In presenting this thesis in partial fulfilment of the requirements for an advanced degree at the University of British Columbia, I agree that the Library shall make it freely available for reference and study. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by the head of my department or by his or her representatives. It is understood that copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Department of Geological Sciences

The University of British Columbia
1956 Main Mall
Vancouver, Canada
V6T 1Y3

Date April 29, 1985
ABSTRACT

The Eureka Sound Formation in the eastern Canadian Arctic Archipelago is an Upper Cretaceous to Paleogene pre- and syn-tectonic deposit that records the uplift and segmentation of the Early Carboniferous to Tertiary Sverdrup Basin.

Scattered outliers of the Eureka Sound Formation on southern Ellesmere Island rest unconformably on or are faulted against Devonian strata. In the vicinity of Vendom, Stenkul, Baumann and Sor Fiords, the Eureka Sound Formation attains a maximum thickness of 480 m and comprises a sequence of nonmarine and brackish water deposits that ranges in age from mid-Paleocene to Late Eocene.

Eureka Sound strata which crop out along the shores of Stenkul Fiord are divided into four lithofacies assemblages. The stratigraphic section is composed mainly of two nonmarine assemblages which alternate throughout the sequence. Lithofacies Assemblage I consists of fining-upward sandstones which attain thicknesses of 20 m and are interpreted as fluvial deposits. Lithofacies Assemblage II comprises interbedded mudstones and coal in seams up to 8 m thick, and are interpreted as floodbasin deposits of an alluvial plain.

Two marine lithofacies assemblages (III, IV) are recognized locally and constitute a minor part of the stratigraphic succession. Lithofacies Assemblage III comprises the basal strata in the study area and consists of approximately 90 m of buff-weathering mudstones and interbedded thin coals which were deposit-
ed in brackish lagoonal, estuarine and salt marsh environments. Lithofacies Assemblage IV occurs locally in the middle of the stratigraphic section and consists of up to 10 m of white, well sorted quartz arenites and minor mudstones, which are interpreted as deposits of a barrier island system.

To the northeast of Stenkul Fiord at Makinson Inlet, outliers of the Eureka Sound Formation rest unconformably on Paleozoic strata, and are in turn overlain with angular unconformity by as much as 120 m of Early Miocene fanglomerates of the Beaufort Formation. The ages of these sediments, in conjunction with ages reported from the Eureka Sound and Beaufort Formations in other parts of Ellesmere and Axel Heiberg Islands, bracket the timing of the orogenic phase of the Eurekan orogeny in the eastern Arctic as Late Eocene to Miocene.
# Table of Contents

ABSTRACT .................................................................................. ii

LIST OF TABLES ........................................................................ vii

LIST OF FIGURES ....................................................................... viii

ACKNOWLEDGEMENTS ............................................................... xii

INTRODUCTION ......................................................................... 1

GENERAL STATEMENT ............................................................... 1

STUDY AREAS .......................................................................... 3

Location ................................................................................... 3

Access ..................................................................................... 5

PHYSIOGRAPHY ........................................................................ 5

PREVIOUS WORK ....................................................................... 6

PART I: STENKUL FIORD AREA .................................................. 8

ABSTRACT ................................................................................. 8

INTRODUCTION ......................................................................... 10

REGIONAL SETTING ................................................................... 12

METHODS .................................................................................. 16

Field Work ............................................................................... 16

Analytical Work ....................................................................... 17

STRATIGRAPHY AND STRUCTURE ........................................... 20

STENKUL FIORD ......................................................................... 21

LITHOFACIES ASSEMBLAGE I .................................................. 27

 Interpretation ........................................................................... 31

LITHOFACIES ASSEMBLAGE II ................................................ 35

 Interpretation ........................................................................... 37

LITHOFACIES ASSEMBLAGE III .............................................. 39
Interpretation ............................................. 40
LITHOFACIES ASSEMBLAGE IV ................................. 41
Interpretation ............................................. 42
VENDOM FIORD ............................................ 43
Interpretation ............................................. 49
BAUMANN FIORD ........................................... 50
Interpretation ............................................. 54
SOR FIORD .................................................. 56
Interpretation ............................................. 60
PETROGRAPHY, PALEOCURRENTS AND PROVENANCE .............. 63
SANDSTONE PETROGRAPHY ................................... 63
Quartz ...................................................... 69
Chert ...................................................... 72
Feldspar .................................................... 73
Sedimentary Rock Fragments .................................. 76
Igneous Rock Fragments ..................................... 76
Metamorphic Rock Fragments ................................. 76
Mica ........................................................ 77
Granule And Pebble Composition ............................. 77
HEAVY MINERALS ........................................ 77
PALEOCURRENT ANALYSIS .................................. 81
PROVENANCE ............................................. 82
DIAGENESIS AND VITRINITE REFLECTANCE .................... 89
FOSSIL CONTENT AND AGE .................................. 92
PALYNOLOGY ............................................... 92
PALEONTOLOGY ............................................. 94
PALEOCLIMATE ............................................. 100
DEPOSITIONAL HISTORY AND PALEOGEOGRAPHY ............... 103
LIST OF TABLES

TABLE I. Petrographic data, including grain size, rounding sorting, modal analyses and heavy mineral compositions of representative sandstones from the Eureka Sound Formation.

pp. 65-67

TABLE II. Paleocurrent data.

p. 83

TABLE III. Vitrinite reflectance results.

p. 91
LIST OF FIGURES

FIGURE 1. Index map to the Queen Elizabeth Islands showing Late Phanerozoic tectonic and structural elements and locations of the study areas. p. 2

FIGURE 2. Outliers of Tertiary Eureka Sound sediments on southern Ellesmere Island showing locations of the study areas. p. 4

FIGURE 3. Geologic map showing the locations of the Vendom, Stenkul, Baumann and Sor Fiord outliers of the Eureka Sound Formation in the study area. p. 13

FIGURE 4. Stratigraphy of the Eureka Sound Formation in the Stenkul Fiord outlier. p. 22

FIGURE 5. Stratigraphic correlation diagram I (in pocket)

FIGURE 6. Stratigraphic correlation diagram II (in pocket)

FIGURE 7. Stratigraphic correlation diagram III (in pocket)

FIGURE 8. Eureka Sound strata in the Stenkul Fiord outlier. p. 25

FIGURE 9. Sedimentary structures, Lithofacies Assemblage I, Stenkul Fiord outlier. p. 29

FIGURE 10. Sedimentary structures, plant fossils and strati-
graphy, Stenkul Fiord outlier.

FIGURE 11. Eureka Sound strata in the Vendom Fiord outlier.

FIGURE 12. Stratigraphic section 26, Vendom Fiord outlier.


FIGURE 14. Eureka Sound strata in the Baumann Fiord outlier.

FIGURE 15. Stratigraphic section 22, Baumann Fiord outlier (in Special Collections pocket).

FIGURE 16. Eureka Sound strata in the Sor Fiord outlier.

FIGURE 17. Stratigraphic section 24, Sor Fiord outlier.


FIGURE 19. Thin section photomicrographs of sandstones, Eureka Sound Formation.

FIGURE 20. Thin section photomicrographs of sandstones, Eureka Sound Formation.

FIGURE 21. Thin section photomicrographs of heavy minerals, Eureka Sound Formation.
FIGURE 22. Fossil remains, Eureka Sound Formation. p. 95

FIGURE 23. Fossil remains, Eureka Sound Formation. p. 98

FIGURE 24. Schematic paleogeographic maps. p. 104

FIGURE 25. General geologic map of the study area. p. 131

FIGURE 26. Angular unconformity north of Makinson Inlet. p. 133

FIGURE 27. Stratigraphic section 16 through lowermost Eureka Sound strata exposed north of Makinson Inlet. p. 135

FIGURE 28. Stratigraphy and sedimentary structures of the Eureka Sound and Beaufort Formations north of Makinson Inlet. p. 136

FIGURE 29. Stratigraphic section 17 across the unconformity between the Eureka Sound and Beaufort Formations north of Makinson Inlet. p. 139

FIGURE 30. Depositional model of the Beaufort Formation north of Makinson Inlet. p. 142

FIGURE 31. Dinoflagellate cysts of the Beaufort Formation (a to f) and spores and pollen grains of the Eureka Sound Formation (g to n) north of Makinson Inlet. p. 144

FIGURE 32. Coalification gradient at Strathcona Fiord (Bustin,
in prep.), and vitrinite reflectance values for coal samples above and below the unconformity.

p. 149
ACKNOWLEDGEMENTS

I am especially grateful to my thesis supervisor Dr. R. Marc Bustin for direction, advice, encouragement and unending patience throughout this study. I would also like to thank Dr. Glenn Rouse for providing the palynological work and plant fossil identification, and for guidance and advice on many aspects of the thesis. I am grateful to Drs. W.C. Barnes and W.H. Mathews for critically reviewing the manuscript and offering many helpful suggestions.

I wish to thank Dr. Loris Russell of the Royal Ontario Museum for identification of fossil samples, and also Ms. L. L. Mathews for many helpful discussions of vertebrate paleontology. Capable assistance in the field was provided by Richard Vincent, Lawrence Fabbro and Eric Panchy, whose enthusiasm and good humour were much appreciated.

Many thanks go to the technical staff at U.B.C., especially to Ed Montgomery for his excellent photographic work and assistance with many of the logistical details encountered during the course of this study. Thanks also to Bryon Cranston for preparation of sandstone and coal samples and Melanie Sullivan and Gord Hodge for help with the drafting.

Petro-Canada provided logistic support during the field work for which I am very grateful. Additional support for the research was provided by a postgraduate scholarship from N.S.E.R.C. and an N.S.E.R.C. Grant, A7337, to Dr. R.M. Bustin.
INTRODUCTION

GENERAL STATEMENT

The Eureka Sound and Beaufort Formations document the latest Cretaceous and Tertiary depositional and tectonic history of the eastern Canadian Arctic Archipelago. Clastic sediments of the Eureka Sound Formation are widespread in the Arctic Islands, and were deposited mainly in pericratonic or intermontane basins formed during the Late Cretaceous to Early Tertiary Eurekan orogeny (Miall, 1979b; 1982). The Beaufort Formation postdates the major phase of Tertiary orogenesis and crops out at several localities in the Canadian Arctic Islands and along the Arctic coastal plain. Eureka Sound and Beaufort sediments comprise both nonmarine and marine strata (Miall, 1979a, 1979b, 1982; Miall et al., 1980; West et al., 1981; Bustin, 1977, 1982), and locally attain thicknesses on the order of 3 300 m.

The present study investigates two occurrences of Tertiary sediments which crop out on southern Ellesmere Island (Figure 1). The most areally extensive occurrence of Eureka Sound strata on southern Ellesmere Island lies in the vicinity of Stenkul Fiord, and is described in the first part of this thesis. At this locality, the principal objectives are to interpret the depositional environment and depositional history of these deposits based on stratigraphic, petrographic, heavy mineral, paleocurrent and vitrinite reflectance analyses and fossil content.
FIGURE 1. Index map to the Queen Elizabeth Islands showing Late Phanerozoic tectonic and structural elements and locations of the study areas (modified from Balkwill and Bustin, 1980).
The second occurrence of Tertiary strata studied on southern Ellesmere Island includes outcrops of Eureka Sound and Beaufort sediments which lies north of Makinson Inlet, adjacent to the Central Ellesmere Ice Cap. An angular unconformity between folded Eureka Sound strata and gently-dipping Beaufort strata is described (see also Riediger et al., 1984). The results of stratigraphic, palynologic, vitrinite reflectance and petrographic analyses provide information regarding the depositional history and provenance of these sediments, as well as providing additional evidence for the chronology of the main compressional phase of the Eurekan Orogeny and a later phase of relative uplift of at least part of eastern Ellesmere Island.

STUDY AREAS

Location

Outliers of the Eureka Sound and Beaufort Formations occur at several localities on southern Ellesmere Island (Figure 2). Most outcrops are poorly exposed, precluding detailed systematic description. Tertiary strata which crop out along the shores of Stenkul Fiord and north of Makinson Inlet, however, are well exposed, and were thus selected for this study. The only known occurrence of Beaufort strata on southern Ellesmere Island lies north of Makinson Inlet and is described in this report.
FIGURE 2. Outliers of Tertiary Eureka Sound sediments (stippled pattern) on southern Ellesmere Island showing locations of the study areas.
Access

This study is based on field work performed in the summer months of 1983. The base camp was situated south of Okse Bay on the west coast of southern Ellesmere Island, and a fly camp was established north of Makinson Inlet. Transportation from Resolute Bay to the base camp was by de Havilland Twin Otter aircraft. Access to the study area was by Aerospatiale A-Star helicopter.

PHYSIOGRAPHY

The study areas (Figure 2) lie within the "Southern Plateau" physiographic division of Roots (in Fortier et al., 1963, pp. 266-271), and represents a total area of approximately 150 square kilometres.

In the area south and east of Vendom Fiord, the topography is subdued. The stream valleys cutting through the plateau are short, and commonly have a braided floodplain (Roots, in Fortier, et al., 1963, p. 269). Areas of tundra polygons or "patterned ground" occur locally in low-lying regions. Evidence of solifluction, slumping and recent mud flows is common on the moderately sloping hillsides.

North of Makinson Inlet, Eureka Sound and Beaufort strata lie between the Central Ellesmere Ice Cap on the east and the mountainous areas of the "Central Mountain Belt" (physiographic division) on the west. The topography is very rugged with steep cliffs rising vertically from sea level to sharp, jagged peaks.
Streams fed by glacial runoff have deeply incised the strata, producing narrow, precipitous stream valleys. Slumping of the valley walls frequently occurs, resulting in excellent outcrop exposure.

PREVIOUS WORK

The Eureka Sound Group was initially defined by Troelsen (1950, p. 78) for nonmarine, coal-bearing sediments on central Ellesmere Island, which he considered to be of Cenozoic age. It was redefined as a formation by Tozer (in Fortier et al., 1963, p. 92) who regarded outcrops of the Eureka Sound Formation on Fosheim Peninsula, adjacent to Eureka Sound, as typical (Tozer, in Fortier et al., 1963, p. 93). The type section was designated by Souther (in Fortier et al., 1963, p. 444) as approximately 2.5 km of intercalated sandstone, siltstone, shale, mudstone and coal on western Axel Heiberg Island. It is now known that the formation ranges from Late Cretaceous to Late Eocene (Jutard and Plauchut, 1973; Doerenkamp et al., 1976; Bustin, 1977; Rouse, 1977; this study) and although predominantly nonmarine in origin, it does contain interbedded marine units (West et al., 1975; Miall, 1981).

The Beaufort Formation was named by Tozer (1956) for post-tectonic gravels and sands cropping out on Prince Patrick Island. Tozer and Thorsteinsson (1964) later expanded the use of "Beaufort Formation" to include Upper Tertiary or Pleistocene coarse-grained clastic sediments of the Arctic coastal plain. A Miocene- (?) early Pliocene age has been reported in studies on Banks Island by Hills and Fyles (1973) and Hills and others
(1974), and on Axel Heiberg Island by Hills and Bustin (1976) and Bustin (1982). An Early Miocene age is reported for Beaufort strata which occur north of Makinson Inlet (Riediger et al., 1984; this study).

Tertiary strata on southern Ellesmere Island at Stenkul Fiord were first described by Nathorst (1915) while a member of the Fram expedition. McGill (1974) described outcrops of the Eureka Sound Formation along the shores of Stenkul and Vendom Fiords. Miall (1981, 1984) noted the occurrence of outliers of the Eureka Sound Formation in the vicinity of Stenkul and Sor Fiords, which are included as part of the Remus Basin (Bustin, 1977). Norris (in Fortier et al., 1963, pp. 338-339) and Okulitch (1982) reported an outcrop of the Eureka Sound Formation along the Meadow River east of Vendom Fiord. Okulitch (1982) also noted Eureka Sound sediments to the east of Troll Bay and south of Sor Fiord.

Although the occurrence of Eureka Sound strata on southern Ellesmere Island has been known for some time, these deposits have received no previous systematic study. Strata of Early Miocene age, herein assigned to the Beaufort Formation, that occur north of Makinson Inlet were reported by Riediger and others (1984) and are further described in this study.
PART I: STENKUL FIORD AREA

ABSTRACT

The Late Cretaceous to Paleogene Eureka Sound Formation in the Eastern Canadian Arctic Archipelago is a pre- and syn-tectonic deposit that records the uplift and segmentation of the Early Carboniferous to Tertiary Sverdrup Basin. On southern Ellesmere Island, scattered outliers of the Eureka Sound Formation rest unconformably on or are faulted against Devonian strata. In the vicinity of Stenkul Fiord on southern Ellesmere Island, the Eureka Sound Formation ranges in age from mid-Paleocene to Late Eocene, has a maximum thickness of 480 metres and comprises a sequence of predominantly nonmarine sandstones, mudstones, coal and minor siltstones. Outliers of the Eureka Sound Formation occur along the shores of Vendom, Stenkul, Baumann and Sor Fiords. These strata are interpreted to include nonmarine alluvial plain and lacustrine and brackish water lagoonal, estuarine and barrier bar deposits.

Four major lithofacies assemblages are recognized based on their stratigraphic and sedimentological characteristics. Two brackish water lithofacies assemblages occur locally and constitute a minor portion of the stratigraphic succession. The first brackish water lithofacies assemblage is recognized at the base of the section and comprises a sequence of predominantly brown and grey mudstones, which weather a conspicuous buff to light cream colour, with interbedded thin coal seams. This lithofacies assemblage is interpreted as a brackish lagoonal or estuarine
deposit. The second brackish water lithofacies assemblage is less than 10 m thick and occurs locally in the middle of the stratigraphic section. White, well sorted quartzose sandstones are the dominant lithology, with minor mudstones. These are interpreted as deposits of a barrier island system.

Two nonmarine lithofacies assemblages are recognized and constitute the bulk of the stratigraphic succession: 1) a fining-upward sandstone lithofacies assemblage which has a sharp, erosional base and attains a thickness of up to 20 metres; and 2) a coal-mudstone lithofacies assemblage characterized by coal seams up to 8 metres thick and grey, commonly carbonaceous mudstones. The coal seams are laterally continuous without major splits for distances of greater than a kilometre. The nonmarine lithofacies assemblages alternate throughout the stratigraphic sequence and are respectively interpreted as fluvial and floodplain deposits of an alluvial plain environment.

Sandstone petrographic, heavy mineral and paleocurrent analyses indicate that the Eureka Sound sediments were mainly derived from Precambrian granulite grade metamorphic rocks of the Canadian Shield to the east and south of the study area.
INTRODUCTION

The Eureka Sound Formation is a widespread sedimentary deposit in the Canadian Arctic Islands, and comprises a sequence of interbedded mudstones, siltstones, sandstones and coal seams. The deposits are predominantly nonmarine, although locally some marine units occur. Eureka Sound strata have been interpreted as deposits of pericratonic or intermontane basins formed during the Late Cretaceous to Tertiary Eurekan Orogeny (Bustin, 1977; Miall, 1979b; 1981), and locally attain thicknesses of 3.3 km. This study of Eureka Sound strata on southern Ellesmere Island provides new information on the nature and extent of Tertiary sedimentation and tectonism in the eastern Canadian Arctic Archipelago.

The purpose of this paper is to document the distribution, stratigraphy, structure and age of the Eureka Sound Formation on southern Ellesmere Island and to outline the Paleogene history of the area.

The Eureka Sound Group was the initial name for interbedded nonmarine sandstones, siltstones, mudstones and coal of Late Cretaceous to Tertiary age given by Troelsen (1950, p. 78). The Eureka Sound was redefined as a formation by Tozer (in Fortier et al., 1963, p. 92), who regarded outcrops of the Eureka Sound Formation on Fosheim Peninsula as typical (Tozer in Fortier et al., 1963, p. 93). It was considered to be Late Cretaceous (Maastrichtian and possibly Campanian) to Middle Eocene in age by Thorsteinsson and Tozer (1970) and Bustin (1977), whereas
others (Jutard and Plauchut, 1973; Doerenkamp et al., 1976; Rouse, 1977) considered the Eureka Sound Formation to be entirely Tertiary.

Tertiary strata on southern Ellesmere Island have received no previous systematic study. Nathorst (1915) was first to describe Tertiary deposits around Stenkul Fiord. McGill (1974), Miall (1981, 1984) and Okulitch (1982) mention the occurrence of Eureka Sound strata on southern Ellesmere Island but provide no detailed description of the deposits.
REGIONAL SETTING

The regional geology of the Canadian Arctic Islands has been described by several authors (Thorsteinsson and Tozer, 1970; Trettin et al., 1972; Drummond, 1973; Trettin and Balkwill, 1979) and will only be briefly reviewed here.

The Eureka Sound Formation in the vicinity of Stenkul Fiord on southern Ellesmere Island rests unconformably on Devonian strata of the Franklinian geosyncline (Balkwill and Bustin, 1980; Embry and Klovan, 1976; Figure 3).

The Franklinian geosyncline contains Upper Proterozoic to Upper Devonian carbonate and clastic sediments, which were deposited on granite and granulite grade gneisses of the Churchill Province of the Canadian Shield (Frisch et al., 1978). The Ellesmerian orogeny terminated Franklinian geosyncline deposition in Middle Devonian to Early Carboniferous time (Balkwill, 1978).

The Sverdrup Basin was superposed with angular unconformity on folded, faulted and eroded Franklinian strata (Balkwill, 1978; Trettin and Balkwill, 1979), and is characterized by carbonate, clastic and evaporite strata with minor igneous intrusions and basalt flows (Balkwill, 1978). The stratigraphic sequence is up to 13 km thick and is essentially concordant at the depocenter on western Axel Heiberg and Amund Ringnes Islands, whereas unconformities are present along the margins of the basin (Balkwill, 1978). Sedimentation occurred within the Sverdrup Basin without any major, basin-wide tectonic interrup-
FIGURE 3. Geologic map showing the locations of the Vendom, Stenkul, Baumann and Sor Fiord outliers of the Eureka Sound Formation in the study area (geology modified from Kerr and Thorsteinsson, 1971 and McGill, 1974).
tion from Early Carboniferous to Late Cretaceous time.

Subsidence and deposition within the Sverdrup Basin was interrupted during Maastrichtian time by the latest Cretaceous to Tertiary Eurekan orogeny (Thorsteinsson and Tozer, 1970). The Eurekan orogeny can be divided into three phases of tectonism in the Arctic Archipelago (Balkwill et al., 1975; Balkwill, 1978; Trettin and Balkwill, 1979). The first phase of the Eurekan orogeny was initiated in the Late Cretaceous (Maastrichtian) with the uplift and erosion of the northern rim of the Sverdrup Basin and the Cornwall and Princess Margaret Arches (Balkwill, 1978). By Paleocene to Early Eocene time (Miall, 1981), the Sverdrup Basin had been segmented into at least seven sub-basins, each with different local source terrains and facies. Sequences of mainly nonmarine clastic sediments up to 3.3 km thick accumulated within the basins which have been collectively assigned to the Eureka Sound Formation (Miall, 1981).

The second, orogenic phase of the Eurekan orogeny resulted in upright to overturned folds and reverse faults in Late Eocene and older strata in the eastern part of the Queen Elizabeth Islands (Balkwill, 1978; Trettin and Balkwill, 1979; this study). The folds and faults on southern Ellesmere Island generally face to the southeast towards a salient of Precambrian basement, although in the vicinity of Stenkul Fiord, folds in Tertiary strata trend north-northwest and are detached from the underlying Devonian strata (Okulitch, 1982). The western coast of Axel Heiberg Island has been considered the western limit of compression during phase two (Late Eocene to Early Miocene) of
the Eurekan orogeny (Balkwill and Bustin, 1980).

The third and final phase of the Eurekan orogeny commenced in the Early Miocene with rejuvenated uplift and erosion of the northern rim of the Sverdrup Basin, the Princess Margaret Arch and at least part of eastern Ellesmere Island. Erosional outliers of coarse clastic sediments of Miocene- (?)Pliocene age on central Axel Heiberg Island (Bustin, 1982) and of Early Miocene age which occur on south-central Ellesmere Island (Riediger et al., 1984; this study) have been assigned to the Beaufort Formation. These deposits are post-phase two compression in the eastern Canadian Arctic Islands, and are indicative of at least local, late Tertiary relative uplift of both central Axel Heiberg and south-central Ellesmere Islands.
METHODS

Field work

Twenty-four stratigraphic sections were measured in the study area. The majority of the sections were measured along the shores of Stenkul Fiord where the best exposures occurred. In other areas, Eureka Sound strata are poorly exposed and consequently only two sections were measured in the Vendom Fiord outlier and one section was measured in each of the Baumann and Sor Fiord outliers (Figure 3).

Stratigraphic sections were measured in detail using a 1.5 metre Jacob's staff equipped with an inclinometer. Stratigraphic correlations were made in the field. Coal seams provided the most identifiable stratigraphic markers, and were easily traced laterally, permitting accurate correlation between stratigraphic sections.

The extent of the Eureka Sound Formation was mapped, and bedding attitudes and fault traces were measured to delineate the structural relationships within the map area.

Several sandstone outcrops contained excellent sedimentary structures. At these outcrops, the attitudes of planar tabular, ripple and trough crossbeds were measured to determine paleocurrent flow directions.

The various lithologic units in the Stenkul Fiord area were sampled for subsequent laboratory analysis. The sand units were,
for the most part, unconsolidated and were sampled using a small shovel. The mud beds were also poorly indurated and were sampled in the same manner. The coal seams were commonly the most resistant units in the study area. Unoxidized samples of coal for vitrinite reflectance were collected from just above the permafrost. Plant fragments, molluscs and trace fossils are commonly preserved in concretionary beds and lenses, and several samples were collected for identification. A fossil tooth was also collected from one locality.

Analytical Work

Grain size, sorting and roundness were determined for each sandstone sample using a binocular microscope. These parameters were estimated using the reference diagrams and photographs of Folk (1980, p. 23), Beard and Weyl (1973) and Powers (1953).

Modal analyses were completed for 29 sandstone samples. Of these, 4 were cemented and 25 were unconsolidated. The cemented sandstones were thin sectioned using conventional techniques. The majority of the unconsolidated sand samples were prepared for thin section analysis by mounting in Lakeside 70®, a cement with the same refractive index as Canada Balsam. The Lakeside 70® compound was first spread on a glass slide and placed on a hot plate to lower the viscosity. The unconsolidated sand was poured onto the heated cement and allowed to settle onto the glass slide. The slide was then removed from the hot plate to cool and harden. The prepared "sections" were then ground to the standard thin section thickness of 0.3 mm. For six of the sand
samples studied, the procedure outlined above did not provide satisfactory thin sections for petrographic analysis. The alternative technique used for these six samples involved mounting the sand grains in Transoptic Powder® (a transparent plastic) using a Buhler® pneumatic heat press. The solid sand and transparent plastic pellet was then cut as a standard thin section, with the plastic providing an artificial cement.

In order to distinguish alkali and plagioclase feldspar from quartz, all thin sections were stained following the procedures of Bailey and Stevens (1960) with the exception that amaranth red dye rather than potassium rhodizonate was used to stain the plagioclase feldspar. All thin sections were covered subsequent to staining.

A minimum of 300 points were counted for each thin section of sand, at a grid spacing of 0.3 mm. Counts were made of monocrystalline and polycrystalline quartz, plagioclase, potassium and perthitic feldspar, plutonic, sedimentary and metamorphic rock fragments and miscellaneous mineral grains which included biotite, muscovite, zircon and other heavy minerals.

Separation of the heavy mineral fraction of the sands was accomplished using bromoform which has a density of 2.89 g/cc. Identification of the heavy mineral fractions thus obtained was achieved by petrographic analysis. Thin sections were prepared using one of the techniques outlined above for the unconsolidated sand samples.

Mudstone samples were processed for palynomorphs using a
standard technique that includes HCl, HF, HNO₃, acetolysis, ZnBr₂ and sieving. Aliquots of palynomorph sediment were mounted on cover slips with Cellosize® and sealed with Flo-Texx® (Lerner Laboratories).

Thirteen coal samples were crushed and dry sieved using a 60 mesh (0.25 mm) US Standard sieve size. The minus 60 mesh fraction of the crushed coals was mixed with Transoptic Powder and made into pellets in a hydraulic press equipped with a heat coupler. The prepared pellets were then polished. A Leitz M.P.V. 2® reflected light microscope was employed to measure the mean maximum reflectivity of each coal sample in accordance with the procedures outlined by Bustin and others (1983).
Stratigraphy and Structure

Scattered outliers of the Eureka Sound Formation crop out along the shores of Vendom, Stenkul, Baumann and Sor Fiords on southern Ellesmere Island. The bulk of the information for this study of the Eureka Sound Formation on southern Ellesmere Island was obtained from the Stenkul Fiord outlier, where good, continuous outcrop is interrupted by only a few creek valleys and covered intervals. This area thus provides the best opportunity to observe and describe facies characteristics and changes. Because of poor outcrop, only one section could be measured in each of the outliers lying along Baumann and Sor Fiords, and two sections were measured in the outlier bordering Vendom Fiord. A continuous, 480 m thick stratigraphic section of the Eureka Sound Formation was measured in the Baumann Fiord outlier (section 22, Figure 15) but contains many covered intervals. The total composite thickness of Eureka Sound strata in the Stenkul Fiord outlier, which provides more continuous outcrop, is estimated to be on the order of 450 metres.

The Eureka Sound Formation in the study area comprises a predominantly nonmarine sequence of clastic sediments and coal, although brackish water deposits occur locally. The Eureka Sound Formation in the Stenkul Fiord outlier is divided into four distinct lithofacies assemblages, which were deposited in different sedimentary environments. In the Vendom, Baumann and Sor Fiord outliers, interpretations of depositional environments are suggested based on the overall stratigraphy.
Eureka Sound outliers on southern Ellesmere Island for the most part lie with angular unconformity on the Devonian Bird Fiord Formation or Okse Bay Group, but in some cases lie in fault contact with the Devonian Blue Fiord and Bird Fiord Formations and the Okse Bay Group (McGill, 1974; this study, Figure 3).

The stratigraphy and structure in each of the four outliers of the Eureka Sound Formation on southern Ellesmere Island are outlined below, together with an interpretation of the depositional environments.

**STENKUL FIORD**

The Eureka Sound Formation at Stenkul Fiord crops out over an area of about 20 square kilometres (Figure 3). The Eureka Sound Formation commonly lies in fault contact with Devonian rocks. Both normal and thrust faults between Eureka Sound and older rocks occur (McGill, 1974). Elsewhere, the Eureka Sound Formation lies with angular unconformity on the Devonian Okse Bay Group (Figure 3).

Eureka Sound strata at Stenkul Fiord are mainly flat-lying or gently dipping and the structure is characterized by open folds and minor thrust faults (Figure 3). However, very tight folds and thrust faults occur locally in the southwest corner of the study area. These structures affect a small area (less than 5 square kilometres), appear only in the upper part of the stratigraphic succession, and are detached from the underlying
FIGURE 4. Stratigraphy of the Eureka Sound Formation in the Stenkul Fiord outlier

A. Glacially deformed strata south of Stenkul Fiord.

B. Outcrops on the south shore of Stenkul Fiord, showing alternating sequence of Lithofacies Assemblage I (LF I) and Lithofacies Assemblage II (LF II).

C. Basal strata on the east shore of Stenkul Fiord, here assigned to Lithofacies Assemblage III.

D. Local occurrence of Lithofacies Assemblage IV, southwest of Stenkul Fiord.
strata (Figure 4A). Okulitch (1982) also observed these structures, but offered no explanation except that they must be compressional in origin. The most plausible interpretation is that these structures are a result of ice thrusting, and deformation of the bedding occurred as glaciers advanced over the area.

Twenty stratigraphic sections were measured and correlated at Stenkul Fiord (Figures 5, 6, and 7, in pocket). The oldest beds of the Eureka Sound Formation which crop out at Stenkul Fiord occur at the base of section 07 (Figure 5, in pocket, and Figure 8). The basal contact is not exposed, but the Eureka Sound beds are probably resting unconformably on the Devonian Okse Bay Formation, as is observed elsewhere. The overall dip of the strata is to the west-southwest, and the beds lying along the south shore of Stenkul Fiord thus constitute the uppermost part of the stratigraphic succession at Stenkul Fiord. A thin (less than 10 m), discontinuous veneer of Quaternary (?) boulder till caps the Eureka Sound Formation in the Stenkul Fiord area.

Two thick, nonmarine lithofacies assemblages are recognized in the Stenkul Fiord area, which alternate throughout the stratigraphic succession (Figure 4B); Lithofacies Assemblage I, characterized by very fine- to coarse-grained fining-upward sandstone units, and Lithofacies Assemblage II which consists predominantly of interbedded coal and dark grey to black mudstone.

Two brackish water lithofacies assemblages are recognized locally and represent marine transgressions into the study area. Lithofacies Assemblage III (Figure 4C), which occurs at the base of the stratigraphic succession, is a sequence of predominantly
FIGURE 8. Eureka Sound strata in the Stenkul Fiord outlier

Aerial photograph (A-16685-47), south of Stenkul Fiord showing the locations of the measured stratigraphic sections (eg. 4-21). Geology modified after McGill (1974).

Q - Quaternary gravels and alluvium
Te - Eureka Sound Formation
Dob - Okse Bay Group

This aerial photograph © 19-7-59 Her Majesty the Queen in Right of Canada, reproduced from the collection of the National Air Photo Library with permission of Energy, Mines and Resources Canada.
brown and grey mudstones, which weather a conspicuous buff to light cream colour, and interbedded thin coal seams. Lithofacies Assemblage IV crops out in the middle of the section (Figure 4D) and consists of thin, predominantly white, well-sorted quartz arenites which intertongue with minor, partly calcareous mudstones.

A marine incursion is recognized locally and is represented by a thin mudstone bed which contains a marine dinoflagellate cyst assemblage (G. Rouse, personal communication, 1984).

LITHOFACIES ASSEMBLAGE I

Sandstone is the primary lithology of lithofacies assemblage I and makes up more than 40 percent of the Eureka Sound Formation at Stenkul Fiord. The arkosic composition and geometry of the sandstones are characteristics which distinguish Lithofacies Assemblage I from other lithofacies assemblages. The sandstones occur as en echelon multi-storied sequences and contain several types of cross-bedding.

The sandstones are moderately to well sorted and vary in grain size from very fine to granule (Table I). They are predominantly grey to brown and weather light grey to buff. The sandstones range in thickness from 1 to 25 m, are commonly arranged in en echelon, multi-storied sequences and extend laterally for distances of 0.5 to 1 km (Figures 5, 6 and 7, in pocket).

The sandstones are subarkoses, lithic subarkoses, lithic
arkoses and arkoses using McBride's (1963) sandstone classification (Figure 18). For the most part, the sandstones are unconsolidated, although rare, thin (less than 10 cm) siderite cemented sandstone lenses occur. The mineral composition includes several quartz types (straight and undulose extinction, composite grains, stretched metamorphic grains and chert), plagioclase, potassium and perthitic feldspars, sedimentary, metamorphic and igneous rock fragments, muscovite and biotite. Carbonaceous plant debris and ironstone nodules and lenses occur within the sandstones.

The basal contact of the sandstones is commonly erosional (Figure 9A). Lag deposits of very coarse-grained sand containing pebbles and cobbles of quartzite, gneiss and granite and rare coal spar (Figure 9B) generally occur in the cut and fill structures (Figure 9C). These coarse basal deposits range from a few centimetres to 40 cm thick. Convolute lamination up to 1.5 m high (Figure 9D), planar tabular, planar tangential and trough cross-bedding and ripple cross-lamination are characteristic of the sandstones. Planar tabular and planar tangential cross-bed sets range from 5 to 30 cm thick (Figure 9E). Trough cross-beds vary from 5 to 15 cm in thickness (Figure 9F), and sets of ripple cross-lamination are from 1 to 5 cm thick (Figure 10A).

A typical vertical sequence of sedimentary structures within the sandstone units is shown on Figure 10B. Coarse basal lag and scour and fill deposits and associated medium-grained sandstones with planar cross-bed sets up to 70 cm thick and occur in the lower part of the outcrop. Fine- to very fine-
FIGURE 9. Sedimentary structures, Lithofacies Assemblage I, Stenkul Fiord outlier

A. Basal erosional contact of a sandstone bed with an underlying coal seam. The scale is 15 cm long.

B. Basal lag deposits containing pebbles, cobbles and coal spar. The scale is 15 cm long.

C. Cut and fill structures. The scale is 15 cm long.

D. Convolute laminations. The staff is 1.5 m high.

E. Planar tabular cross-bedding. The scale is 15 cm long.

F. Trough cross-bedding. The scale is 15 cm long.
grained ripple laminated sandstones in the upper part are capped by a thin, planar parallel laminated siltstone bed.

Siltstone and mudstone beds are locally interbedded with the sandstones. The thin-bedded, planar parallel laminated siltstones are medium brown to grey and weather a buff to light brown colour. The siltstones are commonly argillaceous and contain abundant comminuted plant debris. They range from less than 1 m to 5 m in thickness, and most commonly occur at the top of the sandstone lithofacies. Contacts between the siltstones and adjacent sediments are mainly gradational, except at a few localities where the siltstones have been eroded by an overlying sandstone unit. The mudstones are usually grey to black in colour with no visible lamination and are variably silty and carbonaceous. The mudstone beds average 1 to 2 m in thickness and usually have a gradational contact with the underlying siltstone and sharp or erosional contacts with overlying coal or sandstone respectively.

Interpretation

Lithofacies Assemblage I comprises a sequence of sedimentary facies that is a result of deposition in meandering channels in an alluvial plain environment. The channel sandstones exhibit sedimentary structures and an overall fining-upward sequence which is similar to the stratigraphic succession described by Walker and Cant (1980) for meandering rivers. In particular, the outcrop section depicted in Figure 10B is a good example of features which indicate deposition in a meander loop
FIGURE 10. Sedimentary structures, plant fossils and stratigraphy, Stenkul Fiord outlier.

A. Ripple cross-laminations. The scale is 15 cm long.

B. Typical vertical sequence of sedimentary structures within the sandstones of Lithofacies Assemblage I.

C. Interbedded mudstones and coal seams of Lithofacies Assemblage II (LF II).

D. Amber occurring in an ironstone concretion.

E. Petrified tree stump in growth position. Staff is 1.5 m long.

F. Root mark in resistant calcareous sandstone bed. The scale is 15 cm long.
that was abandoned by chute cut-off (Walker and Cant, 1980).
Coarse channel lag deposits and medium- to coarse-grained planar
cross-bedded channel fill sandstones were deposited in the
active channels, whereas finer-grained ripple cross-laminated
and convolute laminated sandstones and planar parallel laminated
siltstones were formed higher on the point bar of the meandering
channel. These deposits resemble point bar deposits described by
stone composition is predominantly arkosic, and is consistent
with a fluvial channel point bar interpretation.

The sandstones of Lithofacies Assemblage I display several
characteristics which are similar to those of Flores' (1981)
Type I sandstone. The en echelon arrangement of the sandstone
units is a result of lateral shifting of channels into low-lying
areas in adjacent backswamps. Horne and others (1978) and Ferm
and Cavaroc (1968) describe a similar geometric arrangement of
sandstone units in the Allegheny rocks of West Virginia.

The organic-rich siltstone and mudstone beds which are as­
associated with the channel sandstones are interpreted as either
deposits of abandoned channels due to chute or neck cut-off of
the meander loop or as overbank fines on top of the point bar.
These resemble deposits resulting from channel abandonment de­
scribed by Walker and Cant (1980).
LITHOFACIES ASSEMBLAGE II

Lithofacies Assemblage II is mostly composed of interbedded dark grey mudstone and thick coal seams, which are the distinguishing features of this lithofacies assemblage. Mudstone comprises up to 30 percent and coal accounts for as much as 25 percent of the Tertiary succession at Stenkul Fiord. Minor amounts of sandstone, siltstone and ironstone are found in association with the mudstone and coal and are included in this lithofacies assemblage.

The mudstones occur in units locally as thick as 20 m but rarely exceeding 10 m in thickness. The mudstones are dark grey, dark brown or black, and they weather light grey. They are commonly carbonaceous and contain coal stringers and abundant organic debris. The mudstones are massive and some are silty. A marine dinoflagellate cyst assemblage was identified in a thin mudstone unit towards the top of section 18 (sample 18-134, Appendix).

Coal seams vary in thickness from a few centimetres to 15 m (Figure 10C). Coal seams can be traced laterally over distances of greater than 1 km (Figures 5, 6 and 7, in pocket). The coal is of lignite rank and varies from mainly blocky, woody, tough coal to rare layers of essentially uncoalified plant debris consisting of leaf and stem fragments. The coal is generally argillaceous and commonly occurs as thin interbeds within and gradational with the carbonaceous mudstones. Amber, which is common in the coal seams, occurs as small (1 to 10 cm), spheroidal to
irregularly shaped globules scattered throughout and in concentrations along bedding planes, and in ironstone concretions (Figure 10D). The amber is brittle and crumbly, and varies in colour from clear lemon-yellow to translucent yellow-orange. Ironstone concretions, petrified logs and tree stumps in growth position (Figure 10E) commonly occur within the coal seams, whereas carbonaceous mudstone, siltstone and sandstone occur only locally as partings within the coal seams.

Minor amounts of siltstone and sandstone occur interbedded with the coal and mudstone. Siltstone and sandstone beds are usually less than a metre but range up to 5 m in thickness. They most commonly occur as splits within the coal seams, but are also associated with the mudstones. The siltstones are usually brown, locally argillaceous and carbonaceous, with fine parallel laminations and ripple cross-laminations. The sandstones are mostly very fine- to fine-grained but medium- to coarse-grained beds occur. The coarser sandstones often have erosional contacts with the underlying lithologies. Carbonaceous debris, mica flakes and silt occur in many sandstones. Parallel lamination and asymmetrical ripple cross-lamination are rarely observed in the sandstone units.

Ironstone (mainly siderite) is present as nodules in all lithologies at Stenkul Fiord. The ironstones are reddish brown and contain a variety of organic constituents including leaves, stems and branches of plants and trees, yellow to orange amber, plant rootlets, trace fossils and freshwater molluscs.
Interpretation

The sedimentary facies of Lithofacies Assemblage II represent vertical accretion deposits in backswamps or floodbasins and on channel levees in an alluvial plain environment.

The backswamp environment supported abundant freshwater vegetation (*Metasequoia*) which underwent later humification resulting in the formation of coal. Leaf fragments, amber and freshwater pelecypods that occur are common in backswamp deposits (Horne et al., 1978). The common occurrence of large petrified tree trunks and tree stumps in growth position are evidence of arboreal vegetation on the alluvial plain.

Coal seams vary in thickness and lateral extent, and in thickness and number of mudstone, siltstone and sandstone splits. Thick, laterally extensive coals were formed in isolated broad backswamps, where peat formation was rarely interrupted by influx of clastic detritus. Ethridge and others (1981) noted that thick coals in the Powder River Basin were formed in belts peripheral to major trunk streams. They further suggested that thick coal formation was favoured by a moist, sub-tropical climate and the location of groundwater discharge zones along the basin axis. Similar conditions likely favoured the formation of the thick coal seams in the study area, which occur in the axis of the Vendom Syncline, a topographic low formed during the Ellesmerian orogeny (McGil, 1974).

Closer to the active channels, breaching of the channel levees and flooding of the backswamp areas by crevasse splay and
overbank detritus interrupted peat formation, and resulted in thin coal seams. Ethridge and others (1981) suggested that thin seams developed on slightly better drained crevasse splay platforms. Either or both of these suggestions may explain the occurrence of thin coals in the study area.

Laterally continuous organic-rich siltstones and mudstones interbedded with the coal seams that were deposited from suspension during and after flooding of the backswamp areas. Fine-grained deposits occur spatially above and marginal to the channel deposits of Lithofacies Assemblage I, and resemble channel levee-overbank deposits described by Flores (1981).

Occasional breaching of the channel levees resulted in crevasse splays which spread out over the backswamp area, eroding the underlying peat and depositing sand, silt and clay. These deposits resemble crevasse splay and distal splay deposits of the upper Fort Union Formation described by Flores (1981). Fine sediments were also deposited from suspension in oxbow lakes which formed as a result of channel abandonment.

A marine dinoflagellate cyst assemblage dated as Late Eocene (G. Rouse, personal communication, 1984) was identified from a thin mudstone bed near the top of the stratigraphic succession and is evidence of a marine incursion into the area.

Ironstone is found in all rock types in the Eureka Sound Formation and everywhere encloses organic material such as plant fragments, amber and freshwater pelecypods. It is probable that the decay of the organic material created local reducing and/or
higher pH conditions facilitating the precipitation of iron carbonates.

LITHOFACIES ASSEMBLAGE III

Lithofacies assemblage III comprises the oldest strata in the study area and is present only on the east side of Stenkul Fiord. It attains a maximum thickness of approximately 90 m at the base of section 07 (Figure 5, in pocket). The dominant lithologies are brown mudstones with thin, interbedded coal seams averaging approximately 1 m in thickness. Strata of Lithofacies Assemblage III weather a distinctive pale cream to buff colour, which easily distinguishes this from other lithofacies assemblages. The occurrence of calcareous siltstones and sandstones, the fine grain size of the sediments and the occurrence of thin, discontinuous coal seams are the distinguishing features of Lithofacies Assemblage III.

Mudstones of Lithofacies Assemblage III are medium brown to light grey, weather a conspicuous buff to pale cream colour (Figure 4C), are commonly calcareous and resistant, and often contain macerated carbonaceous plant fragments. Marine dinoflagellate cysts were recovered from mudstones which crop out at the base of the section.

The coal seams of Lithofacies Assemblage III are discontinuous and average less than 1 m in thickness. Only one seam is greater than 2 m thick. Most coal is tough and argillaceous but also occurs as layers of uncoalified plant material.
Resistant, well-indurated calcareous siltstones and sandstones, which rarely contain glauconite, occur locally as pods (up to 7 m long) and beds (greater than 20 m in lateral extent). The calcareous siltstones and sandstones are less than 2 m thick and are found in association with fine grained sediments underlying several of the coal seams. The calcareous siltstones and sandstones are light grey, weather light orange and are mainly massive, but fine parallel laminations and ripple cross-laminations occur in the upper part of some units. Contacts with adjacent lithologies are gradational to sharp. Root marks up to 30 cm long (Figure 10F) and fragments of *Metasequoia* are common.

Very fine-grained sandstones and siltstones are mostly unconsolidated, but friable, calcite cemented aggregates of grains occur. Sandstones and siltstones are argillaceous and contain carbonaceous debris, rare glauconite and a few ironstone concretions. Very thin, planar parallel lamination and ripple cross-lamination are present and rare, thin (5 m) coarsening-upward sequences occur toward the base of the section. Lithofacies Assemblage III grades upward into Lithofacies Assemblage II over a distance of about 15 m.

**Interpretation**

The sedimentary facies of Lithofacies Assemblage III are interpreted as brackish water estuarine and marsh deposits and are facies equivalent of marine strata described by Miall (1981) and West and others (1981) near Strathcona Fiord on central
Ellesmere Island.

The fine grain size, abundance of carbonaceous debris and small scale sedimentary structures which characterize the sediments of Lithofacies Assemblage III suggest a microtidal environment similar to the present tidal regime (Miall, 1981). These strata must have accumulated under low energy conditions. Thin, discontinuous coals were formed from peat accumulation along the shores of the estuary. Kraft and others (1979) described recent deposits in the Delaware estuary which are similar. Rare coarsening-upward sequences are indicative of flood-tidal delta deposits which occur along microtidal shorelines (Hayes, 1979; McCann, 1979). Washover fans on barrier bars are common in a microtidal regime (Hayes, 1979) and a few of the sandstone units of Lithofacies Assemblage III may have formed this way, however the sandstones are poorly exposed and sedimentary and biogenic structures, which would provide evidence to support or reject this interpretation, are not preserved.

LITHOFACIES ASSEMBLAGE IV

Lithofacies Assemblage IV crops out at only one locality on the southwest shore of Stenkul Fiord, has a maximum thickness of 10 m, and occurs as a distinctive wedge-shaped body that extends across the exposed face for a distance of about 1.5 km (Figure 4D, Figure 6, in pocket). White to light grey sandstones and minor interbedded light grey to white, partly calcareous mudstones are characteristics of this lithofacies assemblage which distinguish it from other lithofacies assemblages.
The basal contact with an underlying coal seam of Lithofacies Assemblage II is sharp or erosional. The sandstones are medium-grained quartz arenites (Figure 18) and the heavy mineral assemblage is dominated by well-rounded zircons. Bedding in the sandstones is poorly preserved and is either massive or consists of rare, unidirectional planar tabular cross-beds. Carbonaceous debris and thin coaly stringers are common.

The facies change from the sandstones to the light grey to white mudstones is relatively abrupt. The mudstones are less than 5 m thick, are slightly calcareous in part and contain plant fragments and ironstone concretions. The mudstones are composed of the clay minerals kaolinite, illite and chlorite.

Interpretation

The strata of Lithofacies Assemblage IV are interpreted as deposits of a marine transgression and landward migration of a barrier island system. The conspicuous white sandstones rarely exhibit sedimentary or biogenic structures which are necessary for a precise interpretation of their origin. Medium-grained quartz arenites occur both in flood-tidal delta and washover fan deposits (Horne et al., 1978). Landward-oriented planar tabular cross-beds and the overall wedge-shaped sand body geometry are features of modern flood-tidal deltas (Hubbard and Barwis, 1976). On the other hand, planar cross-beds may in fact represent delta foreset strata in a washover fan where the fan extends into the lagoon (Reinson, 1979). Reinson (1979) and Hayes
(1979) note that washover deposits are especially common in microtidal regions, whereas tidal deltas are of relatively minor significance (Hayes, 1979).

The relatively abrupt facies change from the clean sandstones of the washover fan/flood-tidal delta environment to mudstones of the lagoonal facies is common in the back-barrier environment (Reinson, 1979). The mudstones represent subaqueous lagoonal deposits situated landward of and adjacent to the barrier.

The barrier island system of Lithofacies Assemblage IV at Stenkul Fiord is interpreted to have had a northwest-southeast trend, with an open marine environment to the southwest and a lagoon environment to the northeast.

**VENDOM FIORD**

An outlier of the Eureka Sound Formation which crops out along Vendom Fiord covers an area of approximately 55 square kilometres (Figure 3). The southwest boundary of this area is marked by a normal fault, which juxtaposes the Eureka Sound Formation against Devonian strata. The Eureka Sound Formation thins to an erosional edge on the Devonian Okse Bay Formation along the eastern and northern boundaries of the Vendom Fiord outlier (Figure 11).

The topography is subdued in this area, with few streams eroding through the strata, consequently outcrop is poor and only two stratigraphic sections, both less than 90 m thick,
FIGURE 11. Eureka strata in the Vendom Fiord outlier.

Aerial Photograph (A-16685-45) south of Vendom Fiord showing the locations of the stratigraphic sections (eg. ———-26). Geology modified after McGill (1974).

Q - Quaternary gravels and alluvium
Te - Eureka Sound Formation
Dob - Okse Bay Group
Dbi - Bird Fiord Formation
Db1 - Blue Fiord Formation

This aerial photograph ©19-7-59 Her Majesty the Queen in Right of Canada, reproduced from the collection of the National Air Photo Library with permission of Energy, Mines and Resources Canada.
Coal: amber, petrified wood.
Mudstone: med grey.
Coal.
Mudstone: med grey.

Coal.
Mudstone: med grey.

Coal: concretions.
Mudstone: med-dk grey, rooted horizons, coal stringers.

Sandstone: lt-med grey, f-mg, silty, carb., concretions.

Interbedded:
Mudstone(70%): med-dk grey, carb., concretions.
Sandstone(30%): med brown-lt grey, vf-fg, silty, micaceous, planar and wavy laminated.

Interbedded:
Coal(80%): arg., amber, mudstone splits.
Mudstone(20%): med grey-black, carb., silty.
Mudstone: dk grey.

Sandstone: lt-med grey, f-cg, arg., carb., coal spar, planar tabular and planar tangential cross-beds, 10-30 cm sets, some trough cross-beds.

Sandstone: lt grey, mg, arg., coal spar; sample 26-204

FIGURE 12. Stratigraphic section 26, Vendom Fiord outlier.
### Coal: some mudstone splits.
### Mudstone: med grey to med brown.

**Interbedded:**
- Coal (60%).
- Mudstone (30%): med grey, carb., concretions.
- Sandstone (10%): med grey, vfg, thin bedded.

### Mudstone: med grey, carb.

### Coal.

### Sandstone: grey to brown, vf-mg, carb., planar tabular cross-beds, 5-15 cm sets.

### Coal.

### Sandstone: lt brown, vfg, thin bedded.

### Coal: amber, thin mudstone splits.

### Mudstone: med grey, carb., thin to med bedded.

**Interbedded:**
- Sandstone (50%): med grey, vf-fg, micaceous. Coal (50%): amber.
- Sandstone: med brown, vfg, micaceous, thin bedded.

### Siltstone: med brown.

**Interbedded:**
- Mudstone (60%): med grey, carb.
- Coal (40%): amber.

### FIGURE 13. Stratigraphic section 27, Vendom Fiord outlier.
could be measured (sections 26 and 27, Figures 12 and 13).

Medium to dark grey mudstones and minor amounts of interbedded dark brown siltstones are the dominant lithologies which crop out at sections 26 and 27. Mudstone beds range in thickness from 50 cm to 15 m. The mudstones appear unlaminated, some are carbonaceous and a few contain ironstone nodules.

Coal seams vary from 30 cm to 2.7 m but average about 1 m in thickness. Mudstone splits occur within the coal seams and are 15 cm to 1 m thick. The coal is commonly argillaceous, tough and blocky, and commonly contains amber, ironstone concretions and petrified wood. Some layers of uncoalified plant debris also occur in the coal seams.

Grey to brown sandstones range from very fine- to coarse-grained. The thickest sandstone units (7 to 12 m thick) have sharp or erosional basal contacts, contain coal spar and basal lag deposits of coarse sand, and fine upwards. Planar tabular and planar tangential cross-bed sets averaging 15 cm in thickness and some trough cross-bedding occur. The sandstones consist of quartz, feldspar, chert and rare mica. Petrographic data from a subarkose sandstone sample (Figure 18) from section 26 are shown on Table I. Ironstone concretions and coaly plant debris are also present.

Of the thinner sandstone units (50 cm to 3 m) in the stratigraphic sequence, some coarsen upward and exhibit wavy to planar parallel lamination, while others show no detectable grain size variation.
A thin (50 cm) orange- to buff-weathering, resistant dolomitic siltstone which contains root structures, leaf imprints and ripple cross-bedding occurs towards the top of section 26. This unit lies below a 30 cm thick seam of sapropelic coal which fractures conchoidally, is lustrous, nonbanded, and has a brown streak.

Interpretation

Strata exposed in the Vendom Fiord outlier represent alluvial plain deposits, and display characteristics similar to Lithofacies Assemblages I and II from Stenkul Fiord which have previously been described.

Mudstones with interbedded siltstones and associated coal seams which comprise most of sections 26 and 27 were deposited by floodwaters which inundated the backswamps on the alluvial plains. Similar unlaminated mudstones containing comminuted plant debris were described from the Port Hood Formation by Gersib and McCabe (1981) and interpreted as floodplain deposits. Coal was deposited in swampy areas of the floodplain.

The thick, fining-upward sandstone units have sandstone compositions and sedimentary structures which are similar to Type I sandstones of Flores (1981). These sandstones are interpreted as fluvial channel point bar deposits. Thinner sandstones, which locally coarsen upward, resemble crevasse splay sandstones described by Gersib and McCabe (1981).
Dolomitic siltstone overlain by nonbedded sapropelic coal indicates deposition within a small lake on the alluvial plain. Flores (1981) describes grain supported, silty limestones in the upper Fort Union Formation which display similar characteristics, and which he interprets as having formed from precipitation of carbonates in interchannel, freshwater ephemeral lakes. It is suggested here that the dolomitic siltstones formed in a similar manner, and were dolomitized during early diagenesis. Friend and Moody-Stuart (1970) also report dolomitic rocks in fluvial deposits of the Wood Bay Formation. The overlying sapropelic coal also indicates a lake environment. Teichmüller (1982) attributes the formation of sapropelic coals to the deposition of plant detritus, plankton, spores and reworked peat in small swamp lakes.

BAUMANN FIORD

Eureka Sound strata cover an area of approximately 45 square kilometres bordering on the southwest shore of Baumann Fiord (Figure 3). The Eureka Sound Formation lies unconformably on Devonian Okse Bay strata, and is faulted against the Devonian Blue Fiord and Bird Fiord Formations to the west and southwest. The Eureka Sound beds dip at about 10 degrees to the west. The outcrop area has low relief, but sparse outcrop occurs along creeks which cut across the plain. The location of section 22 (Figure 15, in pocket), was measured in the area south of Baumann Fiord and is shown on Figure 14.
FIGURE 14. Eureka Sound strata in the Baumann Fiord outlier


Q - Quaternary gravels and alluvium
Te - Eureka Sound Formation
Dob - Okse Bay Group

This aerial photograph ©13-8-59 Her Majesty the Queen in Right of Canada, reproduced from the National Air Photo Library with permission of Energy, Mines and Resources Canada.
Sandstone and coal are the primary lithologies exposed south of Baumann Fiord. The sandstone varies from brown to light grey and bed thickness ranges from 2 to 12 m. Contacts with adjacent lithologies are commonly covered, but where exposed are sharp or erosional in nature. Petrographic analysis of three samples from this area revealed a range of sandstone compositions (Table I), and are quartz arenite, sublitharenite and lithic subarkose (Figure 18). The sandstones are of two types, based on composition, texture and sedimentary structures.

Type A sandstones are white weathering, predominantly fine-to medium-grained quartz arenites. The sandstones are clean, well rounded and well sorted and contain some carbonaceous debris and rare glauconite. Sedimentary structures were not preserved.

Type B sandstones weather buff to light grey, generally fine upwards and grain size varies from very fine to very coarse. Many basal lag deposits contain granule-size grains and coal spar. Sublitharenite and lithic subarkose are typical Type B sandstone compositions. The sandstones are silty, moderately well to poorly sorted and angular to subrounded. Type B sandstones contain abundant plant fragments, finely divided carbonaceous debris and rare concretions. Sedimentary structures include planar tabular and planar tangential cross-bedding, ripple cross-lamination and convolute lamination.

Type A sandstones predominate towards the base of the section, whereas Type B sandstones are dominant in the upper part of the section.
Coal accounts for a large percentage of Eureka Sound strata which crop out south of Baumann Fiord. Coal seams range in thickness from 50 cm to 5.7 m and often form isolated resistant ridges. The coals are tough and woody, often lustrous, commonly contain amber and rarely include macroscopic iron sulphide and ironstone concretions. Mudstone splits within the coal seams are rare.

Mudstones and siltstones are rarely exposed and are commonly covered by a hard, white crust on the weathered surface. Mudstones are mostly medium to dark grey and carbonaceous. Siltstones are brown to grey and are locally sandy or argillaceous. Mica flakes occur in a few of the siltstones and many contain carbonaceous plant fragments. Mudstones and siltstones are locally interbedded.

Interpretation

The Eureka Sound Formation south of Baumann Fiord comprises a sequence of marine and nonmarine strata. The isolated outcrop exposure with long covered intervals obscure lateral and vertical facies associations and make it difficult to interpret depositional environments.

The compositional and textural maturity of the Type A sandstones and the rare occurrence of glauconite suggests a marine origin. Porrennga (1967) states that glauconite may be considered as a marine clay mineral, and that moderate temperatures favour
its formation. Type A sandstones at the base of section 22 are interbedded with siltstones, mudstones and coal. A basal mudstone bed (sample 22-157, Appendix) contains rare marine dinoflagellate cysts, which also supports a marine interpretation. The fine-grained sediments and thin coals were likely formed in lagoonal back-barrier environments similar to those described by Horne and others (1978). Type A sandstones may represent barrier bar or shallow marine deposits, but the absence of diagnostic sedimentary structures precludes a more precise interpretation.

The basal strata at section 22 are late mid-Paleocene in age (G. Rouse, personal communication, 1984). These strata are likely correlative in part with the basal strata of section 07 on the east shore of Stenkul Fiord and with the uppermost beds of Member III of West and others (1981) at Strathcona Fiord, which they interpret as shallow marine and brackish deposits of a large lagoon or estuary.

The remainder of the section is dominated by Type B sandstones and nonmarine fine-grained clastics and coal, with the exception of a few Type A sandstone units and marine mudstones at the top of the section. A 10 m thick Type A sandstone unit at 240 m may be related to the barrier island system which existed during deposition of Lithofacies Assemblage IV at Stenkul Fiord.

Type B sandstones exhibit many characteristics of point bar deposits in a meandering stream environment, which have been described by several authors (Flores, 1981; Cant, 1980; Walker and Cant, 1980; and others) and are similar to sandstone deposits of Lithofacies Assemblage I in the Stenkul Fiord outlier.
which have previously been described.

Nonmarine coals most commonly occur interbedded with carbonaceous shales and are only rarely associated with Type B sandstones. The nonmarine coals represent organic accumulations of the fluvial backswamp environment and are similar to coals described by Flores (1981).

The majority of the coal seams occur as isolated ridges. The depositional environments of these coal seams are difficult to interpret as adjacent strata are covered and vertical facies sequences cannot be observed. Iron sulphide concretions found in a few of the isolated coals suggest that these coals were formed from brackish peat. The process of sulphate reduction is facilitated by sulphate-reducing bacteria which thrive in brackish peat deposits (Casagrande et al., 1977; Horne et al., 1978).

A mudstone bed containing a marine dinoflagellate cyst assemblage (sample 22-188, Appendix) crops out at the top of the section and represents a thin, Early to early Middle Eocene marine incursion.

**SOR FIORD**

Southwest of Sor Fiord, an outlier of the Eureka Sound Formation lies unconformably on Devonian strata (Figures 3 and 16), and covers an area of 10 square kilometres. Outcrop is sparse, and section 24 (Figure 17) which was measured in this area contains many covered intervals.
FIGURE 16. Eureka Sound strata in the Sor Fiord outlier

Aerial photograph (A-16780-73) south of Sor Fiord, showing the location of section 24. Geology modified after Kerr and Thorsteinsson (1971) and Okulitch (1982).

Q - Quaternary gravels and alluvium
Te - Eureka Sound Formation
Dob - Okse Bay Group
Dbi - Bird Fiord Formation
Db1 - Blue Fiord Formation

This aerial photograph ©17-8-59 Her Majesty the Queen in Right of Canada, reproduced from the National Air Photo Library with permission of Energy, Mines and Resources Canada.
Sandstone: lt grey, mg, massive.

Covered.
Interbedded: Coal(50%) and Mudstone(50%): dk grey, carb.
Mudstone: lt grey.

Covered: mudstone?

Interbedded: Coal(70%) and Mudstone(30%).
Mudstone: lt grey.

Coal.
Covered: mudstone?

Coal: arg., amber.

Mudstone: greenish-grey.

Coal: arg.
Covered: mudstone?

Coal: iron sulphide framboids.

Sandstone: white, f-mg, med wavy laminated.

Interbedded:
Sandstone(95%): lt-dk grey, f-mg, carb., arg., massive.
Coal(5%): amber.

FIGURE 17. Stratigraphic section 24, Sor Fiord outlier.
Sandstones comprise a large part of the stratigraphic succession at Sor Fiord. The sandstones are medium- to fine-grained and range in colour from light to dark grey. Mineralogical composition includes quartz and feldspar. The sandstones are commonly silty and contain carbonaceous plant debris, some thin coaly seams and rare, spherical iron sulphide concretions which occur locally at the base of the section. The only sedimentary structure observed (as a result of poor exposure), was rare wavy lamination in some of the sandstone units at the base of the section.

Coal seams range in thickness from 30 cm to 4 m but are poorly exposed and contain many mudstone splits. Many coal seams contain amber and iron sulphide framboids.

A good exposure of the coal and mudstone occurs in a creek north of the line of section. Here, the coals have an iridescent sheen and consist of compressed reeds and plant material. The mudstone consists of finely interlaminated light and dark grey, waxy layers which weather an orange to yellow-brown colour and commonly contain carbonized plant debris. The laminae range in thickness from 0.3 to 1 cm and are locally wavy. Along strike, weathered outcrops of the mudstones have hard, resistant crusts. Light grey to greenish grey mudstones with similar weathering surfaces occur stratigraphically above this mudstone and coal sequence.
Interpretation

Sandstones which crop out at the base of the section lack visible sedimentary structures and are difficult to interpret. Their stratigraphic position suggests that these sandstones are fluvial deposits. The sandstones are overlain by a sequence of mudstones and coal seams, the lower part of which correlates with a good exposure in a creek north of the section. At this locality, finely laminated mudstone and associated coals with abundant reed and plant fragments are interpreted as lacustrine deposits. The mudstones show even and continuous varve-like laminae which are similar to lacustrine mudstones described by Fouch and Dean (1982). It is therefore suggested that the mudstones with the varve-like laminae were deposited towards the center of a freshwater lake. As pointed out by Picard and High (1981) in many lakes, nearshore coarse clastics are replaced by dense growths of vegetation. This explains the vertical change from the mudstones to the reed-bearing coals with no intervening coarse clastic deposit. Coal seams and mudstones which overlie the lacustrine sequence are poorly exposed, but exhibit similar weathering characteristics and therefore are also tentatively interpreted as lacustrine deposits.

A medium-grained sandstone bed at the top of the exposed section displays no visible sedimentary structures and adjacent lithologies are covered. Based on its textural immaturity and stratigraphic position above the lacustrine deposits, this sandstone bed is thought to represent a return to fluvial conditions.
In summary, the Eureka Sound Formation at Sor Fiord comprises predominantly lacustrine strata which are associated with fluvial deposits. Therefore, it is suggested that the lake occurred on an alluvial plain, and may have formed by channel abandonment or by subsidence below the water table.

No age was obtained for Eureka Sound beds at Sor Fiord, and the stratigraphic relationship of these strata to other Eureka Sound outliers on southern Ellesmere Island is uncertain.
PETROGRAPHY, PALEOCURRENTS AND PROVENANCE

SANDSTONE PETROGRAPHY

Twenty-nine sandstones were thin sectioned, stained and examined by petrographic methods. Staining was not entirely successful. For the most part, potassium feldspars did acquire a yellow stain from the sodium cobaltinitrite; however, plagioclase feldspar grains were not in all cases stained by amaranth red dye. This may have been due either to the fact that plagioclase staining did not immediately follow staining for K-feldspar or that the dye was not fresh. This is not thought to present a significant problem, as the amount of plagioclase present was small and in most cases could be distinguished from quartz by albite twinning or cleavage. In addition, plagioclase acquired a cloudy appearance upon etching with hydrofluoric acid (Deer et al., 1966, p. 335).

Several workers have theorized on the statistical significance of the point counting method for sandstones and the use of modal analysis for interpreting provenance (Van der Plas and Tobi, 1965; Ingersoll et al., 1984; and others). The applicability of the results obtained by these workers to this study is uncertain, as most samples in the study are unconsolidated, and both sampling and sample preparation techniques destroyed the original depositional texture of the sandstones. Statistical data on unconsolidated samples is not reported in the literature, and many studies (Potter, 1978; Ingersoll and Suczek, 1979; Mack, 1981) simply report the number of grains counted per
thin section with no indication of the tested or presumed statistical significance of the results.

Results of the modal analyses are reported on Table I, together with the grain size, sorting and roundness. The sandstones according to McBride's (1963) classification (Figure 18) are lithic subarkoses, subarkoses, lithic arkoses, arkoses, sublitharenites, quartz arenites and feldspathic litharenites. The most abundant minerals are quartz and plagioclase, potassium and perthitic feldspars, with lesser amounts of unstable rock fragments (granite, gneiss, sandstone, carbonate, shale) and heavy minerals. All samples, with the exception of one (11-76), contain less than 25 percent unstable rock fragments. Sample 11-76 is a very coarse-grained sandstone to granule conglomerate, and hence the rock fragments are not broken down into their constituent minerals, such as has occurred in the finer-grained sandstones.

The average clast size varies from very fine- to very coarse-grained, and the majority of the sandstones are fine- to medium-grained and moderately well to well sorted. A few of the sandstones are distinctly bimodal, and have a fine-grained mode consisting of angular grains and a coarse-grained mode comprising subrounded to well rounded grains. Other sandstones show no distinct bimodality, but are very poorly sorted with grain size ranging from coarse or very coarse to very fine or fine. Generally, the finer-grained fractions are angular to subangular and the coarser grain sizes are subrounded to rounded. Very well rounded, medium-grained quartz clasts occur in some sandstones.
TABLE I. Petrographic data including grain size, rounding, sorting, modal analyses and heavy mineral compositions of representative sandstones from the Eureka Sound Formation

Key to Table I

The following abbreviations are used in Table I

<table>
<thead>
<tr>
<th>Modal Analysis - Detrital clasts</th>
<th>Cement types</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Qm</strong> = monocristalline quartz</td>
<td>Ca = carbonate</td>
</tr>
<tr>
<td><strong>Qp</strong> = polycristalline quartz</td>
<td>Si = siderite</td>
</tr>
<tr>
<td><strong>Qt</strong> = total quartz</td>
<td>- = not cemented</td>
</tr>
<tr>
<td><strong>Pl</strong> = plagioclase feldspar</td>
<td>Grain size</td>
</tr>
<tr>
<td><strong>Ks</strong> = potassium feldspar</td>
<td>vf = very fine</td>
</tr>
<tr>
<td><strong>Pt</strong> = perthite feldspar</td>
<td>f = fine</td>
</tr>
<tr>
<td><strong>Ft</strong> = total feldspar</td>
<td>m = medium</td>
</tr>
<tr>
<td><strong>SR</strong> = sedimentary rock fragment</td>
<td>c = coarse</td>
</tr>
<tr>
<td><strong>PR</strong> = plutonic rock fragment</td>
<td>gran = granule</td>
</tr>
<tr>
<td><strong>MR</strong> = metamorphic rock fragments</td>
<td></td>
</tr>
<tr>
<td><strong>Lt</strong> = total lithic fragments*</td>
<td>Location</td>
</tr>
</tbody>
</table>

Heavy minerals

| Al = allanite                   | SF = Stenkul Fiord outlier |
| Bi = biotite                    | BF = Baumann Fiord outlier |
| Cz = clinzoisite                | VF = Vendom fiord outlier  |
| Ep = epidote                    |                           |
| Ca = garnet                     |                           |
| Ky = kyanite                    |                           |
| Ms = muscovite                  |                           |
| Mc = magnetite                  |                           |
| Py = pyrite                     |                           |
| Rt = rutile                     |                           |
| Sl = sillimanite                |                           |
| Sp = sphene                     |                           |
| St = staurolite                 |                           |
| Tm = tourmaline                 |                           |
| Zo = zoisite                    |                           |
| Zr = zircon                     |                           |

* indicates percentage value used on McBride's (1963) classification diagram (underlined on Table I)
<table>
<thead>
<tr>
<th>Location</th>
<th>Grain size</th>
<th>Sorting</th>
<th>Roundness</th>
<th>Cement type</th>
<th>Qm</th>
<th>Qp</th>
<th>Qt</th>
<th>PI</th>
<th>KS</th>
<th>PT</th>
<th>FT</th>
<th>SR</th>
<th>PR</th>
<th>MR</th>
<th>Lt</th>
<th>Minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF-02-12</td>
<td>vf-cg</td>
<td>poor</td>
<td>well rd-ang</td>
<td>-</td>
<td>75</td>
<td>5</td>
<td>80</td>
<td>3</td>
<td>6</td>
<td>4</td>
<td>13</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>7</td>
<td>Ga, Ms, Bi, Zr, Ky, Ep, Zo, Rt</td>
</tr>
<tr>
<td>SF-03-30</td>
<td>vf-cg</td>
<td>poor</td>
<td>well rd-sub ang</td>
<td>-</td>
<td>53</td>
<td>12</td>
<td>65</td>
<td>4</td>
<td>6</td>
<td>13</td>
<td>23</td>
<td>3</td>
<td>8</td>
<td>tr</td>
<td>11</td>
<td>Ga, Zr, Sl, Tm, Ep, Rt, Ga, Bi, Zr, Tm, Ep,</td>
</tr>
<tr>
<td>SF-04-39</td>
<td>vf-cg</td>
<td>poor</td>
<td>rd-sub rd</td>
<td>-</td>
<td>45</td>
<td>8</td>
<td>53</td>
<td>6</td>
<td>9</td>
<td>14</td>
<td>29</td>
<td>6</td>
<td>12</td>
<td>tr</td>
<td>18</td>
<td>Ga, Ms, Bi, Zr, Ky, Ep, Rt, Ga, Bi, Zr, Tm, Tm,</td>
</tr>
<tr>
<td>SF-04-41</td>
<td>mf</td>
<td>well</td>
<td>sub rd-sub ang</td>
<td>-</td>
<td>55</td>
<td>12</td>
<td>67</td>
<td>4</td>
<td>5</td>
<td>12</td>
<td>21</td>
<td>4</td>
<td>8</td>
<td>tr</td>
<td>12</td>
<td>Ga, Ms, Bi, Zr, Ky, Ep, Rt, Ga, Zr, Sl, Tm,</td>
</tr>
<tr>
<td>SF-04-42</td>
<td>cg</td>
<td>well</td>
<td>sub rd-sub ang</td>
<td>-</td>
<td>46</td>
<td>12</td>
<td>58</td>
<td>4</td>
<td>7</td>
<td>12</td>
<td>23</td>
<td>10</td>
<td>7</td>
<td>2</td>
<td>19</td>
<td>Ga, Ms, Bi, Zr, Ky, Tm, Ep, Rt, Ga, Zr, Sl, Tm,</td>
</tr>
<tr>
<td>SF-05-48</td>
<td>vf-cg</td>
<td>poor</td>
<td>sub ang-well rd</td>
<td>-</td>
<td>58</td>
<td>10</td>
<td>68</td>
<td>0</td>
<td>23</td>
<td>0</td>
<td>23</td>
<td>tr</td>
<td>8</td>
<td>1</td>
<td>9</td>
<td>Ga, Bi, Zr, Sl, Ky, Tm, Ep, Zo, Rt, Sp</td>
</tr>
<tr>
<td>SF-07-50</td>
<td>vf-fg</td>
<td>mod</td>
<td>well sub ang</td>
<td>Ca</td>
<td>79</td>
<td>1</td>
<td>80</td>
<td>0</td>
<td>tr</td>
<td>18</td>
<td>18</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>glauconite</td>
</tr>
<tr>
<td>SF-06-51</td>
<td>vf-fg</td>
<td>mod</td>
<td>well sub ang</td>
<td>Ca</td>
<td>77</td>
<td>0</td>
<td>77</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>21</td>
<td>0</td>
<td>0</td>
<td>21</td>
<td>Ms, Zr, Ep</td>
</tr>
<tr>
<td>SF-06-53</td>
<td>f-mg</td>
<td>mod</td>
<td>well sub ang</td>
<td>-</td>
<td>56</td>
<td>13</td>
<td>69</td>
<td>2</td>
<td>6</td>
<td>15</td>
<td>23</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>8</td>
<td>Ga, Ms, Bi, Zr, Ky, Tm, Ep, Zo</td>
</tr>
<tr>
<td>SF-08-60</td>
<td>m-cg</td>
<td>mod</td>
<td>well rd-sub rd</td>
<td>-</td>
<td>52</td>
<td>8</td>
<td>60</td>
<td>6</td>
<td>10</td>
<td>6</td>
<td>22</td>
<td>tr</td>
<td>18</td>
<td>0</td>
<td>18</td>
<td>Ga, Bi, Zr, Ep</td>
</tr>
<tr>
<td>SF-08-62</td>
<td>mg</td>
<td>well</td>
<td>v. well rd-sub ang</td>
<td>-</td>
<td>62</td>
<td>3</td>
<td>65</td>
<td>14</td>
<td>11</td>
<td>2</td>
<td>27</td>
<td>2</td>
<td>6</td>
<td>tr</td>
<td>8</td>
<td>Ga, Zr, Sl, Ky, Tm, Ep, Al, St</td>
</tr>
<tr>
<td>SF-07-69</td>
<td>f-mg</td>
<td>mod</td>
<td>sub rd-sub ang</td>
<td>-</td>
<td>58</td>
<td>13</td>
<td>71</td>
<td>2</td>
<td>7</td>
<td>13</td>
<td>22</td>
<td>tr</td>
<td>6</td>
<td>2</td>
<td>tr</td>
<td>7</td>
</tr>
<tr>
<td>SF-10-71</td>
<td>mg</td>
<td>well</td>
<td>sub rd-sub ang</td>
<td>-</td>
<td>80</td>
<td>6</td>
<td>86</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>11</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>Ga, Bi, Zr, Sl, Ky, Tm, Ep, Rt</td>
</tr>
<tr>
<td>SF-11-75</td>
<td>vf-mg</td>
<td>poor</td>
<td>sub rd-sub ang</td>
<td>-</td>
<td>50</td>
<td>9</td>
<td>59</td>
<td>3</td>
<td>14</td>
<td>12</td>
<td>29</td>
<td>2</td>
<td>10</td>
<td>0</td>
<td>12</td>
<td>Ga, Bi, Zr, Sl, Ky, Tm, Ep</td>
</tr>
<tr>
<td>SF-11-76</td>
<td>veg</td>
<td>mod</td>
<td>well rd-sub ang</td>
<td>-</td>
<td>21</td>
<td>16</td>
<td>37</td>
<td>3</td>
<td>7</td>
<td>7</td>
<td>17</td>
<td>9</td>
<td>33</td>
<td>4</td>
<td>46</td>
<td>Ga, Ms, Bi, Zr, Ky, Ep, Al, St</td>
</tr>
</tbody>
</table>

*Note: Modal analysis - Detrital clasts*
<table>
<thead>
<tr>
<th>Location</th>
<th>Grain size</th>
<th>Sorting</th>
<th>Roundness</th>
<th>Cement type</th>
<th>Modal analysis</th>
<th>Detrital clasts</th>
<th>Heavy minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF-11-78</td>
<td>vf-cg</td>
<td>poor</td>
<td>sub rd-ang</td>
<td>-</td>
<td>Qm 3 Qp 70 Qt 9 Pl 7 Ks 10 Pt 25 Ft tr 4 SR tr 0 PR tr 0 MR tr 4</td>
<td>Ga, Zr, Sl, Ky, Tm, Ep, Rt</td>
<td></td>
</tr>
<tr>
<td>SF-12-79</td>
<td>mg</td>
<td>well</td>
<td>sub rd-well rd</td>
<td>-</td>
<td>Qm 77 Qp 96 Qt 0 Pt tr 2 tr 2 Ft tr 2</td>
<td>Ga, Zr, Sl, Ky, Tm, Ep, Zr, Sp, Rt</td>
<td></td>
</tr>
<tr>
<td>SF-13-80</td>
<td>vf-cg</td>
<td>poor</td>
<td>sub rd-ang</td>
<td>-</td>
<td>Qm 65 Qp 9 Qp 74 Qt 6 Pl 2 Ks 11 Pt 19 Ft tr 7</td>
<td>Ga, Bi, Zr, Sl, Tm, Ep, Zo, Cz, Rt, St</td>
<td></td>
</tr>
<tr>
<td>SF-13-81</td>
<td>f-mg</td>
<td>mod</td>
<td>sub ang ang</td>
<td>-</td>
<td>Qm 47 Qp 12 Qp 59 Qt 2 Pt 8 Ks 10 Ft 20</td>
<td>Bi, Ga, Zr, Sl, Ky, Tm, Ep, Cz, Rt, Sp</td>
<td></td>
</tr>
<tr>
<td>SF-14-89</td>
<td>vf-cg</td>
<td>poor</td>
<td>sub rd-ang</td>
<td>-</td>
<td>Qm 67 Qp 2 Qp 69 Qt 8 Pl 15 Ks 5 Pt 28 Ft tr 2</td>
<td>Ga, Bi, Zr, Sl, Ky, Tm, Ep, Zo, Cz, Rt, St</td>
<td></td>
</tr>
<tr>
<td>SF-15-99</td>
<td>vf-cg</td>
<td>poor</td>
<td>sub rd-ang</td>
<td>-</td>
<td>Qm 52 Qp 9 Qp 61 Qt 8 Pl 11 Ks 9 Pt 28 Ft tr 11</td>
<td>Ga, Bi, Zr, Sl, Ky, Tm, Ep, Zo, Cz, Rt, St</td>
<td></td>
</tr>
<tr>
<td>SF-19-140</td>
<td>mg</td>
<td>well</td>
<td>rd-sub rd</td>
<td>-</td>
<td>Qm 54 Qp 11 Qp 65 Qt 3 Pl 7 Ks 8 Pt 18 Ft 2</td>
<td>Ga, Bi, Zr, Sl, Ky, Tm, Ep, Zo, Cz, Rt, St</td>
<td></td>
</tr>
<tr>
<td>SF-20-141</td>
<td>f-mg</td>
<td>mod</td>
<td>rd-sub rd</td>
<td>-</td>
<td>Qm 55 Qp 4 Qp 59 Qt 1 Pt 4 Ks 23 Pt 28 Ft 0</td>
<td>Ga, Bi, Zr, Sl, Ky, Tm, Ep, Zo, Cz, Rt, St</td>
<td></td>
</tr>
<tr>
<td>SF-20-142</td>
<td>mg</td>
<td>well</td>
<td>rd-sub rd</td>
<td>-</td>
<td>Qm 72 Qp 4 Qp 76 Qt 3 Pl 17 Ks 1 Pt 21 Ft 3</td>
<td>Ga, Bi, Zr, Sl, Ky, Tm, Ep, Zo, Cz, Rt, St</td>
<td></td>
</tr>
<tr>
<td>SF-03-148</td>
<td>f-cg</td>
<td>poor</td>
<td>rd-ang</td>
<td>-</td>
<td>Qm 68 Qp 6 Qp 74 Qt 1 Pt 3 Ks 6 Pt 10 Ft 2</td>
<td>Ga, Bi, Zr, Sl, Ky, Tm, Ep, Zo, Cz, Rt, St</td>
<td></td>
</tr>
<tr>
<td>BF-22-161</td>
<td>m-cg</td>
<td>mod</td>
<td>rd-sub rd</td>
<td>-</td>
<td>Qm 74 Qp 5 Qp 79 Qt 2 Pt 7 Ft 2</td>
<td>Bi, Ep, Ga, Zr, Ky, St, Ep, Cz</td>
<td></td>
</tr>
<tr>
<td>BF-22-166</td>
<td>mg</td>
<td>well</td>
<td>rd</td>
<td>-</td>
<td>Qm 89 Qp 9 Qp 98 Qt 1 Pt 1 Ks 0 Pt 2</td>
<td>Ga, Zr, Ky, St, Ep, Cz</td>
<td></td>
</tr>
<tr>
<td>BF-22-187</td>
<td>vf-cg</td>
<td>poor</td>
<td>sub rd-ang</td>
<td>-</td>
<td>Qm 51 Qp 9 Qp 60 Qt 3 Pl 8 Ks 10 Pt 21 Ft 2</td>
<td>Ga, Ms, Bi, Ga, Zr, Ky, St, Ep, Cz</td>
<td></td>
</tr>
<tr>
<td>VF-26-204</td>
<td>m-cg</td>
<td>mod</td>
<td>rd-sub rd</td>
<td>-</td>
<td>Qm 75 Qp 5 Qp 80 Qt 3 Pt 4 Ks 8 Ft 15 Ft 1</td>
<td>Ga, Ms, Bi, Ga, Zr, Ky, St, Ep, Cz</td>
<td></td>
</tr>
</tbody>
</table>
and are likely recycled from pre-existing sandstones in the source area.

Silt-sized fragments of quartz, feldspar, heavy minerals and rare dolomite and clay minerals occur in varying amounts and comprise the sandstone matrix. Friable aggregates of grains occur in some sandstones, which are partly consolidated by matrix clays and, rarely cemented by siderite or calcite. Siderite occurs as coatings on the grains or as discrete grains in some sandstone samples, indicating previously existing cement. Calcite and rarely siderite cement (Figure 19A) occurs as a crystalline mosaic between the grains and euhedral crystals are observed growing into the pore spaces. Quartz and feldspar grains are partly replaced by calcite. The sandstones are, however, mostly unconsolidated and original textures and grain contacts are not preserved. Grain contacts observed in the calcite or siderite cemented sandstones were floating or tangential according to Adam's (1964) classification.

Quartz

The most abundant mineral species in the sandstones is quartz. (Table I). Both monocrystalline and polycrystalline quartz grains are present and include several of the quartz types described by Krynine (1940).

Monocrystalline quartz comprises the dominant quartz type in all samples. Most monocrystalline quartz grains have straight to slightly undulose or semi-composite extinction. Microlites
FIGURE 19. Thin section photomicrographs of sandstones, Eureka Sound Formation

A. Siderite cemented sandstone containing perthite (Pt), monocrystalline quartz (Qm) and siderite cement (Si). Nicols crossed.

B. Zircon (Zr) inclusion in monocrystalline quartz (Qm).

C. Reworked quartz overgrowth on detrital quartz grain.

D. Chalcedony (Cd) in a chert grain. Nicols crossed.

E. Microcline grain (Mi). Nicols crossed.
and vacuoles occur in some of the monocrystalline quartz grains. The microlites are prismatic or acicular in shape, and are likely zircon (Figure 19B) and rutile, respectively.

Reworked quartz overgrowths are visible on some of the monocrystalline quartz grains (Figure 19C). A few quartz grains have euhedral quartz overgrowths which show no evidence of rounding.

Polycrystalline quartz is present in all samples. The number of crystal units visible per grain in thin section ranges from 3 to more than 20 and is partly dependent on grain size. Recrystallized metamorphic quartz grains have straight grain boundaries which commonly intersect at angles of 120 degrees. The quartz grains have straight to undulose extinction. Stretched metamorphic quartz grains with smooth, crenulated and granulated crystal boundaries and lattice preferred orientation are less commonly observed than other polycrystalline quartz types.

Chert

Chert grains commonly occur in trace amounts in the sandstones. Chert grains are colourless to brown in thin section and in some samples contain radiating fibres of chalcedony (Figure 19D).
Feldspar

Plagioclase, potassium and perthitic feldspars are present in most samples (Table I). Potassium feldspar is usually the most abundant feldspar, but perthitic feldspar and plagioclase feldspar are locally important.

Potassium feldspar includes orthoclase and microcline, and accounts for up to 22 percent of the framework composition. Rare Carlsbad twinning is present in orthoclase, and microcline shows the characteristic "tartan" pattern (Figure 19E).

Plagioclase is most abundant in the upper part of the Eureka Sound Formation at Stenkul Fiord, and locally constitutes up to 14 percent of the total clasts. Albite twinning is ubiquitous in the plagioclase grains (Figure 19F). Sericitization and possibly saussuritization of the plagioclase grains is common.

Feldspar grains showing microperthitic (Figure 20A) and less commonly antiperthitic intergrowth of potassium and plagioclase feldspars occur in the sandstones. Perthite types include stringlets, strings, rods and beads (Alling, 1938). Orthoclase microperthite containing exsolved albite is the most commonly occurring perthite composition, although microcline microperthite is present. Antiperthite rarely occurs and is easily identified by the characteristic microcline "patches" in albite (Figure 20B).

Symplectic intergrowths of quartz and feldspar are present in some grains. Myrmekite (Figure 20C), and less commonly gra-
FIGURE 20. Thin section photomicrographs of sandstones, Eureka Sound Formation

A. Plagioclase (Pl) and quartz (Q). Nicols crossed.

B. Perthite (Pt) in a plutonic rock fragment. Nicols crossed.

C. Antiperthite showing microcline (Mi) and plagioclase (Pl). Nicols crossed.

D. Myrmekite (My) and microcline (Mi). Nicols crossed.

E. Paragneiss grain. Nicols crossed.

F. Cataclasite or mylonite grain. Nicols crossed.
Sedimentary Rock Fragments

Sedimentary rock fragments comprise only a minor component of the Eureka Sound Formation in the study area. Sandstone and carbonate rock fragments are the most commonly occurring sedimentary rock fragments. Siltstone and shale fragments occur rarely. Fragments of sandstone are composed of quartz grains with straight grain boundaries. Quartz overgrowths are rarely observed. Siltstone fragments are colourless to pale brown and shale fragments are brown. Carbonate rock fragments are yellow to brown and have sparry to micritic textures.

Igneous Rock Fragments

Plutonic rock fragments are common and are granitic in composition. Fragments which contain quartz and feldspar or potassium feldspar and plagioclase grains are included in this category (Figure 20A). Biotite is rare in the plutonic rock fragments, whereas chlorite and sericite alteration of the plutonic rock fragments commonly occurs.

Metamorphic Rock Fragments

Metamorphic rock fragments are rare in the sandstones. Grains of paragneiss (Figure 20D), granitic gneiss, stretched metamorphic quartz and cataclasite or mylonite (Wise et al.,
1984) occur in the sandstones (Figure 20E). Plutonic rock fragments and quartzo-feldspathic metamorphic fragments with granoblastic texture are often indistinguishable in thin section.

Mica

Biotite, muscovite and chlorite occur in the sandstones, but do not comprise an appreciable percentage of the total clast composition. Green, brown and red, titanium-rich pleochroic biotite varieties occur. Biotite occurs as plates or as laths and is locally altered to chlorite. Muscovite is colourless and occurs as lath-shaped grains or as fine-grained sericite. Chlorite is green and pleochroic and occurs as a replacement of biotite.

Granule and Pebble composition

Granules and pebbles from basal lag deposits of the sandstone units include shale, chert, granite, quartz gneiss, quartzite and mylonite.

HEAVY MINERALS

Heavy mineral analyses were completed for twenty-one samples, all of which are from the Stenkul Fiord outlier (Figures 3 and 8). Heavy mineral analyses were not performed on samples from Baumann Fiord or Vendom Fiord, however, heavy minerals identified from thin sections of the sandstone samples are in-
FIGURE 21. Thin section photomicrographs of heavy minerals, Eureka Sound Formation.

A. Zircon (Zr), zircon overgrowth on rounded brown detrital zircon grain, tourmaline (Tm), biotite (Bi) and kyanite (Ky) grains.

B. Garnet grain (Ga).

C. Kyanite grain (Ky).

D. Euhedral sillimanite grain (Sl).

E. Fibrous sillimanite grain (Sl).
Grain mounts of the heavy mineral fractions were examined optically and the results are presented on Table I. A few heavy mineral species could not be identified because they were too fine-grained or were not oriented on the thin section such that diagnostic optical properties could be determined. Opaque minerals were not considered in this study. The most common heavy minerals are zircon, tourmaline, garnet and rutile. Zircon is found in all samples from Stenkul Fiord, and comprises almost the entire heavy mineral suite in sample 12-79. The colour varies from colourless to yellow with some brown grains. The majority of the grains are well rounded with high relief, and sphericity ranges from moderate to extreme. A few subhedral to euhedral, slightly rounded grains occur. Zircons with abraded overgrowths on a rounded, detrital core are rarely observed.

Tourmaline occurs in almost all samples from Stenkul Fiord and is mainly composed of indicolite; schorlomite and elbaite rarely occur. Tourmaline ranges in shape from mostly angular, anhedral fragments, to subhedral, prismatic grains. Rutile is present in most samples and usually occurs as very well rounded grains although broken and angular grains are locally present. Garnet is the most abundant heavy mineral in all samples except 12-79. The garnet, which is probably almandine, is colourless to slightly pink in thin section, anhedral and angular with very few well rounded grains (Figure 20F). Sphericity is moderate. Garnet locally contains acicular inclusions of a colourless mineral with parallel extinction, likely sillimanite.
Minerals of the epidote group are present in moderate amounts as very fine sand to silt-size grains. Epidote is most abundant and occurs as subangular to well rounded grains. Zoisite and clinozoisite are less common and occur as subangular, short prismatic crystals to well rounded grains.

Kyanite and sillimanite are very common in the heavy mineral suites. Kyanite occurs as broad, elongate tabular plates (Figure 21A). The grains are always euhedral and occasionally show undulose extinction. Sillimanite principally occurs as very angular, subhedral to euhedral prismatic crystals (Figure 21B). Sillimanite rarely occurs as a fibrous mat of fine crystalline material (Figure 21C).

Staurolite grains are very angular and anhedral in shape, and euhedral sphene crystals with acute rhombic crystal form are present. Long, euhedral prismatic crystals of allanite are present in only a few samples.

**PALEOCURRENT ANALYSIS**

Three types of cross-stratification were identified and measured in the field for paleocurrent studies; planar tabular and trough cross-bedding and ripple cross-lamination.

A total of 331 current structures were measured at 6 sites in order to determine paleocurrent directions. They comprise 128 large-scale structures, mainly planar cross-beds but also trough
cross-beds, and 203 small scale structures. Rarely were more than fifteen sets of cross-beds observed at an outcrop. The majority of the sedimentary structures measured for paleocurrent direction are ripple cross-laminations (Table II).

The paleocurrent vector mean and confidence interval were calculated for each locality (Table II; Figure 24A-D). Vector means were calculated using the method outlined by Cheeney (1983) based on a von Mises distribution. All the data were found to be from a von Mises distribution at the 95 percent confidence level. The calculated k (concentration) parameter (Table II), which is analogous to the dispersion parameters of linear data, increases with increasing preferred orientation of the data, in this case, paleoflow directions.

PROVENANCE

The parent lithologies from which a sandstone is derived may contain a very diverse and complex mineralogy, however few heavy minerals survive weathering, transport and deposition (Blatt, et al., 1972). The mineralogical composition of a sandstone is mainly a function of the source rock(s) from which it was derived, and thus provides the most diagnostic information on sandstone provenance. A wide variety of other processes can have a significant effect on the composition of a sandstone and need to be considered when interpreting sandstone provenance. These processes include climate, relief and sedimentary environment, which determine the degree of chemical weathering and mechanical abrasion that the sand particles are subjected to.
TABLE II. Paleocurrent Data

<table>
<thead>
<tr>
<th>Section number</th>
<th>Interval (metres)</th>
<th>Sedimentary structure measurements</th>
<th>Total number of observations</th>
<th>Concentration factor &quot;K&quot;</th>
<th>Vector mean (degrees)</th>
<th>Confidence Interval (95% level)</th>
</tr>
</thead>
<tbody>
<tr>
<td>05</td>
<td>65 - 67</td>
<td>-</td>
<td>14</td>
<td>9.4</td>
<td>236</td>
<td>± 10</td>
</tr>
<tr>
<td>08</td>
<td>18 - 29</td>
<td>39</td>
<td>39</td>
<td>3.2</td>
<td>359</td>
<td>± 11</td>
</tr>
<tr>
<td>10</td>
<td>59 - 82</td>
<td>34</td>
<td>44</td>
<td>3.6</td>
<td>287</td>
<td>± 10</td>
</tr>
<tr>
<td>13</td>
<td>46 - 60</td>
<td>-</td>
<td>15</td>
<td>5.1</td>
<td>172</td>
<td>± 14</td>
</tr>
<tr>
<td>14</td>
<td>86 - 116</td>
<td>-</td>
<td>37</td>
<td>9.2</td>
<td>173</td>
<td>± 6</td>
</tr>
<tr>
<td>18</td>
<td>70 - 82</td>
<td>-</td>
<td>16</td>
<td>4.5</td>
<td>160</td>
<td>± 14</td>
</tr>
</tbody>
</table>
during deposition. Selective loss of certain mineral species also occurs after deposition by intrastratal solution. Several mineral species and suites of minerals are diagnostic of specific source rock lithologies and, when they occur, provide strong evidence for sandstone provenance. The size and habit of the constituent grains in a sandstone provide valuable clues as to their various origins and transportation histories.

Paleocurrent directions are somewhat less diagnostic of sandstone provenance, as they can be quite variable depending on the degree of sinuosity of the channel and the type of sedimentary structures from which the measurements are obtained (Miall, 1974).

Sandstone petrography, heavy mineral analysis and paleocurrent studies of the Eureka Sound Formation from the study area suggest that Precambrian granites and granulite facies metamorphic rocks of the Churchill Structural Province of the Canadian Shield, which crop out to the east of the study area, (Stockwell, 1982; Frisch, 1983; Figure 1) are the principal source rocks for most sandstones. Precambrian crystalline rocks to the south and Paleozoic clastic and carbonate rocks adjacent to the study area contributed a smaller proportion of detritus to the sandstones.

The angularity of most grains, the absence of conglomerates and the common occurrence of mechanically unstable grains suggest that the sandstones were deposited in low to moderate energy environments close to a high relief source which was subjected to rapid erosion. The climate was cool and wet in the
Paleocene and became warmer in the Eocene (Rouse, 1977), and thus did not have a significant effect on the mineralogy of the sandstones, as short transport distances and rapid deposition did not allow sufficient time for chemical decomposition.

The presence of quartz with acicular inclusions of rutile and microcline, microcline perthite, orthoclase and orthoclase microperthite, which are the dominant alkali feldspars, indicate a plutonic source. The relatively high abundance of perthite, which is very easily decomposed and disintegrated, indicates that the feldspar is probably derived from nearby granitic rocks rather than of recycled origin, as perthite has a low survival potential (Blatt, 1982). Albite twinning is always exhibited by plagioclase, which suggests a granitic parent rock (Blatt, 1982; Pittman, 1970). Myrmekite and graphic intergrowths of quartz and potassium feldspar are especially common in granites, and are observed in several sandstone samples.

Granite rock fragments are common in the samples, and occur both as sand-size grains and as granules and pebbles in basal lag deposits in the sandstones.

The heavy minerals sphene and allanite are both characteristic minerals of igneous rocks, although sphene may also occur in gneisses and schists rich in iron and magnesium minerals.

Metamorphic rocks were also a significant source for Eureka Sound sandstones. Most of the polycrystalline quartz grains and strained, monocrystalline quartz grains are likely of metamorphic origin, although quartz with undulose extinction can also
occur in plutonic rocks. Biotite, muscovite and chlorite are common in the sandstones. The micas are found in various igneous and metamorphic rocks, but occur most commonly in phyllites and schists. The red, titanium-rich biotite observed in some samples indicates a high grade metamorphic source terrane (Deer et al., 1966). Metamorphic rock fragments are more susceptible to weathering which likely accounts for their smaller concentrations in the sand size fraction. Paragneiss, granitic gneiss, schistose metamorphic quartz and cataclasite or mylonite rock fragments rarely occur. Granules and pebbles of quartz gneiss and mylonite also occur. Heavy minerals diagnostic of a metamorphic parent rock also occur, including almandine garnet, sillimanite, kyanite, staurolite and minerals of the epidote group.

Well rounded, monocrystalline quartz grains, grains with rounded quartz overgrowths and a few polycrystalline quartz grains with sedimentary textures indicate a sedimentary source. Euhedral quartz overgrowths which do not show any rounding occur on some well rounded quartz grains and were probably formed in situ and not reworked from older sedimentary rocks.

The presence of chert is indicative of an older sedimentary source. The chert may have been derived from chert nodules and beds in older limestones or reworked from older, chert-bearing sandstones. Because carbonate is easily removed by weathering and transportation, often the only evidence in the sandstone for the existence of carbonate rocks in the drainage basin is chert, derived from chert nodules or chert beds. Sedimentary rock fragments such as sandstone, siltstone, shale and carbonate are sus-
ceptible to abrasion, hence their presence in some samples indicates first cycle origin and short transport distances prior to deposition. Well rounded grains of the stable minerals zircon, tourmaline (group), rutile, and epidote (group) occur most commonly in the heavy mineral suites of the sandstones and indicate that the sediments were at least in part derived from older sedimentary rocks.

Precambrian rocks lying to the east of the study were the major source for the Eureka Sound sediments and are mainly comprised of migmatitic garnet-cordierite-sillimanite-biotite gneiss, anatexic peraluminous granite and pyroxene gneiss (Frisch, 1983). The mineral composition of the sandstones closely reflects the mineralogy of the Precambrian Shield rocks with a few notable exceptions. Cordierite, green spinel and orthopyroxene are common constituents of the gneisses and granites but are either not present or were not recognized in the sandstones from the Eureka Sound Formation. Cordierite is difficult to distinguish from quartz in thin section and orthopyroxene is easily destroyed during sediment transport and is therefore rare in sedimentary rocks. Green spinel is opaque in thin section and may occur in the samples but was not recognized.

Sedimentary rock fragments and polycyclic quartz grains were undoubtedly derived from older carbonate and clastic rocks which surround Eureka Sound outliers in the vicinity of Stenkul Fiord (Figure 3). Sedimentary rock fragments have a low survival potential in the depositional environment and are therefore rare in the sandstones.
In summary, most sandstones from the Eureka Sound Formation at Stenkul Fiord were derived from Precambrian granitic and metamorphic rocks of the Canadian Shield which lie approximately 70 km to the east and 100 km to the south of the study area. However, well rounded quartzose grains with quartz overgrowths, chert and sedimentary rock fragments indicate that the sandstones were at least partly derived from Lower Paleozoic carbonate and clastic sedimentary rocks which were probably exposed in the vicinity of Stenkul Fiord at various times during deposition of the Eureka Sound Formation.
DIAGENESIS AND VITRINITE REFLECTANCE

Strata of the Eureka Sound Formation in the vicinity of Vendom, Stenkul, Baumann and Sor Fiords are not lithified, with the exception of a few localized zones that have been cemented by siderite or calcite.

The essentially unconsolidated aspect of the sandstones of the Eureka Sound Formation is not unique to the study area. Elsewhere in the Arctic Archipelago, Eureka Sound and older sandstones commonly lack appreciable cement (Bustin, 1977; Miall, 1976; 1979a). It is not clear whether the lack of cementation is a result of decementation and dissolution of previously existing carbonate cement, or whether pervasive cementation never occurred in the Eureka Sound Formation. Etched surfaces of quartz grains resulting from replacement by carbonate and later carbonate dissolution have been cited as evidence of decementation (Pettijohn, 1975). Etched quartz grain surfaces are not observed in the unconsolidated sandstones from Stenkul Fiord. Therefore, it is most unlikely that the sandstones of the Eureka Sound Formation were ever cemented. Locally cemented sandstones and siltstones occur only towards the base of the stratigraphic succession and were deposited in brackish water environments.

Although rare euhedral quartz overgrowths occur on well rounded grains and are considered to have formed in situ, quartz cementation does not occur even locally in the sandstones. Coal rank studies suggest that these sediments have not been buried deeply, probably less than 800 m (Bustin, in prep.), which would
explain the lack of pressure solution at grain boundaries.

Siderite cemented sandstones occur in zones containing high amounts of organic plant material. Decay of organic material by micro-organisms uses oxygen, creating local anaerobic reducing environments. Under reducing conditions, carbon dioxide and ferrous iron, provided by iron-bearing silicates, form siderite (Teichmüller, 1982).

Vitrinite reflectance measurements of the coal seams in the Stenkul Fiord area allow inference on the maximum depth of subsidence of the sedimentary pile and the subsequent amount of uplift and erosion, by relating the vitrinite reflectance values to a locally derived coalification gradient. Vitrinite reflectance values were obtained from seven coal samples from the Stenkul Fiord outlier and five coal samples from the Baumann Fiord outlier. The results are shown on Table III. The coal rank varies from 0.15% Romax to 0.3% Romax. Relating these values to the coalification gradient derived by Bustin (in prep.) for Eureka Sound sediments at Strathcona Fiord, located approximately 150 km north of Stenkul Fiord, the maximum depth of burial is on the order of 800 m. The amount and rate of erosion in the Stenkul Fiord area are discussed in a later section of the paper.
<table>
<thead>
<tr>
<th>Location</th>
<th>Sample number</th>
<th>Depth (m)</th>
<th>% R\textsubscript{max}</th>
<th>Standard deviation (95% level)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stenkul</td>
<td>18-136</td>
<td>35</td>
<td>0.15</td>
<td>0.02</td>
</tr>
<tr>
<td>Stenkul</td>
<td>18-133</td>
<td>50</td>
<td>0.20</td>
<td>0.02</td>
</tr>
<tr>
<td>Stenkul</td>
<td>18-132</td>
<td>82</td>
<td>0.20</td>
<td>0.02</td>
</tr>
<tr>
<td>Stenkul</td>
<td>14-147</td>
<td>38</td>
<td>0.24</td>
<td>0.03</td>
</tr>
<tr>
<td>Stenkul</td>
<td>04-149</td>
<td>23</td>
<td>0.23</td>
<td>0.02</td>
</tr>
<tr>
<td>Stenkul</td>
<td>04-155</td>
<td>80</td>
<td>0.29</td>
<td>0.02</td>
</tr>
<tr>
<td>Stenkul</td>
<td>07-55</td>
<td>180</td>
<td>0.30</td>
<td>0.03</td>
</tr>
<tr>
<td>Baumann</td>
<td>22-189</td>
<td>5</td>
<td>0.25</td>
<td>0.03</td>
</tr>
<tr>
<td>Baumann</td>
<td>22-186</td>
<td>103</td>
<td>0.21</td>
<td>0.03</td>
</tr>
<tr>
<td>Baumann</td>
<td>22-165</td>
<td>281</td>
<td>0.19</td>
<td>0.03</td>
</tr>
<tr>
<td>Baumann</td>
<td>22-164</td>
<td>329</td>
<td>0.24</td>
<td>0.03</td>
</tr>
<tr>
<td>Baumann</td>
<td>22-156</td>
<td>476</td>
<td>0.24</td>
<td>0.02</td>
</tr>
</tbody>
</table>
FOSSIL CONTENT AND AGE

The Eureka Sound Formation in the vicinity of Stenkul Fiord yielded a considerable amount of palynological and paleontological data. Palynology provides the most precise tool for determining the ages of these sediments. Age determinations based on paleontological evidence were not as precise, but were consistent with the ages obtained using palynology. Both palynological and paleontological data provide information on the paleoclimatic and paleoenvironmental conditions which existed during deposition of the Eureka Sound Formation in the study area.

PALYNOLOGY

Selected samples were processed to obtain palynomorph assemblages for dating parts of the stratigraphic sections and to provide evidence for paleoclimatic and paleoenvironmental conditions. These were identified by Dr. G.E. Rouse of the University of British Columbia, and related to the palynozones established by Rouse (1977) from the Remus Creek section of the Eureka Sound Formation west of Eureka weather station on central Ellesmere Island. The sample numbers and ages are presented here. The recognized palynomorphs are listed in the Appendix.
<table>
<thead>
<tr>
<th>SAMPLE NUMBER</th>
<th>AGE</th>
<th>PALYNOZONE</th>
</tr>
</thead>
<tbody>
<tr>
<td>83-18-134</td>
<td>Late Eocene</td>
<td>E-2</td>
</tr>
<tr>
<td>83-22-188</td>
<td>Early to early Middle Eocene</td>
<td>E-1</td>
</tr>
<tr>
<td>83-22-157</td>
<td>Late Middle to early Late Paleocene</td>
<td>P-3</td>
</tr>
<tr>
<td>83-23-178</td>
<td>Late Paleocene</td>
<td>P-4</td>
</tr>
<tr>
<td>83-07-58</td>
<td>mid- Paleocene</td>
<td>P-2</td>
</tr>
<tr>
<td>83-07-54&amp;56</td>
<td>mid- Paleocene</td>
<td>P-2</td>
</tr>
</tbody>
</table>

The palynomorph assemblages are mainly terrestrial, except for 18-134 and 22-188. These two samples contain several contemporary dinoflagellate cysts as well as a very diverse and well preserved spore pollen assemblage, indicating deposition very near shore, close to well developed plant communities.

Of added interest is the presence of Maastrichtian - Campanian recycled palynomorphs in the oldest samples (07-54&56). Such recycled Upper Cretaceous palynomorphs are widespread in the lower sections of the Eureka Sound and equivalent formations in the Arctic (Rouse, 1977, p. 48; Norris and Miall, 1984).

Prior to this investigation, the youngest conclusively dated Eureka Sound strata seen in outcrop were of Middle Eocene age (Thorsteinsson and Tozer, 1970; Bustin, 1977; Rouse, 1977). Late Eocene and Oligocene palynomorph assemblages have been re-
cognized in some wells in the Mackenzie Delta (Rouse, 1977), however the recognition of a Late Eocene palynomorph assemblage at Stenkul Fiord is the first known occurrence of Upper Eocene Eureka Sound strata in outcrop.

PALEONTOLOGY

Several specimens of fossil plants and animals (both vertebrate and invertebrate) were collected from the Eureka Sound beds at Stenkul Fiord.

Ironstone nodules and beds which occur throughout the stratigraphic sequence commonly contained leaf imprints and molds and casts of branches (Figure 23B) and reproductive parts of the paleoflora. Leaves and reproductive parts collected from the study area were identified by Dr. G.E. Rouse of the University of British Columbia and are listed below. Several plant fossils are shown on Figures 22 and 23. Modern relations are shown in brackets following each name.

LEAVES

Metasequoia occidentalis (dawn redwood), Figure 22A
Crednaria spectabilis (relations unknown)
Phyllites cf. disturbans (relations unknown), Figure 22B
cf. Sapindus affinus (soapberry)
Viburnum tilioides (arrow-wood), Figure 22C
FIGURE 22. Fossil remains, Eureka Sound Formation.

A. *Metasequoia occidentalis* (dawn redwood).

B. *Phyllites* cf. *disturbans* (relations unknown).

C. *Viburnum tilioides* (arrow-wood).

D. *Nelumbium montanum* (sacred bean).

E. Unionid pelecypod cf. *Plesielliptio priscus* (Meek and Hayden).

F. Unidentified trace fossils.
REPRODUCTIVE PARTS

female cone of *Metasequoia occidentalis* (dawn redwood), Figure 23A

*Nelumbium montanum* (sacred bean), Figure 22D

conifer male cone cf. spruce

cf. endocarp and seed of *Carya* (hickory)

cf. fruiting head of *Liquidambar* sp. (sweetgum)

The nodules and beds of ironstone also contained faunal remains. Imperfect and entire samples of unionid pelecypods frequently occurred as molds and casts within the concretionary units (Figure 22E). Dr. L.S. Russell of the Royal Ontario Museum identified one of the specimens collected as cf. *Plesielliptio priscus* (Meek and Hayden), which is of Paleocene age. Unionid pelecypods are freshwater clams, and *Plesielliptio priscus* at least appeared to have preferred active stream channels to quiet, standing water environments (L.S. Russell, personal communication, 1984). Unionid pelecypods from outcrops of the Eureka Sound Formation near the head of Strathcona Fiord on Ellesmere Island have previously been reported by Dawson and others (1976).

Trace fossils preserved in an ironstone concretion are shown on Figure 22F. The trace fossils were recovered from non-marine beds on the east side of Stenkul Fiord, but have not been identified.

The discovery and identification of a fossil tooth from Eureka Sound beds on the east side of Stenkul Fiord provides
FIGURE 23. Fossil remains, Eureka Sound Formation

A. Female cone of *Metasequoia occidentalis*

B. Ironstone cast of a branch.

C. Lower left canine tooth of *Coryphodon*, lateral views.
evidence that a vertebrate fauna inhabited this area. The tooth (Figures 23C, D), identified by Dr. L.S. Russell of the Royal Ontario Museum, is the lower left canine of Coryphodon, a large hippopotamus-like mammal measuring 2.5 metres from nose to base of tail (Kurtén, 1971). Coryphodon is presumed to have been mainly a vegetable feeder, but was probably omnivorous and not limited to any specific type of food (Cope, 1884).

Assemblages of terrestrial vertebrates, including representatives of Coryphodon have been recovered from the Eureka Sound Formation in the vicinity of Strathcona Fiord on central Ellesmere Island by West et al. (1977). The fossil tetrapods described by West et al. (1977) occur in two discrete faunal levels. The vertebrate assemblage of the lower level, which includes Coryphodon, suggests a late Early Eocene age. The upper level contains a smaller assemblage and is considered to be of Middle Eocene age.

PALEOCLIMATE

The fossil content of the Eureka Sound Formation in the study area is useful for determining not only the age of the strata, but also the climatic conditions which must have existed during deposition.

Palynology is the most useful for interpretation of the paleoclimate of all of the fossils examined. Fossil leaves and reproductive parts, Unionid pelecypods and the fossil tooth from Coryphodon substantiate the paleoclimatic interpretations based
on palynology.

Palynomorph assemblages from the study area have been related to the palynozones constructed by Rouse (1977) in a previous section. The similarity between the palynomorph assemblages from the Eureka Sound Formation in the study area and the assemblages from the Remus Creek section suggests that similar climatic conditions must have prevailed in both areas during the Paleogene.

The Early to mid-Paleocene was dominated by a cool and probably wet climate as indicated by the occurrence of triradial and bladdered and taxodiaceous conifer pollen (Rouse, 1977; this study, Appendix). A marked warming during mid- to Late Paleocene is indicated by an increase in tricolporate pollen and the appearance of *Pistillipollenites macregorii*, possibly related to the genus *Tournefortia*, presently native to the subtropical parts of Central America (Rouse, 1977).

By Early to Middle Eocene time, the Arctic regions were favoured by a subtropical to warm temperate climate, as suggested by the occurrence of species such as *Rhoiipites latus* and *Pistillipollenites* (Rouse, 1977). Wolfe (1980) also proposed similar climatic conditions for Paleogene floras in Alaska. An even stronger line of evidence to support this interpretation comes from the rich lower and higher vertebrate record of the Early-Middle Eocene Eureka Sound Formation on Ellesmere Island (Dawson et al., 1976; West, et al., 1977; Estes and Hutchison,
Evidence from this study that Coryphodon existed in the vicinity of Stenkul Fiord suggests that an abundant vertebrate fauna may also have existed in the study area on southern Ellesmere Island in Early to Middle Eocene time. Thus both palynological results and vertebrate faunal remains indicate a subtropical to warm temperate climate in the Arctic during Early to Middle Eocene time, and a lowland, coastal habitat with extensive broad leaved vegetation in the Ellesmere Island area (Estes and Hutchison, 1980).

A major climatic deterioration occurred at the end of the Eocene, and the vegetation in the Alaskan region comprised a mixed broad leaved deciduous and coniferous forest (Wolfe, 1980).
DEPOSITIONAL HISTORY AND PALEOGEOGRAPHY

Eureka Sound strata in the vicinity of Stenkul, Vendom, Baumann and Sor Fiords were deposited unconformably on Devonian and older sedimentary rocks. The depositional history of the Eureka Sound Formation on southern Ellesmere Island can be divided into two major transgressive-regressive cycles, with at least two local marine incursions toward the top of the stratigraphic section. Palynological dating of the sediments provides constraints on the timing of these events, and permits comparison with paleogeographic interpretations proposed by previous authors (Bustin, 1977; Miall, 1981).

The first transgressive-regressive cycle lasted from late Early (?) Paleocene to Late Paleocene. The second cycle occurred from Late Paleocene to Late Eocene. Schematic paleogeographic maps (Figures 24A-D) depict the paleogeography and tectonic elements of the eastern Arctic from late Early (?) Paleocene to Late Eocene time.

Late Early (?) to mid- Paleocene

The basal strata in the study area crop out at the base of section 07 and are of mid-Paleocene age (G. Rouse, personal communication, 1984). Late mid-Paleocene strata occur at the base of section 22 south of Baumann Fiord. These strata are at least in part contemporaneous with brackish marine Eureka Sound strata which crop out north of Makinson Inlet (Riediger et al., 1984) and with the shallow marine and brackish water strata of Member
FIGURE 24. Schematic paleogeographic maps

LEGEND
- Alluvial plain deposits
- Marine deposits
- Highland source areas
- Measured paleocurrent direction
- Inferred paleocurrent direction

Facies change
SFB Strand Fiord Basin
RB Remus Basin
PMA Princess Margaret Arch
PCS Precambrian Canadian Shield

late Early (?) to mid-Paleocene
mid- to Late Paleocene
Late Paleocene
Early to Late Eocene
III of West and others (1981; Lithofacies Asemblage A of Miall, 1981) at Strathcona Fiord. The uppermost beds of Member III at Strathcona Fiord are of mid-Paleocene age (G. Rouse, personal communication, 1984).

A calcite cemented sandstone bed, which occurs in mid-Paleocene strata on the east shore of Stenkul Fiord, contains abundant reworked detrital quartz grains and carbonate fragments and indicates that Paleozoic strata which lie northwest of the study area were being eroded at that time. This highland area may have been uplifted near the end of the Early Paleocene, coeval with uplift of ancestral Princess Margaret Arch (Bustin, 1982). Lower Paleocene strata may occur in the Stenkul Fiord area but are not exposed.

Miall (1981) suggested a protected marine embayment or estuarine environment of deposition for the strata of Lithofacies Asemblage A in the Strathcona Fiord area. It is suggested that this marine embayment occupied a shallow valley in the axis of the Vendom syncline, between Paleozoic strata on the west and Precambrian crystalline rocks on the east, and extended southward from Vesle and Strathcona Fiords to southern Ellesmere Island along the axis of the Schei syncline during late Early (?) to mid-Paleocene time (Figure 24A).

The Vendom and Schei synclines were formed during the Ellesmerian orogeny (McGill, 1974), and appear to have been topographic lows which received clastic sediments at various times. Farther north, on Fosheim Peninsula, alluvial plain and deltaic sedimentation occurred during this time (Bustin, 1977). A cool
and wet climate prevailed on Ellesmere Island during Early to mid-Paleocene time (Rouse, 1977).

Mid- to Late Paleocene

From middle to Late Paleocene time, relative uplift of Precambrian crystalline rocks of the Canadian Shield to the east of the study area resulted in the southwesterly withdrawal of the marine embayment. Fluvial sandstones and extensive peat deposits prograded over mid-Paleocene brackish water strata in the Stenkul Fiord area. Paleocurrent data indicates that the alluvial plain sediments were deposited by westerly-flowing rivers (Figure 24B) and sandstone petrographic and heavy mineral analyses indicate that uplifted Precambrian rocks to the east were the dominant source lithologies for the sandstones. An abundance of freshwater pelecypods are further evidence of the nonmarine environment which existed near Stenkul Fiord at this time. Thick, laterally extensive peat deposits formed in backswamps on the alluvial plain and palynological data (Rouse, 1977) indicate a climatic warming trend from middle to Late Paleocene.

Late Paleocene

During Late Paleocene time, a marine transgression resulted in the northward migration of coastal marine facies over middle to Late Paleocene alluvial plain sediments (Figure 24C). Lithofacies Assemblage IV at Stenkul Fiord and strata at the base of the section in the Baumann Fiord outlier comprise la-
goonal, marsh, flood-tidal delta and washover sheet sand deposits. At Stenkul Fiord, the prominent white sandstones of Lithofacies Assemblage IV interfinger with lagoonal and fine-grained alluvial plain deposits to the east, and thus represent the eastern extent of the Late Paleocene marine transgression (Figure 24C).

**Early to Late Eocene**

Early to Late Eocene nonmarine and marine strata are preserved in the Stenkul and Baumann Fiord outliers. Eureka Sound strata in the Sor Fiord outlier are possibly of similar age based on lithological similarity, but in the absence of palynological age dates, this correlation is only tentative.

By Early Eocene time, the sea had retreated to the south, possibly as a result of renewed uplift to the north and east of the study area. Alluvial plain facies prograded over the area, and paleocurrent data indicates that the predominant paleoflow direction at this time was mainly from north to south (Figure 24D). However, sandstone petrography and heavy mineral analyses indicate that Precambrian rocks to the east persisted as the major sediment source. Such evidence suggests that at least the southern portion of the north-south valley in the axis of the Vendom syncline, which was formerly occupied by the late Early (?) to mid-Paleocene shallow marine embayment contained a major trunk stream, possibly similar to the Spirit River Channel envisioned by McLean (1977) for deposition of the Lower Cretaceous Cadomin Formation of the Rocky Mountain Foothills, and by
Ethridge and others (1981) for the Wasatch (Eocene) and upper Fort Union (Late Paleocene) Formations in the Powder River Basin, Wyoming. Streams and alluvial fans flowing westward from Precambrian Shield source rocks and, to a lesser extent eastward from Paleozoic strata, fed the trunk stream (Figure 24D). The trunk stream flowed southward through the Stenkul Fiord area, depositing alluvial plain sediments, and then probably swung towards the west down the axis of the Schei Syncline (Figure 24D). An outlier of Eureka Sound strata west of Okse Bay on southwestern Ellesmere Island may have been deposited by this westerly-flowing fluvial system.

A northerly paleocurrent direction was obtained from a wedge-shaped channel sandstone body which crops out on the south shore of Stenkul Fiord. This suggests intermittent uplift of Precambrian Shield rocks south of the study area (Figure ?).

Two marine dinoflagellate cyst assemblages of Early to early Middle Eocene and Late Eocene age occur in thin (50 cm) mudstone beds in the Baumann Fiord and Stenkul Fiord outliers respectively, which suggests that there were at least two minor marine incursions into the study area during Eocene time.

From Late Paleocene until at least Middle Eocene time, alluvial plain sedimentation persisted north of the study area, with relatively rapid sedimentation in the central region of the Remus Basin at Fosheim Peninsula (Bustin, 1977). Fluvial conditions existed in the Strathcona Fiord area during deposition of Member IV of West and others (1981) in Early to Middle Eocene time.
The climate during the Eocene was subtropical to warm temperate which supported an abundant vertebrate fauna (West et al., 1977; Estes and Hutchison, 1980; McKenna, 1980) and a diverse vegetation, and was favourable to the development of thick peat deposits at Fosheim Peninsula, Strathcona Fiord and Stenkul Fiord.

**Post-Eocene Erosion**

The amount of erosion in the Stenkul Fiord area can be estimated by relating vitrinite reflectance values obtained from coal seams in the Stenkul Fiord area to a local coalification gradient. The maximum coal rank in the Stenkul Fiord area is 0.3% Romax, and was obtained from a coal seam at the base of the section, which is presently overlain by approximately 180 m of sediment. Relating this value to the coalification gradient derived by Bustin (in prep.) for Eureka Sound strata at Strathcona Fiord, the maximum depth of burial of the sediments at Stenkul Fiord is estimated to be 800 m. The age of a mudstone bed lying directly below this coal seam was determined to be mid-Paleocene in age. Therefore, something on the order of 620 m of strata were removed over a period of approximately 60 million years, which translates into an average denudation rate of about 10 m/Ma.
SUMMARY AND CONCLUSIONS

The Eureka Sound Formation occurs on southern Ellesmere Island as outliers along Vendom, Stenkul, Baumann and Sor Fiords. The strata are flat-lying to gently dipping and the structure is characterized by broad open folds and minor thrust faults. The total composite thickness of the Eureka Sound Formation in the study area is estimated to be 450 m. The stratigraphic succession comprises predominantly nonmarine strata, but marine units occur locally.

Two transgressive-regressive cycles are recognized. Lagoonal and back barrier deposits occur at the base of the section and are of late Early (?) Paleocene to mid-Paleocene age. Ancestral Princess Margaret Arch on Axel Heiberg Island was a strong positive tectonic element at this time and shed clastics to the south and southeast into the Stenkul Fiord area. Uplift of crystalline rocks of the Canadian Shield to the east resulted in progradation of alluvial plain facies over the brackish water deposits. Thick peat deposits were formed on the alluvial plain.

A second marine transgression occurred in Late Paleocene time. A thin (less than 10 m) sequence of quartzose sandstones and white weathering mudstones were deposited in the Stenkul Fiord area in a back barrier environment. Rivers flowing southward on an alluvial plain prograded over the brackish water units during Eocene time. The Precambrian Shield rocks to the east were the main source rocks which shed clastic detritus to
the west into a major trunk stream flowing down the axes of the Vendom and Schei Synclines. Intermittent uplift of Precambrian Shield rocks south of Stenkul Fiord resulted in streams which flowed north into the Stenkul Fiord area.

The presence of marine dinoflagellate cyst assemblages in mudstone samples from the Stenkul and Baumann Fiord outliers suggests two marine incursions into the Stenkul Fiord area, in Early to early Middle and Late Eocene time. The identification of a Late Eocene marine dinoflagellate cyst assemblage at Stenkul Fiord represents the only conclusively dated occurrence of Late Eocene strata of the Eureka Sound Formation in the Canadian Arctic Islands.

Vitrinite reflectance values, related to a local coalification gradient, provided an estimate of approximately 620 m of strata that have been removed since the end of the Paleocene, which represents an average denudation rate of 10 m/Ma in the study area.

The climate during the Eocene was subtropical, and supported a lush flora and likely an abundant vertebrate fauna similar to that reported from the Strathcona Fiord area (West et al., 1977; McKenna, 1980; Estes and Hutchison, 1980).
REFERENCES CITED


Beard, D.C. and Weyl, P.K., 1973, Influence of texture on poro-


Cant, D. J., 1982, Fluvial facies models and their application; In Scholle, P.A. and Spearing, D., eds., Sandstone depositional environments; American Association of Petroleum
Geologists, Memoir, 31, pp. 115-137.


Hayes, Miles O., 1979, Barrier island morphology as a function of tidal and wave regime; In Leatherman, S.P., ed., Barrier islands—from the Gulf of St. Lawrence to the Gulf of Mexico; Academic Press, New York, pp. 1-27.


Hills, L.V. and Fyles, J.G., 1973, The Beaufort Formation,
Canadian Arctic Islands, Programs and Abstracts, Symposium on the Geology of the Canadian Arctic; Canadian Society of Petroleum Geologists-Geological Association of Canada, pp. 11.


Hubbard, D.K. and Barwis, J.H., 1976, Discussion of tidal inlet sand deposits-examples from the South Carolina coast, In Hayes, M.O. and Kwana, T.W., eds., Terrigenous clastic depositional environments: some modern examples; University of South Carolina Department of Geology, Coastal Research Division, pp. II-128-II-142.

Ingersoll, R.V. and Suczek, C.A., 1979, Petrology and provenance of Neogene sand from Nicobar and Bengal fans, DSDP Sites 211 and 218; Journal of Sedimentary Petrology, v. 49, pp. 1217-1228.

Ingersoll, R.V., Bullard, T.F., Ford, R.L., Grim, J.P., Pickle,


McCann, S.B., 1979, Barrier islands in the southern Gulf of St. Lawrence; In Leatherman, S.P., Barrier islands—from the Gulf of St. Lawrence to the Gulf of Mexico, Academic Press, New York, pp. 29-63.


Miall, A.D., 1974, Paleocurrent analysis of alluvial sediments—a discussion of the directional variance and vector magnitude; Journal of Sedimentary Petrology, v. 44, pp. 1174-

Miall, A.D., 1979a, Mesozoic and Tertiary geology of Banks Island, Arctic, Canada; the history of an unstable craton margin; Geological Survey of Canada Memoir 387, 235 p.


Miall, A.D., 1984, Variations in fluvial style in the Lower Cenozoic synorogenic sediments of the Canadian Arctic Islands; Sediment. Geol., v. 38, pp. 499-523.


Norris, G. and Miall, A.D., 1984, Arctic biostratigraphic heterochroneity; Science, v. 224, pp. 174-175.


Pittman, E.D., 1970, Plagioclase feldspars as an indicator of


Stockwell, C.H., 1982, Proposals for time classification and
correlation of Precambrian rocks and events in Canada and adjacent areas of the Canadian Shield. Part I. A time classification of Precambrian rocks and events; Geological Survey of Canada Paper 80-19, 135 p.


Troelsen, J.C., 1950, Contributions to the geology of northwest Greenland, Ellesmere Island and Axel Heiberg Island; Meddelelser om Groenland, B.D. 149, Nr. 7.

Van der Plas, L. and Tobi, A.C., 1965, A chart for judging the reliability of point counting results; American Journal of Science, v. 263, pp. 87-90.


West, R.M., Dawson, M.R. and Hutchison, J.H., 1977, Fossils from the Paleogene Eureka Sound Formation, N.W.T., Canada: occurrence, climatic and paleogeographic implications; In
Paleontology and plate tectonics; Proceedings of a symposium, Milwaukee Public Museum, Special publications in biology and geology, No. 2, pp. 77-93.


PART II. MAKINSON INLET AREA

ABSTRACT

Discovery of a post-orogenic coarse-grained sandstone and pebble to cobble conglomerate unit on south-central Ellesmere Island provides important new evidence for the chronology of the Eurekan Orogeny in the eastern Arctic Archipelago. Palynological studies indicate an Early Miocene age for these deposits, which rest with marked angular unconformity on mid-Paleocene strata. In adjacent areas, strata of the Eureka Sound Formation as young as Late Eocene are folded, thereby bracketing the major orogenic phase of the Eurekan Orogeny on southern Ellesmere Island as post-Late Eocene to pre-Early Miocene. Furthermore, the occurrence of the coarse-grained sandstone and conglomerate deposits indicates an Early Miocene phase of epeirogenic relative uplift of southeastern Ellesmere Island and possible coeval tectonism along the margin of Baffin Bay.

The discovery and dating of these post-orogenic deposits provide additional chronological evidence for tectonism that constrains paleogeographic and paleo-plate reconstructions of the eastern Arctic during the Tertiary.
INTRODUCTION

The Eurekan Orogeny was named for latest Cretaceous and Tertiary tectonic events in the Queen Elizabeth Islands by Thorsteinsson and Tozer (1970). Subsequent studies in the eastern Queen Elizabeth Islands have differentiated three orogenic phases: 1) a Late Cretaceous to Early Paleocene phase of uplift of intrabasin arches and Sverdrup Rim; 2) a Late Eocene to Miocene- (?) Pliocene phase of compression; and 3) a later phase of uplift of some arches (Balkwill et al., 1975; Balkwill, 1978; Balkwill and Bustin, 1980; this study). The chronology of the main compressional phase (phase two) is based on the occurrence of folded and faulted Late Eocene strata of the Eureka Sound Formation but the only conclusively dated post-phase two deposits are erosional outliers of Miocene- (?) early Pliocene age on central Axel Heiberg Island (Bustin, 1982) and Early Miocene age north of Makinson Inlet (Riediger et al., 1984; this study) that have been assigned to the Beaufort Formation.

The purpose of this study is to describe the occurrence of an angular unconformity and post-phase two deposits on south-central Ellesmere Island, north of Makinson Inlet. These strata provide additional evidence for the chronology of phase two of the Eurekan Orogeny and a later phase of relative uplift of at least part of eastern Ellesmere Island.
REGIONAL SETTING

The regional geology of the Queen Elizabeth Islands has been summarized by Tozer and Thorsteinsson (1970), Drummond (1973) and Trettin and Balkwill (1979; Figure 1). Basement in the eastern Queen Elizabeth Islands consists of granulite grade gneisses of the Churchill Province of the Canadian Shield (Balkwill and Bustin, 1980). Overlying basement is the Franklinian succession composed of Upper Proterozoic and Lower Paleozoic sediments deformed during the Middle Devonian to Early Carboniferous Ellesmerian Orogeny (Trettin and Balkwill, 1979). The Sverdrup Basin is an elongate pericratonic depression of Early Carboniferous and younger age developed on deformed Franklinian rocks. The Sverdrup basin contains a maximum thickness of 13 km of predominantly clastic rocks in the depocentre on western Axel Heiberg and Amund Ringnes Islands and thins towards the margins of the basin.

During the initial phase of the Eurekan Orogeny, commencing in the Late Cretaceous, the Sverdrup Basin was segmented into several sub-basins by uplift of the Cornwall and Princess Margaret Arches and the northern rim of the Sverdrup Basin (Balkwill, 1978). Within these sub-basins sequences of mainly non-marine clastic sediments up to 3.5 km thick accumulated, which collectively have been assigned to the Eureka Sound Formation (Miall, 1981). By Paleocene to Early Eocene time, the Queen Elizabeth Islands had been segmented into at least seven sub-basins (Miall, 1981) with different local source terrains and facies. Phase two of the Eurekan Orogeny resulted in shor-
trending of Late Eocene and older strata by upright to overturned folds and reverse faults. The folds and faults in southeastern Ellesmere Island face to the southeast towards a salient of Precambrian basement whereas on central Ellesmere Island folds and faults face to the east and on Axel Heiberg Island to the southwest or northeast parallel to Princess Margaret Arch (Figure 1). On northern Ellesmere Island the structural grain trends northeasterly and some structures such as the Lake Hazen Fault were clearly active in post-Eocene times, although the timing has yet to be resolved (Miall, 1979). The western limit of compression has been considered the western coast of Axel Heiberg Island (Balkwill and Bustin, 1980). The only conclusively dated post-phase two deposit in the northeastern Queen Elizabeth Islands is an erosional outlier of Miocene-(?)Pliocene age on central Axel Heiberg Island assigned to the Beaufort Formation (Bustin, 1982; Figure 25). Elsewhere, the Beaufort Formation mainly crops out along the northwest Arctic Coastal Plain.

The study area, located on south-central Ellesmere Island (Figures 1 and 25), is east of the present eastern margin of the Sverdrup Basin. Here, strata of the Franklinian succession, erosional outliers of the Eureka Sound Formation and younger deposits crop out. The younger deposits, dated here as Early Miocene, are assigned to the Beaufort Formation in keeping with the general use of Beaufort Formation for Neogene sediments in the Canadian Arctic Archipelago (Hills and Fyles, 1973; Bustin, 1982). Immediately east of the study area, nunataks of orthopyroxene granites and granitic gneisses of the Churchill
FIGURE 25. General geologic map of the study area (geology in part modified from Frisch, 1983 and Okulitch, 1982).
Province are exposed above the ice cap (Frisch, 1983).

**STRATIGRAPHY**

Outliers of the Eureka Sound and Beaufort Formations crop out north of Makinson Inlet on south-central Ellesmere Island. At this locality, coarse-grained clastics, here assigned to the Beaufort Formation, rest with angular unconformity on folded fine-grained sediments of the Eureka Sound Formation (Figure 26).

**Eureka Sound Formation**

The Eureka Sound Formation is divisible into two lithofacies in the study area: a) a lowermost micaceous siltstone-calcareous sandstone lithofacies, and 2) a calcareous mudstone-siltstone-sandstone lithofacies which overlies it. The contact between the two lithofacies is covered at this locality.

**Micaceous siltstone-calcareous sandstone lithofacies**

The lowest strata which crop out north of Makinson Inlet generally coarsen upward from micaceous siltstones with interbedded calcareous sandstones to very fine- to fine-grained sandstones and minor amounts of mudstone and coal (Figures 27 and 28A). The micaceous siltstones exhibit fine parallel lamination and contain abundant plant fragments and rare marine pelecypod shells. Calcareous sandstones occur as thin, resistant, well-
FIGURE 26. Angular unconformity north of Makinson Inlet.

Coarse-grained clastic sediments of the Early Miocene Beaufort Formation rest with angular unconformity on folded strata of the late Early to early mid-Paleocene Eureka Sound Formation north of Makinson Inlet. Stars indicate locations of samples collected for palynological and vitrinite reflectance analyses.
Siltstone: dk brown, micaceous; 30 cm coal seam.
Sandstone: med brown, silty, micaceous, plant fragments, fine planar lamination.

Interbedded: Coal(95%): woody. Mudstone(5%): plant fragments. Mudstone sample 16-105.
Sandstone: dk brown, vfg, silty, thinly bedded, carb. debris; rare lenses of sandstone, vfg, calc., 5-15 cm thick, 5-15 m long.

Interbedded:
Siltstone(90%): dk brown, micaceous, fine planar lamination.
Sandstone(10%): lt grey, vfg, calc., plant fragments, fine planar lamination.
Sandstone: lt brown, fg, rare coal clasts.
Coal: woody mudstone splits. Coal sample 16-103.
Interbedded:
Siltstone(90%): dk brown, micaceous, fine planar lamination.
Sandstone(10%): lt grey, vfg, calc., plant fragments, fine planar lamination.
Sandstone: med brown, fg, carb. debris, coal spar, convolute bedding.
Siltstone: lt brown, micaceous, carb. debris.
Sandstone: med brown, vfg, micaceous.

Interbedded:
Sandstone(90%): dk brown, micaceous, fine planar lamination.
Sandstone(10%): lt grey, vfg, calc., plant fragments, pelecypod fragments, fine planar lamination.

FIGURE 27. Stratigraphic section 16 through lowermost Eureka Sound strata exposed north of Makinson Inlet.
FIGURE 28. Stratigraphy and sedimentary structures of the Eureka Sound and Beaufort Formations north of Makinson Inlet.

A. Micaceous siltstone-calcareous sandstone lithofacies of the Eureka Sound Formation.

B. Recessive micaceous siltstone and resistant calcareous sandstone beds of the Eureka Sound Formation. Shovel is 1 m long.

C. Angular unconformity between the calcareous mudstone-siltstone-sandstone lithofacies of the Eureka Sound Formation and coarse-grained sediments of the Beaufort Formation.

D. Symmetrical ripple marks in tidal flat deposits of the calcareous mudstone-siltstone-sandstone lithofacies. Scale is 15 cm long.

E. Flaser bedding in sediments of the calcareous mudstone-siltstone-sandstone lithofacies. Scale is 15 cm long.

F. Conglomerates and sandstones of the Beaufort Formation. Staff is 50 cm long.
indurated beds intercalated with the more recessive, poorly-indurated micaceous siltstones (Figure 28B). The very fine-grained calcareous sandstone beds are generally 5 to 15 cm thick, with sharp upper and lower contacts, and rarely show fine, parallel lamination. Very fine- to fine-grained, medium to dark brown sandstones become increasingly abundant towards the top of the exposed section, and are generally silty and micaceous with rare plant fragments and thin discontinuous coal stringers up to 15 cm thick. Minor interbedded mudstones contain plant fragments and lignitic, argillaceous coal seams which pinch out laterally from thicknesses of up to 1.5 m over distances of about 50 to 100 m. Mudstones and coal seams are most common in the upper part of the section.

The lithology, sedimentary structures and overall upward increase in grain size suggests a distal to proximal delta front environment of deposition for the micaceous siltstone-calcareous sandstone lithofacies. Thin, discontinuous coal seams are interpreted as local accumulations of transported plant debris. Equivalent strata occur farther north in the Strathcona Fiord area and are interpreted as distal delta front deposits by Miall (1981).

Calcareous mudstone-siltstone-sandstone lithofacies

Eureka Sound strata which overlie the micaceous siltstone-calcareous sandstone lithofacies are composed of a sequence of finely interlaminated calcareous mudstones, siltstones and sandstones and rare, thin coal seams (Figures 28C, 29). The sedi-
Interbedded:
- Conglomerate (50%): cbl, clasts avg 5-15cm, rare boulders, granite, quartzite, garnet gneiss clasts, clast supported, fg-cg sandstone matrix.
- Sandstone (50%): lt grey, vf-cg, silty, carb debris, micaceous, rare ripple lamination, scour and fill; rare conglomerate lenses 1.3m thick, 50m long.
- Interbedded: Siltstone (60%): micaceous, carb. Coal (40%): 3-5cm stringers. Coal sample 17-128.
- Interbedded:
  - Sandstone (55%): lt grey-white, vf-mg, silty, carb. debris, tr soft sed. deformation, planar parallel and ripple trough cross-lamination; rare vcg sandstone lenses; rare calc. mudstone beds. Mudstone sample 17-126.
  - Conglomerate (45%): pbl-cbl, clasts avg 3-8 cm, gneiss, quartzite, granite, chert clasts, clast to matrix supported, m-cg sandstone matrix, tr. calacareous, scour and fill; rare cg sandstones.

Siltstone: med brown, micaceous, coaly debris.
- Conglomerate: pbl-cbl, clasts avg 3-8 cm, quartzite, granite, chert, mudstone clasts, clast supported, c-mg sandstone matrix; rare calc. mudstone beds. Mudstone sample 17-125.

\[ \text{UNCONFIRMITY} \]
- Sandstone: lt grey-white, vf-mg, clean, tr. calc., tr. carb. debris, tr. concretions, planar to wavy lamination, ripple cross-lamination, rare planar cross-bedding, scour and fill; Coal sample 17-121.
- Interbedded:
  - Sandstone (65%): lt grey-white, vfg, clean, tr. carb. debris, tr. roots, calc., fine planar to wavy lamination, ripple cross-lamination, symmetrical ripples.
  - Siltstone (35%): lt grey-buff, calc., carb. debris, marine pelecypod fragments, burrows, tr. iron sulphide concretions, fine planar lamination; Mudstone sample 17-117.
- Mudstone: lt grey, calc., burrows, symmetrical ripples.
- Interbedded:
  - Sandstone (85%): lt grey-white, vfg, calc., carb. debris, micaceous, pelecypod fragments, trails, Skolithos burrows, fine planar and ripple cross-lamination, flaser bedding, symmetrical ripples. Mudstone (15%): lt grey-white, calc., carb. debris, fine planar lamination.
  - Siltstone: buff, fine planar lamination.
- Sandstone: white, vfg, clean, rare concretions, planar parallel and planar cross-beding.

FIGURE 29. Stratigraphic section 17 across the unconformity between the Eureka Sound and Beaufort formations north of Makinson Inlet.
ments are light grey to white, and commonly contain shallow marine pelecypod shells, trails and *Skolithos* trace fossils indicating a fairly abundant marine fauna. Sedimentary structures include planar parallel lamination, ripple trough cross-lamination, symmetrical ripples (Figure 28D) and flaser bedding (Figure 28E). Carbonaceous debris, plant fragments and thin coal laminae are common, whereas iron sulphide concretions are rare.

The fine grain size, small scale sedimentary structures and faunal content indicate deposition under low energy, brackish water conditions, such as is found in a large lagoon or estuary. The occurrence of rare flaser bedding, symmetrical ripples and marine pelecypod and trace fossils suggests a tidal flat environment (Reinson, 1979; Weimer et al., 1982). Thin coals could have formed either from transported material or from peat deposits along the shores of the estuary. The similarity of strata of the calcareous mudstone-siltstone-sandstone lithofacies to strata exposed farther north at Strathcona Fiord (Miall, 1981; West et al., 1981) and to the south at Stenkul Fiord (this study) suggests that these outliers are erosional remnants of a large shallow marine embayment which extended from southern Ellesmere Island to Vesle and Strathcona Fiords during late Early to mid-Paleocene time (Figure 24A).

**Beaufort Formation**

Strata assigned to the Beaufort Formation above the unconformity are characterized by pebble to cobble conglomerates interbedded with very fine- to coarse-grained sandstones, minor
siltstones and rare, thin calcareous mudstones and coal (Figures 28F, 29). The strata are presently preserved only as erosional outliers in a narrow belt about one-half kilometre wide and 5 km long, north of Makinson Inlet (Figure 25). The calcareous mudstones contain a nearshore mixed marine dinoflagellate cyst/spore and pollen assemblage (see palynology section). The conglomerates are predominantly clast-supported with a poorly sorted coarse- to medium-grained sandstone matrix, and attain thicknesses of up to 15 m. The well-rounded clasts are composed mainly of granite, garnet gneiss and quartzite, which suggests local derivation from uplifted Phanerozoic and Precambrian rocks to the east. At least four low angle (5° to 20°) intraformational angular unconformities exist within the sequence. The intraformational unconformities suggest periodic relative uplift to the west and erosion of the strata. Very fine- to coarse-grained sandstones are silty, micaceous and contain carbonaceous plant debris. Sedimentary structures include scour and fill structures, rare ripple cross-lamination and planar parallel lamination. Coal occurs as thin, 5-15 cm seams which are comprised of transported woody material. The presence of poorly to moderately well sorted conglomerates together with the occurrence of a mixed nearshore marine dinoflagellate cyst/spore and pollen assemblage suggests that Beaufort strata at this locality represent part of a fan-delta deposit that built out into a marine embayment (Figure 30). The origin of minor folds in the Beaufort Formation is unknown. They may be either tectonic or a result of Pleistocene ice thrusting.
Lower Paleozoic strata and Precambrian crystalline basement

Beaufort Formation

Eureka Sound Formation

FIGURE 30. Depositional model of the Beaufort Formation north of Makinson Inlet.
Samples 16-105 (Figure 27) and 17-117, 17-121, 17-125, and 17-126 (Figure 29) were collected from the Eureka Sound and Beaufort Formations and were processed for palynomorphs using standard techniques.

The palynomorph assemblages represent two disparate time intervals of the Tertiary. The assemblage from the Eureka Sound Formation below the unconformity, contains mainly terrestrial spores and pollen. The overall assemblage corresponds most closely to those from the interval of the Eureka Sound Formation interpreted by Rouse (1977) as being late Early to early mid-Paleocene. The most diagnostic species are listed below and are illustrated in Figures 31g to 31f, inclusive.

Paraalnipollenites confusus, (Figure 31g)
Momipites rotundus, (Figure 31h)
Triporopollenites mullensis, (Figure 31i)
Myricipites dubius, (Figure 31j)
Cupuliferidaepollenites liblarensis, (Figure 31k)
Praxinoipollenites variabilis, (Figure 31l)
Rhoiipites pseudocingulum, (Figure 31m)
Multicellaesporites -6, (Figure 31n)

The overall palynoassemblage suggests a rather cool tem-
FIGURE 31. Dinoflagellate cysts of the Beaufort Formation (a to f) and spores and pollen grains of the Eureka Sound Formation (g to n) north of Makinson Inlet.

**Beaufort Formation**

a- *Batiacasphaera sphaerica*; b- *B. micropapillata*; c- *Paralacaniella indentata*; d- *Apteodinium -C*; e- *Deflandrea phosphoritica*; f- *Leptodinium -3*.

**Eureka Sound Formation**

g- *Paraalnipollenites confusus*; h- *Momites rotundis*; i- *Triporporpollenites mullensis*; j- *Myricipites dubius*; k- *Cupuliferoidaepollenites liblarensis*; l- *Fraxinoipollenites variabilis*; m- *Rhoiipites pseudcingulum*; n- *Multicellaesporites -6*.
perate and probably wet paleoclimate during deposition of the lower unit, as previously indicated (Rouse, 1977) for the P-1 stage of the Eureka Sound in the Remus Creek section to the north on the Fosheim Peninsula.

The assemblage from the Beaufort Formation above the unconformity appears to be Early Miocene, correlating most closely with Early Miocene assemblages from offshore Atlantic sediments reported by Stover (1977), offshore Labrador (Bujak and Williams, 1977), offshore Africa (Manum, 1976), and from the Beaufort Sea (Rouse, unpublished). The most diagnostic palynomorphs are the marine dinoflagellate cysts listed below which are shown in Figures 31a to 31f, inclusive.

*Batiacasphaera sphaerica*, (Figure 31a)

*B. micropapillata*, (Figure 31b)

*Paralacaniella indentata*, (Figure 31c)

*Apteodinium -C*, (Figure 31d)

*Deflandrea phosphoritica*, (Figure 31e)

*Leptodinium -3*, (Figure 31f)

Of these, *Batiacasphaera sphaerica*, *Paralacaniella indentata*, *Apteodinium -C* and *Leptodinium -3* appear to be limited to the Early Miocene. *Deflandrea phosphoritica* and *Batiacasphaera micropapillata* range through the Oligocene, and disappear at the end of the Early Miocene. Other dinoflagellates in the assemblage include *Thalassiophora pelagica, T. cf.*
vellata, *Cyclopsiella elliptica* and *Selenopemphix nephroides*. Terrestrial pollen admixed with the dinoflagellate cysts include bladdered conifer pollen of spruce (*Picea*) and pine (*Pinus*), porate grains of the birch family (*Alder- Alnus*, hazel or hop-hornbeam, *Corylus* or *Carpinus*, and birch- *Betula*), sweet gale-*Myrica*, oak- *Quercus*, and sweet-gum (*Liquidambar*). The admixture of terrestrial and marine palynomorphs indicates a depositional setting not too distant from forested land areas.

Also present in relatively large numbers are recycled Late Cretaceous and Paleocene palynomorphs probably derived from erosion of sediments of the Kanguk and Eureka Sound Formations.
PRE-EARLY MIOCENE EROSION

The amount of sediment of the Eureka Sound Formation removed by erosion prior to deposition of the Beaufort Formation can be estimated using vitrinite reflectance measurements, by relating vitrinite reflectance values on either side of the unconformable surface to a locally derived coalification gradient.

The coalification gradient at Strathcona Fiord, located approximately 100 km north of the unconformity at Makinson Inlet, was derived by Bustin (in prep.) and is reproduced on Figure 32. Coalification gradients determined at several locations throughout the eastern Arctic were found to be very similar to the Strathcona Fiord gradient (Bustin, in prep.), and thus it is assumed that a similar coalification gradient existed at Makinson Inlet. Local variations in vitrinite reflectance values can be caused by igneous intrusions, evaporite diapirs, and major overthrusts; however, none of these features were observed in the study area.

The vitrinite reflectance values for Eureka Sound and Beaufort strata are plotted on Figure 32. The stratigraphic separation between samples 16-103 (Figure 27) and 17-121 (Figures 26 and 29) could not be determined. Samples 17-121, from below the unconformity, and 17-128, from above the unconformity, are presently separated by approximately 100 m of sediment (Figure 29). If the coalification gradient at Makinson Inlet is similar to the Strathcona Fiord gradient, and if no hiatus in sedimentation had occurred between the deposition of samples 17-121 and 17-128, then Figure 32 illustrates that approximately 550 m of
FIGURE 32. Coalification gradient at Strathcona Fiord (Bustin, in prep.), and vitrinite reflectance values for coal samples above and below the unconformity.
sediment would have separated these two samples. These results thus suggest that erosion of the Eureka Sound Formation on the order of 450 m occurred prior to deposition of the Beaufort Formation.

The rate of denudation can be very roughly estimated from the age of the strata and the amount of sediment removed. Assuming an erosion of 450 m between mid-Paleocene and Early Miocene yields an average denudation rate of 1.3 m/Ma. If the erosion was post-Late Eocene to pre-Early Miocene, then the rate of denudation, and thus uplift, would be on the order of 30 m/Ma.
TECTONIC IMPLICATIONS

The occurrence of Lower Miocene strata unconformably overlying folded Paleocene strata north of Makinson Inlet provides additional evidence for the chronology of tectonism in this part of the Archipelago. The unconformity indicates a period of post-mid Paleocene to pre-Early Miocene folding and erosion. To the south at Stenkul Fiord, Eureka Sound strata equivalent to that at Makinson Inlet are conformably (or paraconformably) overlain by strata as young as Late Eocene. It is thus highly suggestive that the unconformity at Makinson Inlet represents a post-Late Eocene to pre-Early Miocene phase of compression. As such, the chronology of compressional orogenesis in this part of the Archipelago is consistent with that documented from central Axel Heiberg Island by Balkwill and others (1975) and suggests that the chronology of orogenesis (phase two) of the Eurekan Orogeny is coeval throughout the eastern Queen Elizabeth Islands.

The occurrence and composition of the Lower Miocene, conglomeratic fan-delta deposits at Makinson Inlet indicates that the Paleozoic strata and the Precambrian Shield to the east underwent relative uplift during the Early Miocene. The fan-delta deposits undoubtedly are the erosional remnants of a larger fan-delta-alluvial fan complex, but there is presently no evidence for the pre-erosional extent of the deposits or of uplift. No other conclusively dated post-Late Eocene strata are known from this part of the Archipelago apart from the Miocene deposits on Axel Heiberg Island (Bustin, 1982; Figure 25). Other possible syn- or post-tectonic (post-phase two) deposits are Oligocene(?).
deposits at Lake Hazen (Miall, 1979; 1981) and conglomerates at Yelverton Bay, northern Ellesmere Island (Wilson, 1976).

The Eurekan orogenic events in the eastern Queen Elizabeth Islands have been considered to have resulted from and to be evidence for Tertiary plate motions in the eastern Arctic (McWhae, 1981; Kerr, 1980; 1981a, b; Peirce, 1982, and others). Central to these arguments is the origin of Baffin Bay and the nature of Nares Strait. Although it is beyond the scope of this paper to add to the large amount of speculation on the plate tectonic history of the area, the chronology of tectonism does constrain some interpretations. As initially pointed out by Balkwill (1978), compressional events of the Eurekan Orogeny are post-Middle Eocene to Early Miocene, whereas Baffin Bay/Labrador Sea spreading is supposed to have occurred during the Late Paleocene-Early Oligocene. Thus the timing of Eurekan compression does not support transpression along Nares Strait (Wegener transform fault) accompanying spreading in the Labrador Sea and Baffin Bay, if spreading took place between Late Paleocene and prior to Early Oligocene as has been proposed (McWhae, 1981; Srivastava et al. 1981). The suggestions that some of the presumed offset along Nares Strait was accommodated by folding and faulting in the eastern Queen Elizabeth Islands in response to rotation of Greenland (Srivastava et al., 1981) or compression north of a transform pivot in southern Ellesmere Island (Kerr, 1981a,b) similarly is not consistent with the timing of Eurekan compression if the timing of sea floor spreading in Labrador Sea and Baffin Bay is correct. The chronology of the Eurekan compressional event on Ellesmere Island actually correlates better
with cessation of spreading in Labrador Sea and (?) Baffin Bay (post 36 Ma, anomaly 13). If phase two of the Eurekan Orogeny is a result of spreading in Labrador Sea-Baffin Bay then either the timing of spreading is in error or only post-Late Eocene to Early Oligocene spreading resulted in compression in the eastern Queen Elizabeth Islands.

The significance of relative uplift in the Early Miocene in the study area is unknown. It is likely that part of the present high elevation of the east coast of Ellesmere Island and possibly eastern Devon Island dates from Miocene uplift and coeval tectonism should be suspected along the western margin of Baffin Bay. The interval Miocene to Pliocene was considered by Kerr (1981a, b) to be the final phase of plate motion in the Canadian Arctic when faults from the Atlantic Ocean broke through to the Arctic Ocean.
SUMMARY AND CONCLUSIONS

Discovery and dating of a post-mid Paleocene (likely post-Late Eocene) to pre-Early Miocene angular unconformity on south-central Ellesmere Island indicates that the chronology of the compressive phase of the Eurekan Orogeny established from central Axel Heiberg Island (Balkwill et al., 1975) can be extended to Ellesmere Island and thus likely to the entire eastern Queen Elizabeth Islands. The amount of strata of the Eureka Sound Formation deposited and subsequently eroded near Makinson Inlet is estimated to be about 450 m based on coalification levels. The Lower Miocene conglomeratic succession at Makinson Inlet, here assigned to the Beaufort Formation, is considered to represent fan-delta deposits that prograded into a shallow marine embayment (Figure 30). The occurrence and provenance of the conglomeratic sequence provides evidence for at least a local Early Miocene phase of relative uplift of the Precambrian shield of eastern Ellesmere Island. The extent and significance of the uplift is unknown because of the present restricted distribution of Lower Miocene strata.
REFERENCES CITED


Frisch, T., 1983, Reconnaissance geology of the Precambrian


Kerr, J.W., 1981b, Stretching of the North American Plate by a now dormant Atlantic spreading center; In Kerr, J.W. and
Fergusson, A.J., eds., Geology of the North Atlantic borderlands; Canadian Society of Petroleum Geologists, Memoir 7, pp. 245-278.


Okulitch, A.V., 1982, Preliminary structure sections, southern


Weimer, R.J., Howard, J.D. and Lindsay, D.R., 1982, Tidal flats and associated tidal channels; In Scholle, P. A. and Spearing, D., Sandstone depositional environments; American Association of Petroleum Geologists, Memoir 31, pp. 191-245.


APPENDIX

SAMPLE NUMBER: 07-54&56
PALYNOZONE: P-2
AGE: Middle Paleocene
LIST OF SPECIES

POLLEN

Paraalnipollenites confusus
Senipites drumhellerensis
Triporopollenites mullensis
Carpinipites ancipites
Areципites tenuiexinous
Pterocarya stellatus
Betulaceoipollenites infrequens
Caprifoliipites - A
Lycopodium reticulumsporites
Alnus verus

DINOFLAGELLATE CYSTS

Areoligera senonensis
Deflandrea speciosa
Apteodinium sp.
SAMPLE NUMBER: 07-58
PALYNOZONE: P-2
AGE: Middle Paleocene
LIST OF SPECIES

POLLEN

Paraalnipollenites confusus

Betulaceoipollenites infrequens

Pinus haploxyylon

Picea grandivescipites

Sequoiapollenites polyformosus

Carpinites ancipites
SAMPLE NUMBER: 23-178
PALYNOZONE: P-4
AGE: Late Paleocene
LIST OF SPECIES

POLLEN

*Sequoiapollenites polyformus*

*Triporopollenites mullensis*

*Cedripites* sp.

*Alnus verus*

*Pistillipollenites macgregorii*

*Cupuliferoipollenites* – A
SAMPLE NUMBER: 22-157

PALYNOZONE: P-3

AGE: late mid- to early Late Paleocene

LIST OF SPECIES

POLLEN

Triporopollenites mullensis

Paraalnipollenites confusus

Alnus verus

Betulaceoipollenites infrequens

Cupuliferoipollenites - A

Momipites rotundus

DINOFLAGELLATE CYSTS

Paralacaniella indentata

FUNGAL SPORES

Pesavis tagluensis
SAMPLE NUMBER: 18-188
PALYNOZONE: E-1
AGE: Early-Middle Eocene
LIST OF SPECIES

POLLEN

Tilia vescipites
Tetracolporopollenites sp.
Arecipites columellus
Araliaceoipollenites granulatus
Ericipites redbluffensis
Horniella modica
Paraalnipollenites - 2
Jussiaea type
Verrutricolporites cruciatus
Carya viridifluminipites
Cupuliferoipollenites insleyanus
Planera thompsoniana
Striatopollis terasmaei
Rousea sp.
Myrica - 2
Tetracolporopollenites megadolium

Milfordia minima

Toroisporis postregularis

Striadiporites sp.

Circulosporites sp.

Pesavis tagluensis

Pistillipollenites macgregorii

Horniella - A

Tricolporopollenites - A

Rhoiipites latus

Caprifoliipites tantalus

DINOFLAGELLATE CYSTS

Baltisphaeridium sp.

Lejeunia hyalina

Lejeunia - 3

FUNGAL SPORES

Pluricellaesporites sp.

Diporisporites - A
Dicellaesporites - A
SAMPLE NUMBER: 18-134
PALYNOZONE: E-2
AGE: Late Eocene
LIST OF SPECIES

POLLEN

Osmunda heterophyllites

Tsuga heterophyllites

cf. Keteleeria

Fraxinoipollenites medius

Ulmipollenites undulosis

Carya veripites

Aralaceoipollenites grahulatus

cf. Gothanipollis sp.

Laevigatosporites

Paraalnipollenites confusus

Triporopollenites mullensis

Siltaria scabriextinous

Arecipites columellus

Cupuliferoidaepollenites liblarensis

Parsonidites conspicuus
Tilia vescipites

Caprifoliipites tantalus

Liliacidites tritus

Araliaceoipollenites profundus

DINOFLAGELLATE CYSTS

Lejeunia cf. hyalina

Deflandrea phosphoritica

Cf. Chiropterium dispersum

Cleistosphaeridium aff. echinoides

Apteodinium sp.

Spiniferites sp.

FUNGAL SPORES

Pluricellaesporites

Punctodiporites