Sandstone, fine-grained, brownish grey, quartzose; thick-bedded; brown-weathering		

The contact of the Savik and underlying beds is not exposed in the bank of the creek at the described section although it is evident that soft grey mudstone lies directly on massive Borden Island sandstone. The upper beds are gradational into the Jaeger.

The shales are abundantly fossiliferous with several horizons of belemnite "battlefields". Numerous ammonites were collected on the northeastern point of the peninsula. Pelecypods are abundant in a sandy unit about 150 feet above the base.

The Dactylioceras spp. (GSC loc. 80734) obtained from the lower 50 feet of the Savik Formation are dated as early Toarcian and assigned to the falciferum zone by Frebold. He stated that higher beds containing Catacoeloceras sp., Pseudolioceras sp., and Grammoceras? sp. (GSC loc. 80741) were of late Toarcian age (see Frebold, 1960, Table I). An early Bajocian age was assigned to the sandy beds near the middle of the Savik Formation which yielded Leioceras opalinum (Reinecke), Gresslya sp., Oxytoma septentrionalis (Haughton) (GSC loc. 80740) and Oxytoma jacksoni Pompeckj (GSC loc. 80742) (see Frebold, 1960, Table I and 1961, Table I). Fossils from upper shales of the Savik include Cranocephalites sp. ex. gr. C. vulgaris Spath and C.

pompeckj (Madsen) (GSC loc. 80739, 80765, 80766, 80767), assigned by Frebold to the pompeckj zone of early Bathonian age (see Frebold, 1961, Table I, and 1964, Table II). The Savik Formation of Ellef Ringnes Island, therefore, contains Lower and Upper Toarcian, Lower Bajocian, and Lower Bathonian faunas. It is equivalent to much of the Wilkie Point Formation as described by Tozer and Thorsteinsson (1964, p. 126) from the western Queen Elizabeth Islands. It is equivalent, at least in part, to the Savik Formation of Axel Heiberg Island and Ellesmere Island which ranges from late Toarcian to Callovian (Frebold, 1960, 1964; Tozer, 1963b). The sandy, glauconitic beds of Unit 5, containing early Bajocian fossils, may be a tongue of the Jaeger sandstones which occur farther southeast on Cornwall Island (Greiner, 1963, p. 535) and farther east on western and northern Ellesmere Island (Tozer, 1963, p. 22).

Jaeger Formation

Jurassic varicoloured sands and sandstones, in part pebbly, glauconitic, and with common ironstone nodules, occurring on Cornwall Island were defined by Greiner (1963, p. 535) as the Jaeger Formation. It was considered by Greiner to be approximately 1,000 feet thick and to be of mixed marine and non-marine origin. The formation is overlain on Cornwall Island by the Jurassic Awingak Formation. A similar succession of Jurassic sandstone and sand with some glauconite, dusky red ferruginous beds, and about 600 feet thick in the western Queen Elizabeth Islands, was given the name "Wilkie Point" by Tozer (1956, p. 18). Tozer and Thorsteinsson (1964, p. 125) reported that grey shale occurs at the base of the succession on Borden and Mackenzie King Islands and this they considered to represent a tongue of the Savik Formation of Axel Heiberg Island. Some 200 feet of green, glauconitic sandstone with dusky-red, hard beds occurring in the middle of Savik shales on Fosheim Peninsula on western Ellesmere Island were assigned by Tozer (1963, p. 21) to the Jaeger Member. These sand-shale relationships indicate the facies change from shale to sand between the axis and margin of the Sverdrup basin (Tozer, 1960, Fig. 5; Tozer and Thorsteinsson, 1964, Fig. 7). The glauconitic sandstone facies occurring above the Savik shale on Ellef Ringnes Island is closely related to the marginal sandstone facies. Although the sandstones on Ellef Ringnes Island were observed by St. Onge (1965), they were not given any formational assignment. In the light of current knowledge, it seems appropriate to apply the name Jaeger, not only because of the proximity of the type Jaeger on Cornwall Island, but also because Jaeger is commonly used for the dominantly marine, sandy sediment lying beneath the Awingak Formation in the eastern part of the Sverdrup basin. The name Wilkie Point might also be applied but Tozer (pers. comm.) believes that the Wilkie Point Formation, as presently applied in the western Queen Elizabeth Islands, includes beds equivalent to the Awingak and that future investigations will result in the recognition of the Jaeger and Awingak Formations.

The total thickness of the Jaeger was not determined but is estimated to be in the order of 150 to 200 feet. The formation occurs on the top of hills in the western half of Reindeer Peninsula and in the vicinity of the headwaters of Contact River.

The formation includes soft grey and green sand, abundantly glauconitic in most places. Hard beds of yellowish brown-weathering, grey, calcareous sandstone and dark red, ferruginous sandstone are common. The glauconitic sandstone is very dark where weathered, bearing some resemblance in aerial photographs to the weathered igneous rocks of the island.

The Jaeger beds lie on Savik shales containing Cranocephalites of early Bathonian age. The only Jaeger fossils of younger age were collected northeast of the large delta bordering Reindeer Peninsula. The collection (GSC loc. 80754), identified by Frebold, includes Cadoceras septentrionale Frebold, Cadoceras spp., and Kepplerites spp. (new for Canadian Arctic). Frebold dated this fauna as early Callovian, probably of the calloviense zone (see Frebold, 1964, Tables I, II). Cadoceras barnstoni (Meek) (GSC loc. 44041) was collected from the same general region by J. L. Usher (Frebold, 1964, pp. 1, 14). Fauna of this age was not reported from the western Queen Elizabeth Islands by Tozer and Thorsteinsson (1964). Collovian beds, with Cadoceras, are known from the region of Richardson and British Mountains, on Cornwall Island in the sand facies (Jaeger Formation) and on western Axel Heiberg Island in Savik shale (Frebold, 1964; Tozer, 1963b).

The Jaeger Formation of Cornwall Island contains fossils of Toarcian and early Callovian age (Greiner, 1963, p. 535). The Jaeger Member on Fosheim Peninsula contains beds of Toarcian age and may range as high as late Bajocian or early Bathonian (Tozer, 1963, p. 22). The lower part of the Wilkie Point Formation of the western Queen Elizabeth Islands contains marine fossils ranging from Toarcian to late Bathonian, and its upper non-marine beds may be equivalent to the Awingak of Late Jurassic age (Tozer and Thorsteinsson, 1964, p. 126). The Jaeger sandstone of Ellef Ringnes Island, being of early Callovian age, is approximately equivalent to the upper Jaeger of Cornwall Island, is younger than the Jaeger Member of Ellesmere Island, and younger than the dated marine Wilkie Point.

JURASSIC-CRETACEOUS ROCKS

Deer Bay Formation

Black shales, occurring along the axis of Louise Anticline in the vicinity of Deer Bay east of Isachsen, were defined as the Deer Bay Formation by Heywood (1957, p. 9). It is the main sedimentary formation between Gabbro Peninsula and Louise Fiord. It is found also on the east side of Reindeer Peninsula where basal beds are exposed.

Heywood (op. cit., p. 9) indicated that he mapped only the upper 600 feet of the formation but gave no estimate of the total thickness. No continuous section was found although much of the formation is exposed northeast of Reindeer Cape. It is probably less than 1,000 feet thick.

The formation is in contact with the underlying Jaeger Formation on Reindeer Peninsula and northwest of Isachsen. Although the actual contact is not well exposed, the dips of both formations appear the same and no discordance is evident. Talus near the contact includes pebbly, concretionary sandstone, probably representing a thin basal conglomerate of the Deer Bay.

The formation is divisible into two informal members which can be recognized reasonably well in aerial photographs. The lower member outcrops at the southern end of Reindeer Peninsula and also in the centre of the Louise Anticline east of Isachsen. It comprises light grey-weathering, concretionary shales. The basal beds consist of black, soft mudstone with red- to reddish brown-weathering, ferruginous concretionary plates. Stratigraphically higher shales contain calcite rosettes and large, yellowish concretions which weather to large conical piles of rubble. Nearly 100 feet of those shales, exposed near Reindeer Cape, are overlain by 40 to 50 feet of sandy, glauconitic mudstone. The latter bears some similarity to the Jaeger beds but the Deer Bay shales weather to much lighter colours. Traces of pelecypods and ammonites were found in the concretions. The upper member comprises soft, black shale that appears very dark in outcrop and in photographs.

Despite the fact that the Deer Bay is probably entirely marine, fragments of petrified wood are common throughout the formation. They are most abundant in the upper part.

At the west end of Contour Dome, Paleozoic limestones are overlain unconformably by 100 to 150 feet of black shale with reddish brown-weathering concretions and thin, yellowish brown sandstone. These beds grade into overlying Isachsen sandstones. The following microfauna was identified by T.P. Chamney:

Haplophragmoides sp.
Haplophragmoides cf. *H. neocomianus* Hecht
Glomospira cf *G. gordialis* (Jones and Parker)
Gaudryina cf. *G. topagorukensis* Tappan
Ammobaculites cf. *A. venustus* Loeblich and Tappan
A. alaskensis Tappan
Lituotuba? *irrugularis* Tappan
Trochammina? sp.

Although Chamney indicated that these fossils are from the Jurassic-Cretaceous boundary interval, he stated that there is more evidence of late Upper Jurassic than early Lower Cretaceous age. It, therefore, seems evident that the shales should be assigned to the Deer Bay Formation, although the total thickness at that locality is much less than elsewhere on Ellef Ringnes. The unconformity at the base represents all of the Permian and Triassic periods and a large part of Jurassic time, indicating either (or both) an elevated land-area throughout a long interval of time or pronounced erosion prior to the deposition of the Deer Bay sediments. The small thickness of Deer Bay shale may be attributed either to a condensed section or to intervals of non-deposition; in either case, the area of Contour Dome at that time seems to have been considerably higher than the surrounding basin.

A rather large assemblage of fossils, collected by earlier workers and identified by J.A. Jeletzky, has been reported from the Deer Bay Formation. The precise location and stratigraphic position of the collections are lacking in many cases. They include

Buchia cf. *B*. *mosquensis* (Buch)
Buchia *inflata* (Toula) et var. *majuscula* (Tullberg, 1881)
Buchia *keyserlingi* (Lahusen)
Buchia *okensis* (Pavlow)
Buchia *sublaevis* (Keyserling)
Buchia cf. *B*. *okensis* (Pavlow) var. *canadiana* Crickmay
Buchia cf. *B*. *volgensis* (Lahusen)
Buchia cf. *B*. *bulloides* (Lahusen)
Buchia cf. *B*. *crassa* (Pavlow)
Buchia cf. *B*. *nuciformis* (Pavlow)
Buchia cf. *B*. *sublaevis* (Keyserling)
Buchia cf. *B*. *terebratuloides* (Lahusen)
Buchia cf. *B*. *werthii* (Pavlow)
Buchia ex gr. *keyserlingi* (Lahusen)
Acroteuthis? *subquadratus* (Roemer) emend Swinnerton, 1935
Acroteuthis (a new genus?) n. sp. A
Homolsomites cf. *H*. *quatsinoenis* (Whiteaves)
Polyptychites? cf. *P*. ? *densicosta* Parlow
Polyptychites (*Euryptychites*) *stubbendorfi* (Schmidt) var. *middendorfi* Parlow
Anatina (Cercomya)? sp.
Nucula? sp.
Astarte? sp.
Arctica? sp.
Inoceramus sp.
Leptosolen sp.

Buchia cf. *B*. *mosquensis* Buch, obtained from beds along Louise Anticline, is dated by Jeletzky as mid-upper to late Jurassic. Although the record of Jurassic fossils in the Deer Bay is meagre on Ellef Ringnes Island, Jurassic fossils are known to occur in the formation on Axel Heiberg Island and in equivalent rocks on Prince Patrick and Mackenzie King Islands (Tozer, 1960, p. 12), and on Ellesmere Island (Frebold, 1961, pp. 23-24; Tozer, 1963b; Jeletzky, 1966). According to Jeletzky, representatives of several earliest Cretaceous zones are present on Ellef Ringnes, ranging from the Verriasian to late Valanginian substages of the Neocomian stage. The Deer Bay Formation, therefore, includes beds of Late Jurassic to earliest Cretaceous age.

CRETACEOUS ROCKS

Isachsen Formation

A succession of non-marine, quartzose sandstone, shale, and coal seams, about 3,000 feet thick, was included by Heywood (1957, p. 11) in the Isachsen Formation. It outcrops in a broad belt extending across Noice and Christopher Peninsulas and occurs in steeply dipping strata around the margins of all the domes.

The formation is almost completely exposed in a series of gently dipping cuestas lying east of Deer Bay and appears to be thickest in that region. It is in fault contact with older rocks in most places around the domes, making it difficult to obtain a total thickness in the central and eastern parts of the island. At the west end of Contour Dome, where the Isachsen is separated from Paleozoic limestones by a thin succession of Deer Bay shale, the formation seems to be thinner. There is also some indication that the uppermost sandstone, well developed between Dumbbells and Contour Domes, thins toward the culminations of the domes.

According to Heywood, the lower contact of the Isachsen was "arbitrarily placed at the lowest occurrence of sandstone above the Deer Bay Formation", thereby suggesting a gradational and conformable relationship. In a small outlier remnant south of Louise Fiord, where the actual contact is covered, Deer Bay shales and Isachsen sandstone are less than 5 feet apart with no transition zone. Northeast of Isachsen, fine-grained, flaggy sandstone is overlain by pebbly, medium-grained sandstone and a distinct break in lithology is evident along the slopes. These relationships indicate some possibility of an unrecognized hiatus at the base of the Isachsen.

The Isachsen Formation can be divided into four informal members. In earlier work, McLaren (1963, p. 555) divided the Isachsen in the vicinity of Hoodoo Dome into five informal members. Although no attempt was made in the field to reconcile that succession with the present subdivision, it appears that McLaren's member 1 roughly approximates the writer's second member, McLaren's members 2 and 3, the writer's third, and McLaren's members 4 and 5 seem about equivalent to the writer's fourth or upper member.

The lower member comprises light coloured sand and sandstone with layers of dark rust- to maroon-weathering sandstone. Much of the sandstone is medium- to coarse-grained with some pebbles. It is quartzose, friable, thick-bedded to massive, grey- to brown-weathering, and commonly calcareous. A bituminous residue was noted at the two small remnants on Reindeer Peninsula. Some small hoodoos are developed within crossbedded indurated units.

The main development of hoodoos occurs within the second member where differential weathering of crossbedded sandstone has produced pillars 25 to 30 feet high. The sand and sandstone are medium- to coarse-grained with pebbles up to 2 inches in diameter. The whole succession is very light coloured and appears almost white on aerial photographs. The succession is readily traced from Noice Peninsula northward to Louise Fiord.

The third member consists of darker sands and sandstone with units of dark siltstone, mudstone, and coal seams. The interbedded dark mudstones and lighter coloured sandy beds produce a distinct banding. Some of the sand is white to yellowish grey, but much is light brown to olive-brown. Some thick conglomerates, consisting of white quartz pebbles in a dark sandy matrix occur near the base. Plant fragments are common throughout.

The fourth or upper member is a lighter grey sequence on aerial photographs, lacking the strongly banded appearance of the underlying third member. It contains fine- to medium-grained sandstone and sand that is platy to flaggy, and white to light grey and brown in colour. It also includes some very coarse-grained to conglomeratic sandstone. Intercalated beds of black flaky shale and mudstone occur near the top.

Only a few diagnostic fossils have been found in the Isachsen Formation. Heywood (1957) reported Buchia (Aucella) cf. B. bulloides (Lahusen) and Buchia cf. B. terebratuloides (Lahusen) from the lowest 100 feet of the formation, dated by Jeletzky as Infravalanginian to Valanginian. Because the Isachsen Formation is overlain by the Albian Christopher Formation, it can be dated as late Neocomian (early but not earliest Cretaceous).

Christopher Formation

The Christopher Formation (Heywood, 1957, p. 12) includes a thick succession of dark marine shales. It extends northeasterly from Dome Bay along Haakon River and underlies a large area around Dumbbells and Contour Domes. It also surrounds Hoodoo Dome.

The thickness of the Christopher Formation was reported by Heywood to be about 1,540 feet, presumably determined by him in the vicinity of Isachsen Dome. Blackadar (1963, p. 562) reported a thickness of 1,330 feet from the northwest flank of Dumbbells Dome. An additional measurement, obtained during the present study by taping and calculations, gave a thickness of over 2,500 feet adjacent to Helicopter Dome. The reason for the discrepancy between the latter thickness and the others is not immediately apparent but could be related to depositional thinning in the vicinity of the major domes.

The lower contact of the Christopher Formation is placed above a prominent ridge-forming sandstone that appears to persist throughout the island.

The Christopher Formation is considered to lie conformably on the Isachsen beds and consists mainly of soft,dark grey to black shale with hard beds and concretions of calcareous mudstone and clay ironstone that weather to yellow and red colours. A few thin beds of dense limestone occur in the lower part of the formation. Thin, platy, fine-grained sandstone is more abundant near the top of the formation. Basal beds of the Christopher appear to be much sandier in the immediate vicinity of Contour Dome. Lithified tree-stems were noted within these beds.

Gastroplites nov. sp. aff. G. liardensis (Whiteaves) and G. cf. G. canadensis (Whiteaves) were identified by Jeletzky from collections made by earlier workers from the Christopher Formation south of Contour Dome. Those were dated by him as latest middle Albian. G. ex aff. G. liardense (Whiteaves) was also reported from a locality west of the north end of Dumbbells Dome. A third collection obtained near Malloch Dome (Greiner, 1963, p. 568) includes Beudanticeras? sp., identified and tentatively dated by Hans Frebold as probably of Albian age. Tozer (1960, p. 13) suggested that the lower Christopher beds might be as old as Aptian, but considered most of the formation to be of Albian age.

Hassel Formation

The Hassel Formation was defined by Heywood (1957, p. 13) to include a thick succession of sandstone occurring in the vicinity of Isachsen Dome. It occurs along the axis of the broad Haakon Syncline lying between Haakon River and Dumbbells Dome, south of Helicopter Bay, and as a narrow band encircling Hoodoo Dome.

The thickness of the formation in the vicinity of Isachsen Dome was reported by Heywood to be 1,800 feet. Nearly 1,200 feet were measured on the east flank of Haakon Syncline southwest of Dumbbells Dome and 1,800 feet in a section west of Helicopter Dome, but neither of those two measurements reached the upper contact. Two additional measurements were made on the flanks of Hoodoo Dome. The first, on the west and southwest of the gypsum core, indicated a thickness of about 500 feet. The second, on the east flank, gave less than 300 feet. It is readily apparent from a study of aerial photographs that additional beds occur within the Hassel Formation at the northern and southern ends of the dome. Other evidence of thinning in the vicinity of piercement structures was noted by Gould and de Mille (1964, p. 726) who reported that a unit at the base of the Hassel thins nearly 200 feet in a distance of 2 miles from a locality near the axis of Christopher Syncline to one near Isachsen Dome. It is evident that the Hassel Formation thins markedly in the vicinity of the greatest uplift of the domal structures.

The appearance of this formation is one of the more striking on the island because of the sequence of multicoloured sand and shale. The sand is oxidized to various shades of red, orange, and yellow and the darker shale beds are brown, grey, and green, The dominant rock type is quartzose sand and sandstone. Much of the sand is unconsolidated and, as a result, prominent ledges and cliffs are generally lacking. The sand is medium- to coarse-grained but thick units of conglomerate were not encountered. Thin beds of coal and carbonaceous layers are present throughout the formation.

Some large angiosperm leaves were collected about 1,200 feet above the base of the formation south of Dumbbells Dome.

Kanguk Formation

The Kanguk Formation was originally described by Souther (1963, p. 442) from exposures on Axel Heiberg Island. The formation was recognized also in the vicinity of Transection River on Ellef Ringnes Island by Greiner and Roots during the same operation.

The dark marine shales extend southeasterly from Transection River to Hoodoo River, and are found on the flanks of Meteorologist Anticline and form the most southerly exposures of bedrock on Meteorologist Peninsula. A remarkable escarpment formed by the lower Kanguk shales extends west-east across the island from Isachsen dome to distributaries of Divergent River.

The thickness of the Kanguk Formation was estimated to be between 650 and 700 feet (Greiner, 1963, p. 569). No additional measurement was obtained during the present work.

The Kanguk shales are dark grey to black, fissile to rubbly. They are silty in part and contain interbedded siltstone and fine-grained sand and sandstone. Basal beds of the Kanguk Formation include a unit of flaky, shaly siltstone that weathers medium grey. Those beds are overlain by shales containing very dark concretions. Several beds of bentonite, noted in the lower part of the formation, appear to be continuous for long distances. Ironstone concretions, weathering reddish brown, are abundant.

Inoceramus ex gr. *I. lobatus-patootensis* collected from the middle of the formation during Operation Franklin were assigned a Santonian to lower Campanian age by F.H. McLearn.

UPPER CRETACEOUS AND TERTIARY ROCKS

Eureka Sound Formation

A succession of non-marine sediments that overlie the Kanguk Formation are tentatively included in the Eureka Sound Formation on the basis of similar stratigraphic position and analogous lithologies to beds assigned to that formation in other parts of the Arctic Archipelago. Thus, the writer's classification of those sediments follows that of Greiner (1963, p. 569) and Tozer (1963a, p. 93). However, the present study has indicated that two distinctive lithologic units are recognizable in the Eureka Sound Formation on Ellef Ringnes Island and further investigation may necessitate raising those units to separate formational rank.

The Eureka Sound Formation was described by Greiner as "some 200 feet of sandstones and siltstones with interbeds of silty shale and of conglomerate." The formation as used herein also includes sediments designated by Greiner as "Tertiary (?) sands with logs". Therefore, the thickness of beds included in the Eureka Sound Formation by the writer probably exceeds Greiner's estimate but no measurement was made.

The formation occurs in the shallow Christopher Syncline extending from Transection River southeastward along the west side of Meteorologist Peninsula. It is also recognized on the east side of the island south of Hoodoo River and in a small area between Haakon Fiord and Cape Cairo.

The contact with the underlying Kanguk is gradational with dark shales grading upward into hard platy to thin-bedded concretionary sandstone. The upper surface of the sediments assigned to the Eureka Sound Formation is erosional. The formation is, therefore, the youngest in the concordant Jurassic to Tertiary succession of Ellef Ringnes Island.

The formation can be subdivided into two distinct lithologic units. The lower unit contains consolidated beds whereas the upper unit is dominantly sand. As pointed out by Greiner, the upper sediments may be much younger than the consolidated beds and separated from them by an unconformity.

The lower succession, transitional from the Kanguk marine shales, comprises bedded sandstone and shale. The sandstone ranges from fine- to coarse-grained, is dark brown to rusty brown in colour, dark maroon- to brown-weathering. The mudstone and shale are dark grey to brownish grey with large dark reddish brown-weathering concretions. Some unconsolidated grey sand occurs within this unit.

The overlying succession weathers much lighter and consists mainly of unconsolidated sand, a distinct change in lithology that is evident in aerial photographs. The unconsolidated sand is fine- to medium-grained, with some beds of coarse-grained sand containing pebbles and cobbles. Layers of soft, grey clay and sandy mudstone with some concretions occur sporadically through this succession. The sediments contain much carbonized wood. Large concretionary masses with inclusions of coalified logs as much as 6 inches in diameter and several feet long are present near Transection River. Six beds of lignitic to subbituminous coal, noted north of Haakon Fiord in this interval, range from 6 inches to 2 feet in thickness. The sands resemble the Recent alluvial and marine deposits which mantle much of the coastal region and become almost indistinguishable from the younger sediments.

The basal beds, being transitional from the Santonian to Campanian Kanguk shales, are considered to be of Late Cretaceous age. The only fossils reported to date are those plants collected by Greiner (1963, p. 570) and identified by W. L. Fry who was only able to suggest a Late Cretaceous or early Tertiary age. As indicated by Greiner, the carbonization of the logs suggests that the upper beds are Tertiary and considerably older than other unconsolidated sands containing unaltered fossil wood, such as those of the Beaufort Formation. The Eureka Sound Formation of Ellesmere and Axel Heiberg Islands is dated as Tertiary; the lower beds may possibly be latest Cretaceous and the youngest beds, Oligocene or Miocene (Tozer, 1963a, p. 94; 1963b, pp. 29-32).

TERTIARY AND/OR PLEISTOCENE ROCKS

Beaufort Formation

The Beaufort Formation, named by Tozer (1956), includes crossbedded sand and gravel that covers the Arctic Coastal Plain from southern Banks Island to Meighen Island (Craig and Fyles, 1960; Thorsteinsson, 1961; Tozer and Thorsteinsson, 1964).

On Ellef Ringnes Island, these deposits overlie unconformably the Jurassic Borden Island, Savik and Jaeger formations and the Jurassic-Cretaceous Deer Bay Formation. Elsewhere, the Beaufort has been shown to be probably younger than the Eureka Sound Formation (early Tertiary) and to be older than the glaciation of the islands. It has been concluded (Craig and Fyles, 1960; Tozer and Thorsteinsson, 1964) that the Beaufort is probably late Tertiary or very early Pleistocene.

The Beaufort of Ellef Ringnes Island was examined at only a few localities. The formation, covering the northern part of Isachsen Peninsula, contains fine- to coarse-grained, laminated to crossbedded sands, siltstones, and yellowish to dark grey clay. Lenses of coarse sand and gravel include well-rounded pebbles and cobbles of chert, quartz, and quartzite. Non-petrified logs and wood debris and thin carbonaceous seams occur abundantly. St. Onge (1965) concluded from various analyses that the material was derived from metamorphic rocks and acid extrusions and deposited as part of a vast deltaic complex covering the coastal plain.

Gravels capping high hills

Sand and gravel deposits, similar to those of the Beaufort Formation, occur at the summit of several hills scattered throughout the island. St. Onge (1965) believed that these sediments were at one time part of a deposit which covered the whole island and that the Beaufort Formation constitutes part of the same cover. However, the Beaufort, where examined during the present investigations, did not contain the large boulders which are common in the ridge deposits. A small hill of these bouldery gravels was observed lying on Beaufort sands on Isachsen Peninsula. It seems possible that the bouldery gravels are somewhat younger than the Beaufort, perhaps representing fluvial deposits related to Pleistocene glaciation.

The most southerly locality comprises two deposits resting on the Eureka Sound Formation some 15 miles north of Cape Nathorst. There, the boulders are as much as 2 feet in diameter and the rock types include limestone, quartzite, gabbro, and granite. The gravels are underlain by 50 to 60 feet of very fine-grained, grey sand which is in turn underlain by the typical dark mudstone with maroon concretions of the Eureka Sound Formation. Almost directly east, gravels capping three small hills lie on Christopher and Hassel strata at the south end of Meteorologist Anticline.

The long ridge of gravels to the north, lying between Malloch Dome and Hoodoo River, and the large deposits 4 miles south of Divergent River were described by St. Onge (1965). Another long ridge extends southwesterly from Divergent River toward Malloch Dome. A similar deposit, found between Haakon River and Dumbbells Dome, is not so continuous, being comprised of a series of low hills having a sinuous trend. The most prominent ridge, lying mainly on Isachsen strata between Deer Bay and Haakon River, was identified as an esker by St. Onge (1961). A smaller deposit is present on the west flank of Dumbbells Anticline on Christopher Peninsula and another occurs about 3 miles north of Contour Dome. A similar hill of gravel was noted south of Lily Point on Isachsen Peninsula. It is reasonable to expect that other occurrences of similar deposits will be discovered by more detailed investigations of the island.

DIABASE, BASALT, AND GABBRO

Intrusive bodies of diabase, basalt, and gabbro that occur in the northern part of the island are most abundant in a belt extending across the southern part of Isachsen Peninsula and the northern tip of Christopher Peninsula. Numerous dykes intrude the Deer Bay shales near Isachsen and remnants of sills lie on Isachsen sandstone around Louise Fiord. Large blocks and masses of these rocks occur as inclusions in the anhydrite cores of most of the diapirs. Intrusions were noted in the Hassel and older formations but not in any of the younger strata.

The occurrence and petrography of these rocks were discussed in some detail by Heywood (1957) and Blackadar (1963a, p. 96). They determined that the rock is essentially composed of laboradorite and pyroxene with minor amounts of apatite, hornblende, magnetite, and quartz. Many of the intrusions are fine-grained and classed as diabase but toward the centre of some of the large masses, phenocrysts may have a length of almost one inch. Contact effects are not strong although aphanitic rocks, representing chilled borders, commonly occur at contacts. Some baked shale and sandstone were found around the margins and also as inclusions within the dykes. The igneous rocks are dark green to black on a fresh surface but weather a dark rusty brown.

In the southern part of Isachsen Peninsula, a series of circular to semi-circular ridges, formed of diabase and gabbro are surrounded by Deer Bay shales. The shales dip gently away from the igneous bodies, appearing to have been intruded by the latter. These structures are considered to be ring dykes, perhaps intruded along fractures related to collapse of strata at depth associated with movement of evaporites.

Diabase sheets overlying Deer Bay and Isachsen strata occur west of Louise Fiord and also at the northern tip of Christopher Peninsula. These rocks are not overlain by any sedimentary rocks. Within these sheets, several circular areas enclosing Isachsen and Deer Bay sediments appear similar to the central part of the ring dykes and to have originated in similar manner.

Small dykes occurring in the Deer Bay Formation east of Deer Bay, are narrow and steeply dipping to vertical. These dykes are related to a larger igneous mass occurring at the contact of the Deer Bay and Isachsen Formations. Other small dykes occur on Gabbro Peninsula and north of Dumbbells Dome. Some of the narrow dykes have been intruded along faults and several at the south end of Isachsen Peninsula are too small to be shown on the map.

Sills are not abundant in rocks younger than the Isachsen Formation but do form distinctive features in two areas. A thin sill in the Christopher Formation east of Deer Bay is partly responsible for the development of the prominent cuesta that extends in a broad arc from Noice Peninsula toward Haakon River. A somewhat similar relationship is found near Haakon Fiord where sills are found in both Christopher and Hassel rocks. There, the intrusions have cross-cutting relationships in a few places. Much country rock is incorporated in the igneous rocks, producing the appearance of agglomerate.

Two small, isolated masses of igneous rock occur farther south. One, on Noice Peninsula, intrudes the Isachsen Formation. The other, on the west flank of Meteorologist Anticline, intrudes basal beds of the Hassel Formation.

Diabase, gabbro, and basalt inclusions are present in all the domes with the exception of Hoodoo. Those of the Isachsen Dome were described by Heywood (1957, p. 15). Greiner (1963, p. 566) noted fine-grained basic igneous rocks with true pillow structures within Malloch Dome. Within Dumbbells Dome, irregular masses of diabase have a roughly concentric orientation, parallelling to some degree, the edge of the piercement structure. These masses show as resistant ridges or mounds with greenish, dark coloured talus. In some places, the surrounding gypsum is stained by iron oxides and bright red to orange gossans streak the rocks. Magnetite was found in Contour Dome and Blackadar (1963, p. 561) reported traces of malachite and chalcopyrite in Dumbbells Dome. Several wide dykes occur within Helicopter Dome, the dark green talus contrasting with the pastel colours of the gypsum. Similarly at Haakon Dome, several large areas of igneous rocks occur within limestone.

These basic intrusive rocks cut strata ranging in age from late Paleozoic to late Early Cretaceous but do not penetrate younger beds. It appears, therefore, that the latest phase was probably of late Early Cretaceous age but it is not known if all the intrusions are the same age. On the basis of paleomagnetic determinations, Larochelle and Black (1963) suggested that a belt of diabasic rocks near Isachsen appeared to be of Cretaceous age. However, that opinion was contradicted by their whole rock potassium-argon age determinations which indicated a Permian age (241 and 249 m.y.). As a result of their conflicting results, additional age determinations were made (Larochelle, Black, and Wanless, 1965) and a range of 102 to 110 m.y. obtained. The consistency of those determinations indicated that the rocks are of Early Cretaceous age. The age of the intrusions in the piercement structures is still in doubt.

STRUCTURAL GEOLOGY

Ellef Ringnes Island lies within the Sverdrup Basin (Thorsteinsson and Tozer, 1960; Fortier et al., 1963). The basin is a major synclinorium situated west and north of the exposed part of the Franklinian geosyncline and its axis strikes northeasterly from Sabine Peninsula on Melville Island to northwestern Ellesmere Island, crossing the southern tip of Ellef Ringnes Island. The basin comprises an essentially conformable sequence of Early Carboniferous to early Tertiary formations which lie with profound angular unconformity on folded lower Paleozoic rocks, as shown by outcrops along the northeastern, southern, and western margins. The northwestern margin of the basin is largely covered by Beaufort sediments of the Arctic Coastal Plain although small areas of Jurassic rocks on Reindeer Peninsula presumably represent exposures of that flank. The basin has experienced several distinct stages of vulcanism; two during the Early Carboniferous and Permian (R. Thorsteinsson, pers. com.), and others during Cretaceous time when agglomerates, basic dykes and sills became widely distributed. Another significant feature is the zone of diapiric and piercement intrusions of Permo-Carboniferous evaporites which lies approximately along the longitudinal axis of the basin. The part of the basin found on Ellef Ringnes Island was deformed by diapirism and possibly was affected by the late Tertiary orogeny of the eastern part of the basin.

Thorsteinsson and Tozer (1960) suggested, by means of a longitudinal section across the Sverdrup Basin, that about 16,000 feet of undeformed sediments were present in the vicinity of Ellef Ringnes Island. Of that thickness, some 3,000 feet were thought to be Permo-Pennsylvanian, 3,000 to 4,000 feet, Triassic, and the remainder, younger Mesozoic rocks. Later, Hobson (1962, p. 271) reported that the top or near-top of the Permo-Pennsylvanian rocks was indicated by refraction profile at about 19,000 feet at the most southerly extent of Ellef Ringnes Island. As velocities associated with "basement" were not recorded, he estimated that 30,000 to 40,000 feet of unmetamorphosed sediments may be present in the thickest sedimentary section of the basin. These thickness figures indicate the presence of several thousand feet of sediments which either do not outcrop on the island or are poorly known. Hobson reported a much thinner section in the vicinity of Isachsen and Deer Bay, stating that refraction, reflection, and velocity profiles indicated about 430 feet of low velocity material — probably recent sediments; 4,000 feet of Mesozoic sediments, and 3,000 feet of Permo-Pennsylvanian. He concluded that "the total thickness of sediments places the crystalline "basement" suggested here as being represented by the 20,400 ft/sec. velocity, at a depth of approximately 7,000 feet sub-sea." Weber and Sobczak (1963, p. 184) came to similar conclusions on the basis of gravity measurements stating "the observations, when correlated with available seismic, magnetic, and geological information, indicate the depth to basement rock varies from about 6,800 feet near Isachsen to at least 42,000 feet near the axis of the Sverdrup Basin." The structural high on Isachsen Peninsula is reflected by the occurrence of some of the older rocks on the island.

Large broad open folds with their associated diapiric structures are the dominant features within the island. The diapirs commonly occur along the crests of the major anticlines. Large thrust faults are unknown but a series of small normal faults occur in the northern regions and also around the piercement domes.

FAULTS

The greatest concentration of faults occurs in the region of the igneous intrusions. The main system of faults has a northeast-southwest trend with a secondary set forming an angle of 60 degrees with the first. These faults appear to have had a small vertical movement, producing linear scarps within the sheets of igneous rocks. The linear nature of most of the faults suggests that they are high angle or vertical faults. This pattern of faults breaks Reindeer Peninsula into a series of blocks where the pattern results generally in the south and east sides being dropped downward. The largest throw on the faults is in the order of a few hundred feet. The belt of northeasterly trending faults continues southward across Noice Peninsula where the second set is not well developed. With the exception of one or two faint lineaments, there is no indication that the faults cut the Beaufort Formation and they are assumed to predate that formation.

The cores of all the piercement structures are assumed to be in fault contact with the encircling, upwarped Isachsen Formation. These faults have an arcuate to circular trace. Faults within the diapirs are not conspicuous but probably do exist. One prominent fault does extend across Christopher and Isachsen strata into the anhydrite core at Fitzpatrick Hill on Dumbbells Dome, disappearing into a stream valley. Tangential faults occur on Contour Dome and along the core of Hoodoo Dome. Radial faults extend outward from the main culmination of Meteorologist Anticline and numerous smaller faults of a similar nature occur on its flanks.

A small circular mound, 3 miles west of Crab Claw Hills and lying at the southern end of a fault, apparently represents a spring deposit. The rock is light grey, occurs in small blocks, plates, and concretionary-like masses on the surface of the mound. Amorphous silica, the main constituent, forms a dense matrix which encloses subangular to subrounded fragments of similar rock and some quartz grains. Irregular patches of carbonate occur as a minor constituent. No flow of water was evident at the time the deposit was examined.

FOLDS

Folds have a northerly to northwesterly trend and gently dipping limbs. In general, the folds plunge southerly toward the axis of the Sverdrup Basin.

The Noice Syncline is not well defined in the southern part of the peninsula, where it is broken by several northeasterly trending normal faults and associated small folds. It appears to extend southeasterly across Thor Island.

The Dome Bay anticline extends from the northeast corner of Noice Peninsula to Kristoffer Bay. It is terminated at the north by a series of small faults and to the south, it plunges into the sea. The axis might possibly swing southeasterly to Malloch Dome as other major folds are known to have sinuous trends.

The Christopher Syncline, the longest on the island, trends southeasterly from near Louise Bay to west of Jackson Bay. It is cut by faults in its northern part and a small anticline lies athwart its northwestern flank near Isachsen Dome. It may be linked with another synclinal axis that lies <u>en echelon</u> to the southwest, extending toward Jackson Bay. The axis of Christopher Syncline forms one of the structurally lowest areas on the island, equivalent depressions being developed only on the eastern side of Meteorologist Peninsula and near Cape Cairo where upper beds of the Eureka Sound Formation outcrop.

Meteorologist Anticline trends northwesterly from the southern end of the island to Divergent River. The anticline is disrupted at Hoodoo River by doming, the development of cross-folds, and a series of faults. A series of radial faults occurs around the main culmination, some extending outward from the main domal area and others being developed only on the flanks.

Dumbbells Anticline has a sinuous axial trace, trending almost east-west across the island in the vicinity of Contour dome and then swinging almost due north on Christopher Peninsula. It culminates in the two largest piercement structures on the island, Dumbbells and Contour Domes.

Haakon Syncline is asymmetrical with steeper dips along the east flank near Dumbbells Dome. Its axial trace more or less parallels that of Dumbbells Anticline to the east and Louise Anticline to the west. Beds flatten rapidly from the Isachsen and Dumbbells Domes toward the axis lying within the Hassel Formation. Very low dips occur in the Isachsen and Christopher strata along the northern extension of the syncline.

Helicopter Anticline is a symmetrical structure extending in an easterly direction from Helicopter Bay to Dumbbells River. It is broken on the northeastern flank by a fault which brings Isachsen strata into contact with Christopher shales.

Two shallow basins lie adjacent to Dumbbells Dome. One, lying between the diapirs and Helicopter Anticline, is floored mainly by the Christopher Formation but in its deepest part at the headwaters of Contour River, a small area is underlain by Hassel sandstones. The second area lies south of Contour River between Dumbbells and Helicopter Domes. There, the surface bedrock is the Hassel Formation. Dips around the scarp are in the order of 15 to 20 degrees on the west side, flattening eastward into the centre and then steepening to as much as 56 degrees near Helicopter Dome.

The axis of Trio Syncline, lying to the west of Haakon Dome, probably plunges southeastward across Haakon Fiord toward Cape Cairo, disappearing into Peary Channel. Beds along the coast south of Cape Cairo may lie on the west flank of an extension of the Haakon Syncline.

DOMES

Isachsen Dome

This dome has been examined in considerable detail by Heywood (1957, p. 24). He noted that the intrusion of the gypsum and anhydrite core was surrounded by steeply dipping strata but that the effects of the doming were not apparent at a distance of 1 to 3 miles. Tangential faults were inferred to occur between the core and the Isachsen sandstone. Radial faults were found to extend several thousand feet into the surrounding strata but no faults were found within the central part of the dome. According to Heywood, folding within the core "varies from broad gentle folds in the central area to tight, intricate folds near the outer contact of the core. These folds are diversely oriented; a change of strike of nearly 90 degrees occurs across a narrow canyon."

Heywood described inclusions of diabase, basalt, and gabbro in the Isachsen Dome, noting some parallellism of a longer tabular inclusion to the periphery of the core. He suggested that some inclusions may have been part of a more or less continuous sheet of basalt.

Hoodoo Dome

This dome, originally called Meteorologist Peninsula dome by McLaren (1963, p. 552) has only a small core of anhydrite and secondary gypsum but is part of a much larger structure lying along Meteorologist Anticline. A very large negative gravity anomaly is centred over the anticline according to Sobczak (1963). The main part of the dome is an east-west structure lying athwart the axis of the major Meteorologist Anticline. Several faults occur in the central part of the dome, the major ones being in part parallelled by Hoodoo River. Two faults, tangential to the diapir, extend southwesterly across the Isachsen, Christopher, and Hassel Formations. No intrusive rocks were noted.

Two small bodies of gypsum occur outside the main dome, lying within Christopher strata on the eastern flank of Meteorologist Anticline. The more northerly one has been intruded along bedding planes, appearing to be almost a true bedded deposit within the shales. Part of the gypsum shows fine lamination but part is intensively brecciated and fragmented. The other body is a small conical mass comprising gypsum stained with iron oxides, limestone, sandstone, some slightly baked shale, and diabase. The dyke rock and the small intrusion within the Hassel Formation on the west flank are the only known igneous rocks occurring within Meteorologist Anticline.

Malloch Dome

Malloch Dome, first described by Greiner (1963, p. 570) forms a small peninsula on the western side of the island. The anhydrite core is bounded by the sea except on the north where Isachsen beds are in fault contact. As Greiner indicated, it is difficult to determine if this dome is related to a larger regional structure. Its position east of Christopher Syncline and in line with a possible extension of the Dome Bay Anticline, suggests that such a regional relationship may exist.

The diapir truncates Isachsen beds which dip steeply northward. The dip of overlying beds decreases within a short distance of the core, assuming the gentle inclination of the region. A high ridge of banded gypsum forms the northern boundary of the core. Beds within the main anhydrite core appear to be very contorted and fold patterns would only be determined by more detailed investigations. A small dyke of diabase intrudes the diapir.

Dumbbells Dome

Dumbbells Dome is the largest piercement structure found on the island. Its northwestern margin was mapped by Blackadar (1963, p. 558) but no other ground observations have been published. The dome occurs along the crest of the major Dumbbells Anticline.

The evaporite core is encircled by the Isachsen Formation which dips steeply (as much as 80 degrees or more) away from the anticlinal axis. Dips of overlying beds flatten rapidly toward the troughs of bordering synclines. Within the core, the gypsum and anhydrite are extremely contorted and isolated exposures give an impression of complete chaos.

Many small masses of diabase are scattered through the core, some appearing to have been part of a larger continuous sheet.

A tangential fault along the eastern end of the core cuts at a slight angle across Isachsen strata which have apparently been thrust upward through Christopher shales.

Contour Dome

The southeastern piercement structure that was formerly included as part of Dumbbells Dome is cut by Contour River which provides the name for this dome. The structure is asymmetric, forming one of the culminations on Dumbbells Anticline. Beds on the periphery dip less steeply than those around the neighboring Dumbbells Dome, most dips being in the order of 50 degrees or less. A tangential fault on the east end extends northward into Christopher strata and is parallelled by a similar fault extending outward from the core.

Several large bodies of igneous rock occur in the northern part of the dome. Limestone blocks are also present within the contorted evaporitic sediments that form the main core.

Haakon Dome

Haakon Dome includes an elongate peninsula as well as Trio Island located on the east side of Christopher Peninsula and northernmost tip of Haakon Fiord. The exposures above sea-level have a combined length of about five miles but the width is less than 1 mile. On Trio Island, gypsum is bounded by the Isachsen Formation. South of Gypsum Point, the main mass of the exposed core comprises Paleozoic limestone and intrusions of basalt and diabase. A narrow elongate core of anhydrite and gypsum is present on the west side, lying in fault contact with Isachsen sandstone.

The extent of this diapir is unknown. It may be related to a large negative gravity anomaly centred off Cape Cairo which Sobczak (1963) attributed to the probable presence of gypsum.

Helicopter Dome

The exposed parts of this diapir form two curved bodies lying immediately southeast of Helicopter Bay. The radius of curvature of these outcrops suggests that a much larger part of the core lies beneath Hassel Sound but the structure might also be elliptical, similar to Haakon Dome. A pronounced gravity anomaly occurs in this region (Sobczak, 1963). Isachsen strata are steeply upwarped along the western edge of the diapir, being truncated by the intruded gypsum and anhydrite.

Considerable variation in the gypsum was noted in this dome. Bedded, laminated grey to white gypsum is most abundant but pink to reddish varieties are also present. A dyke of greenish weathering diabase appears to dip westward. There is no indication of bedding within the sediments and most of the core is chaotic. Dark grey, aphanitic limestone forms steep cliffs at the north end of the dome, just south of Helicopter Bay.

Evidence of growth

Earlier workers (Fortier et al., 1963; Thorsteinsson and Tozer, 1961) have suggested that the intrusion of evaporite masses in the Sverdrup basin is related to the Tertiary orogeny which is well documented on Ellesmere and Axel Heiberg Islands. On the other hand, Gould and de Mille (1964), who accepted that compressional stresses were responsible for development of piercement structures in eastern regions, believed that the western structures differed in their origin. The motivating force producing the domes in the western Sverdrup basin was attributed by Gould and de Mille (1964, p. 746) to a combination of halokinesis and geostatic loading. They suggested that late Paleozoic salt with associated anhydrite and limestone began to rise at least during Early Cretaceous time. They further postulated that the doming resulted in an early period of erosion, as evidenced by limestone conglomerates, followed by the eventual penetration of Upper Cretaceous and Tertiary rocks. Schwerdtner and Clark (1967) suggested that differences in plasticity rather than differences in specific gravity between source beds and overburden could result in the rise of the diapirs, indicating that a thick salt unit would not necessarily have to be present. They showed that layered anhydrite behaved essentially as a source material for two domes on Axel Heiberg Island and postulated that large radial fractures developed during late and brittle phases of deformation.

Stratigraphic evidence supports the theory that the diapirs may have been rising during early Mesozoic time and certainly during Cretaceous. It is possible that movements have occurred continually since then. There is some evidence that Mesozoic rocks lie unconformably on Paleozoic strata within the diapirs (Blackadar, 1963, p. 561; Gould and de Mille, 1964, p. 728). The lack of Triassic beds and also the Jurassic Borden Island, Savik, and Jaeger strata above Paleozoic beds at the west end of Contour Dome and their presence in neighboring regions further indicates local high areas within the basin of deposition. The Deer Bay shales are very thin at Contour Dome and there is also some indication that the Isachsen Formation and units within it thin in the vicinity of the culminations of Dumbbells and Contour Domes, providing further evidence of growth in Late Jurassic and Early Cretaceous time. Variations in the thickness of the Christopher Formation have been observed on the island and marked decreases in the thickness of Hassel Formation in the vicinity of Hoodoo Dome has been documented, indicating that the domal areas remained high at least until the beginning of Late Cretaceous time. This stratigraphic evidence indicates that isostatic loading is largely responsible for the diapirs.

Some doubts have been expressed that geostatic loading alone could cause the rise of diapirs composed mainly of gypsum and anhydrite whose specific gravities do not favour such movements. However, as Gould and de Mille (1964) point out, if salt were present, the 40,000 feet of sediments in the Sverdrup basin would probably be more than sufficient to cause the autonomous, isostatic rise of salt columns and associated evaporites. The occurrence of 3,000 feet of salt of Ordovician age in the Dominion Explorers et al. Bathurst Caledonian J-34 well (Workum, 1965, p. 182) indicates that salt deposits are present in the region and are likely to be more widely distributed than earlier workers anticipated. Moreover, as previously noted, Schwerdtner and Clark (1967) indicate that salt need not be present, that the occurrence of anhydrite alone could result in diapiric intrusions.

The role of the Tertiary orogeny in the development of the diapirs of Ellef Ringnes Island is difficult to assess. On the one hand, the diapirs evidently have had a long history of growth prior to Tertiary movements. On the other hand, the general trends of the folds on Ellef Ringnes Island are similar to those of the Tertiary folds and faults of Axel Heiberg and Ellesmere Islands. However, the trends on Ellef Ringnes Island were probably well established by Early Cretaceous time and those of the more easterly islands may also be related to older structures (see Trettin, 1968, p. 697). It seems most likely that the diapirs developed as a result of geostatic loading above evaporitic beds. The Tertiary orogeny in more easterly regions may have produced compressional forces which enhanced the movement of the evaporites. However, it appears that the Tertiary orogeny was at most a secondary influence rather than the primary cause of the development of diapirs on Ellef Ringnes Island.

ECONOMIC GEOLOGY

COAL

No detailed investigations were made of the coal occurrences on Ellef Ringnes Island. However, several coal seams were observed and it is possible that substantial reserves are present.

Seams, a few inches to 3 feet thick, occur in the Isachsen and Hassel Formations. Several of the Isachsen seams appear to extend for a considerable distance in the region between Louise Fiord and Noice Peninsula where the coal is well exposed in the cuestas. Coal occurs in the Hassel Formation near Haakon River and one of the better seams was observed on the escarpment south of Contour Dome. Thin layers of coaly material and lignite were observed in the Eureka Sound Formation. Six seams, ranging from a few inches to 2 feet thick, occur south of Cape Cairo.

PETROLEUM AND NATURAL GAS

The petroleum potential of the Sverdrup basin was reviewed by Douglas et al. (1963) who outlined the major prospective strata. The potential of Ellef Ringnes Island for producing petroleum or natural gas lies in structural traps and stratigraphic reservoirs related to the development of the piercement structures. Because most of the Mesozoic rocks described in this report occur at the surface, it is improbable that they contain any reserves. Nevertheless, the present structure is very favourable to the entrapment of hydrocarbons. If suitable reservoir rock is present at depth, prospects of future discoveries are excellent.

If, as presently believed, the domes have been rising from at least the beginning of the Mesozoic, several unconformities and wedges of coarse clastic sediments can be anticipated in the vicinity of the domes. Furthermore, the inclined strata and thick successions of impermeable shale also favour entrapment of hydrocarbons.

Although no continuous succession of Paleozoic rocks is known in the region, the isolated inclusions of the diapirs give some indication of the type of rock that may occur at depth. Bituminous limestones occur within Dumbbells Dome and porous, fragmental limestones are present within Haakon Dome. In addition, the sandstone of the Borden Island Formation is clean and porous and would form an excellent reservoir rock. Bituminous residue was found in basal Isachsen sandstone on Reindeer Peninsula.

The structurally highest region, with the exception of the domes, lies at the north end of Reindeer Peninsula where Lower Jurassic rocks are brought to the surface. The total thickness of those sandstones is unknown and Triassic beds might also be present at depth. It appears that the top of the Paleozoic beds may be relatively close to the surface in that region. Paleozoic beds may also be fairly close to the surface in Meteorologist Anticline but could be severely deformed by diapiric movements.

METALLIC AND INDUSTRIAL MINERALS

Large quantities of gypsum are available from the exposed cores of all the domes. These vary in area, the largest being over 30 square miles with up to 500 feet of relief. The gypsum is partly massive, partly banded, and is mixed with anhydrite. It includes blocks of limestone and diabase. No thorough study has been undertaken.

Occurrences of hematite and magnetite were found on Contour Dome but these are small and related to the basic intrusions. Blackadar (1963, p. 561) reported chalcopyrite, malachite, and magnetite on the northwestern flank of Dumbbells Dome.

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