# SEDIMENTOLOGY AND PALYNOLOGY OF CRETACEOUS AND TERTIARY STRATA, SOUTHEAST BAFFIN ISLAND, NORTHWEST TERRITORIES, CANADA



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# CRETACEOUS AND TERTIARY STRATA,
# SOUTHEAST BAFFIN ISLAND,
# NORTHWEST TERRITORIES, CANADA

by

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A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE
STUDIES IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

DEPARTMENT OF EARTH SCIENCES
MEMORIAL UNIVERSITY OF NEWFOUNDLAND
JUNE 1987

ST. JOHN'S NEWFOUNDLAND

ISBN 0-315-39471-4

## ABSTRACT

The geologic history of sedimentary strata exposed off the southeast coast of Baffin Island on Quqaluit, Durban and Padloping islands is poorly understood. A model explaining the environments of deposition and age of these strata is a valuable contribution towards the construction of the geologic history of this region, both in terms of plate tectonics and hydrocarbon exploration.

By using facies analyses, deposition at the onset of faulting took place in braided streams which was followed by deposition in backswamp regions of fluvial environments, meandering streams, and locally, distal alluvial fans. Volcaniclastic facies are also represented at the upper contact of strata with volcanic basaltic breccia.

Two miospore assemblages consisting of: Assemblage 1 (dominated by bisaccate pollen, and contains specimen(s) of Distaltriangulisporites perplexus (Singh) Singh, Foveogleicheniidites confossus (Hedlund) Burger, Lycopodiacidites canaliculatus Singh and Cedripites canadensis Pocock among others and woody and coaly debris) and Assemblage 2 (containing specimens of Trivestibulopollenites betuloides Pflug and Pesavis tagluensis Elsik and Jansonius among others and dinoflagelates) are dated as Aptian to latest Albian and Late Paleocene-Eocene, respectively. Dating using paleobotany is supportive of these ages. Assemblage 1 occurs in Durban Island strata, and in strata located below the first volcanic ash and debris flow on Padloping and Quqaluit islands, respectively. Assemblage 2 occurs in strata located in and above the first volcanic ash on Padloping Island and in strata located above the debris flow on Quqaluit Island.

The vegetation in this small fault-bounded basin appears to be that of a conifer dominated forest. High percentages of bisaccate pollen in the meandering stream complex may indicate a vegetation preference with fluvial style, however, hydrodynamic conditions played an important role in pollen distribution.

Thermally immature, wood and coal dominate the organic matter in these beds.

Therefore, these strata, given a sufficient geothermal history, may source gas and minor liquid hydrocarbons offshore.

The depositional model indicates that the timing of either initial rifting or crustal attenuation between Greenland and North America was Early Cretaceous.

KEY WORDS: Sedimentology, Palynology, Facies, Fluvial, Hydrocarbons, Baffin Island, Cretaceous.

## ACKNOWLEDGEMENTS

In the course of this research many people have encouraged and offered helpful advise. My supervisors Elliott Burden and Ali Aksu are acknowledged for their constant assistance, friendship and patience. Fellow graduate students, in particular Paul Myrow, Chris Ryley and Brian Sears, are thanked for their informative conversation, editing and valuable suggestions. H. Gillespie assisted with palynomorph processing.

Financial and logistical support was provided by the Geological Survey of Canada (E. Burden), Natural Sciences and Engineering Research Council (E. Burden) and Polar Continental Shelf Project (E. Burden), a Texaco Research Grant (A. Langille), and Department of Indian Affairs and Northern Development-Northern Scientific Training Program Grant (A. Langille). Logistical support was also provided by Parks Canada (Broughton Island). Chevron Canada Resources Limited and Shell Canada Resources Limited are thanked for their support.

Acknowledgements are also addressed to J. Bassinger, E. Deutsch, H. Kutluk, B. Clarke, and J. McMillan. A special thanks to my mom, late father and sisters whose endless moral support has been invaluable. Final thanks are addressed to my wife, Anne Charlebois, for her constant understanding, encouragement and love.

# DEDICATION

This thesis is dedicated

to the memory of

my unequalled educator;

Bennie Langille,

my dad.

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# CHAPTER 1 INTRODUCTION

## 1.1 Purpose and Objectives

Discovery of hydrocarbon slicks in Baffin Bay during the 1970's has initiated an interest in the sedimentary outliers exposed along the southeast coast of Baffin Island (Loncarevic and Falconer, 1977; Levy, 1978, 1979; MacLean and Falconer, 1979; Levy and MacLean, 1981; Grant et al., 1986). Study of the pre-Quaternary sedimentary geology of this area contributes information towards a better understanding of the timing of tectonic events in Baffin Bay and Davis Strait. Research of this nature also provides important data concerning the hydrocarbon potential of the adjacent offshore region. This study is a sedimentological and palynological investigation of the reported Cenozoic strata off the southeast coast of Baffin Island in Merchants Bay, on Padloping, Quqaluit, and Durban islands (Figure 1.1).

This research involves the identification of depositional environments, utilizing facies analysis and age refinement of strata using palynology and paleobotany, thus establishing a basis for postulating sedimentary basin development. Investigative techniques for each subdiscipline of this study are presented at the beginning of each chapter.

## 1.2 Previous Studies

The first documented reports of sediments on Padloping, Quqaluit, and Durban islands is from the Norse sagas (Mowatt, 1965). Mowatt (1965) states that in 982 (A.D.) Erik the Red crossed Davis Strait and explored the coast of Baffin Island. Mowatt (1965) mentions a prominent point, known to Erik and his people as Coal Cape, which may have been the sediments near Cape Dyer (Figure 1.2). Sutherland (1853) reported coal at Cape Durban which was used to supply whaling fleets along the coasts of Baffin Island and Greenland. Mowatt (1965) and Sutherland (1853) constitute the only reports of coal occurring on the coast of Baffin Island. However,

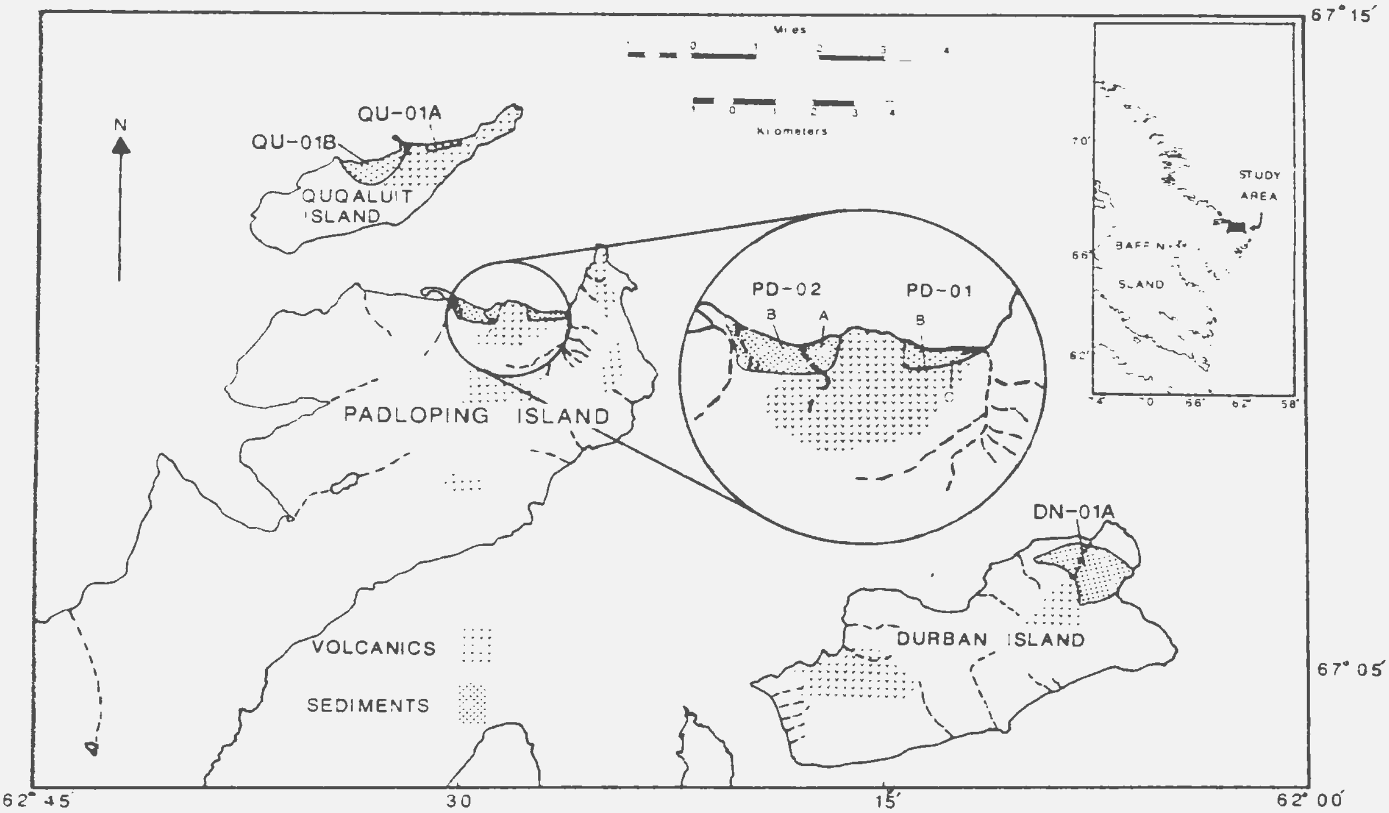



Figure 1.1 Location of study area.

this author suspects Sutherland (1853) is referring to Padloping Island since the only coal observed in the study is on Padloping Island.

Based on megafloral remains found in shales on Durban Island, McMillan (1910) proposed a Tertiary age for the sedimentary strata in the region.

Over the next sixty years literature concerning this area deals mainly with volcanic rocks which conformably overlie the sedimentary strata. Works by Kidd (1953), Wilson and Clarke (1965), Clarke (1967), Clarke (1968), Clarke (1970), Clarke and Upton (1971), Deutsch et al. (1971), and Kristjansson and Deutsch (1973) discuss the volcanics in detail. Clarke and Upton (1971) mention the sedimentary strata briefly and suggest that the coastal outliers at the Cape Dyer area are erosional products created during the rifting stage prior to the opening of Baffin Bay. They also state, based on paleobotanical work by Bell that the sediments on Quqaluit, Padloping and Durban islands, are Tertiary in age.

During 1976 and 1979 hydrocarbon slicks were observed in Scott Inlet and Buchan Gulf (Loncarevic and Falconer, 1977; Levy, 1978, 1979; MacLean and Falconer, 1979; Levy and MacLean, 1981; Grant et al., 1986) (Figure 1.2). These observations, at a time when Canada was attempting to secure hydrocarbon reserves for future self-sufficiency, generated a great deal of interest in the sedimentary strata below Baffin Bay and Davis Strait and in the pre-Quaternary sediments exposed along the coast of eastern Baffin Island.

The most recent works in the study area are those of Holloway (1984) and Sears (1986). Holloway (1984) reached the following conclusions: (a) the age of the sediments on the three islands is Early Cretaceous; (b) the depositional environment was terrestrial; and (c) the sediments may or may not be related to the rifting of Baffin Bay. Sears (1986) states that the sediments are of a fluviodeltaic origin and were derived from the surrounding gneiss and local granite. He correlated the sedimentary outliers from the three islands and suggests that the strata on Durban Island represents a distinct lobe of a delta comlplex.

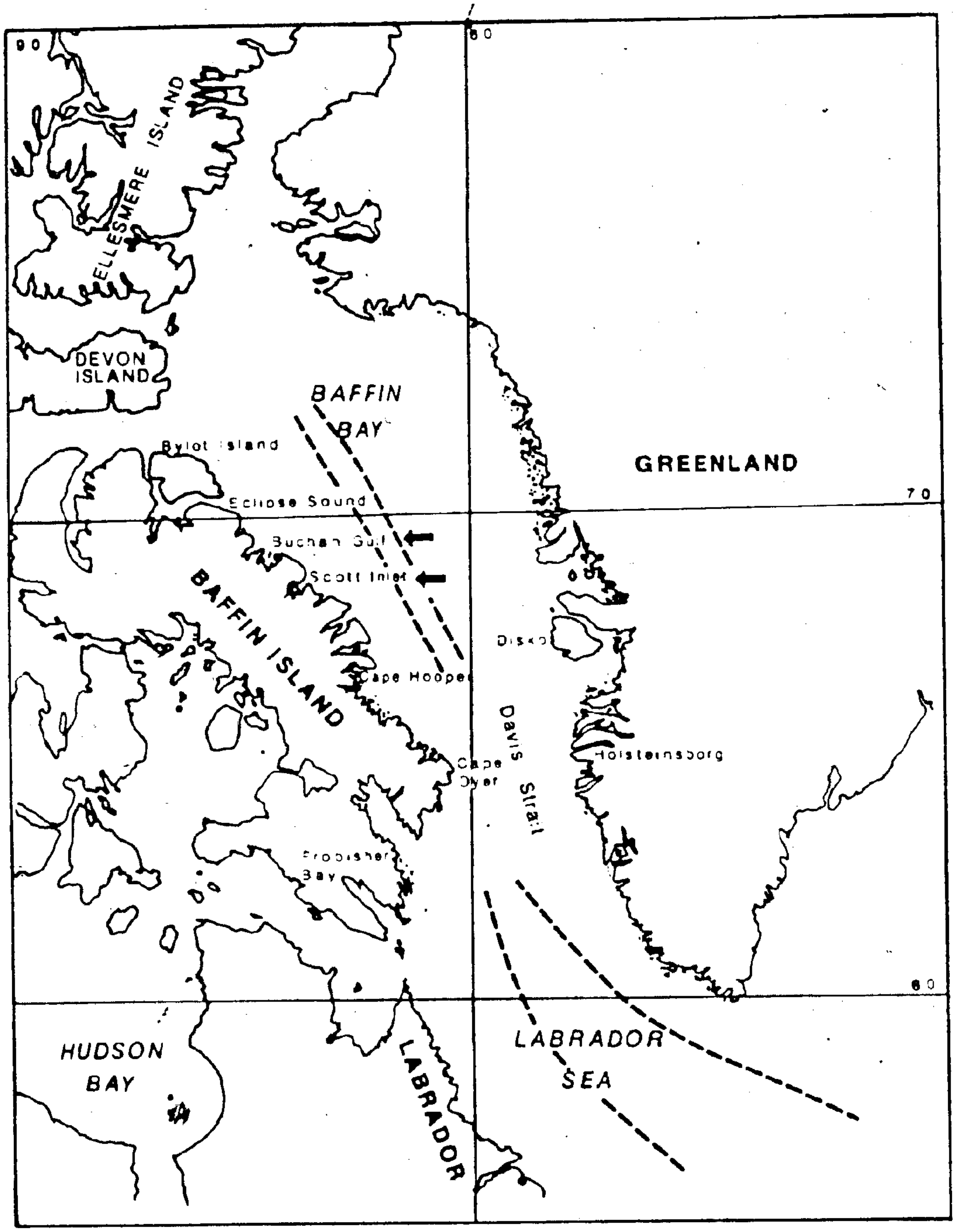



Figure 1.2 Regional Map (arrows show location of Buchan Gulf and Scott Inlet, area within dotted lines contains oceanic crust (according to Shell Canada Resources Limited, 1986)).

### 1.3 Access and Logistics

Access to the study area is achieved by flying north from Montreal to Iqaluit (formerly Frobisher Bay) and Broughton Island. The study area lies approximately 80 km southeast of Broughton Island. Travel to this remote locality is by small inshore fishing vessel.

Weather and ice conditions play a major role in the quality and quantity of geologic field work that can be carried out on the southeast coast of Baffin Island. Without helicopter support the field season can be very short, three to four weeks in late July and early August because of poor weather and pack ice conditions. During the field season of 1985, weather and ice conditions presented no transportation or access problems. The field season of 1986 was not so favorable; thick pack ice shortened the field season to only two days.

The main base camp for field operations in 1985 and 1986 was constructed on the north shore of Padloping Island, just inland from a prominent spit. From this location the strata on Padloping Island, east of the camp, and the strata on the north coast of Quqaluit Island, were examined. Field work on Durban Island (1985 field season only) was based in an abandoned D.E.W. (Distant Early Warning) Line Station warehouse. Sedimentary strata are located on cliffs east of the island top camp.

#### 1.3.1 Field Methods

Field operations consisted of detailed measurement of sections noting lithology, color, grain size, bed contacts, (scoured, sharp or gradational), and primary and secondary sedimentary structures. Palynological samples were collected approximately every five metres.

Five stratigraphic sections have been measured (two sections from Quqaluit and Padloping islands and one section from Durban Island) (Appendix $A_1$-$A_3$) (Figure 1.1). Collections include (a) 150 palynological samples, (b) 26 petrology samples (thin sectioned), and (c) 15 samples of fossil plants and plant remains. The sedimentary sections on all three islands are located on steep cliff faces adjacent to Davis Strait (Figure 1.3).

## 1.4 Geologic Setting

### 1.4.1 Tectonics

The tectonic history of Baffin Bay is a complex, and to date, contested issue. The present geological setting is explained by invoking one of two general models. The first states that Baffin Bay formed in the Paleogene as seafloor spreading along the western arm of the Mid-Atlantic Ridge seperated Labrador and Baffin Island from Greenland (ClarkeUpton, 1971; Keen et al., 1972, 1974; Srivastava, 1978; Jackson et al., 1979; Menzies, 1982; Rice and Shade, 1982) (Figure 1.4A). The second model states that Baffin Island and Greenland did not drift apart to form Baffin Bay. Baffin Bay formed by the foundering of continental crust by extensional forces; little new oceanic crust was produced (Grant, 1975, 1980; Umpelby, 1979; Kerr, 1980) (Figure 1.4B). A small belt of oceanic crust has been observed near the centre of Baffin Bay parallel to, and running between, Cape Hooper and Bylot Island; (Figure 1.2). Oceanic crust has not been observed in Davis Strait east of Cape Dyer (J. Knill and O. Friedenreich, pers. comm., Shell Canada Resources Limited). However, according to Rice and Shade (1982), only a portion of Davis Strait is not floored by true oceanic crust.

According to Rice and Shade (1982) sedimentary strata preserved in the Cape Dyer area on Quqaluit, Padloping and Durban islands, mark the initiation of the Cretaceous-Tertiary spreading events of Baffin Bay and are therefore a key in understanding the tectonic history of this area. Srivastava (1978) suggests a Late Cretaceous (75 Ma) date for the initiation of rifting between Greenland and North America. This present study has redefined the age of the strata as Aptian to latest Albian and

Figure 1.3 Sedimentary strata overlain by volcanics and talus on Padloping Island.

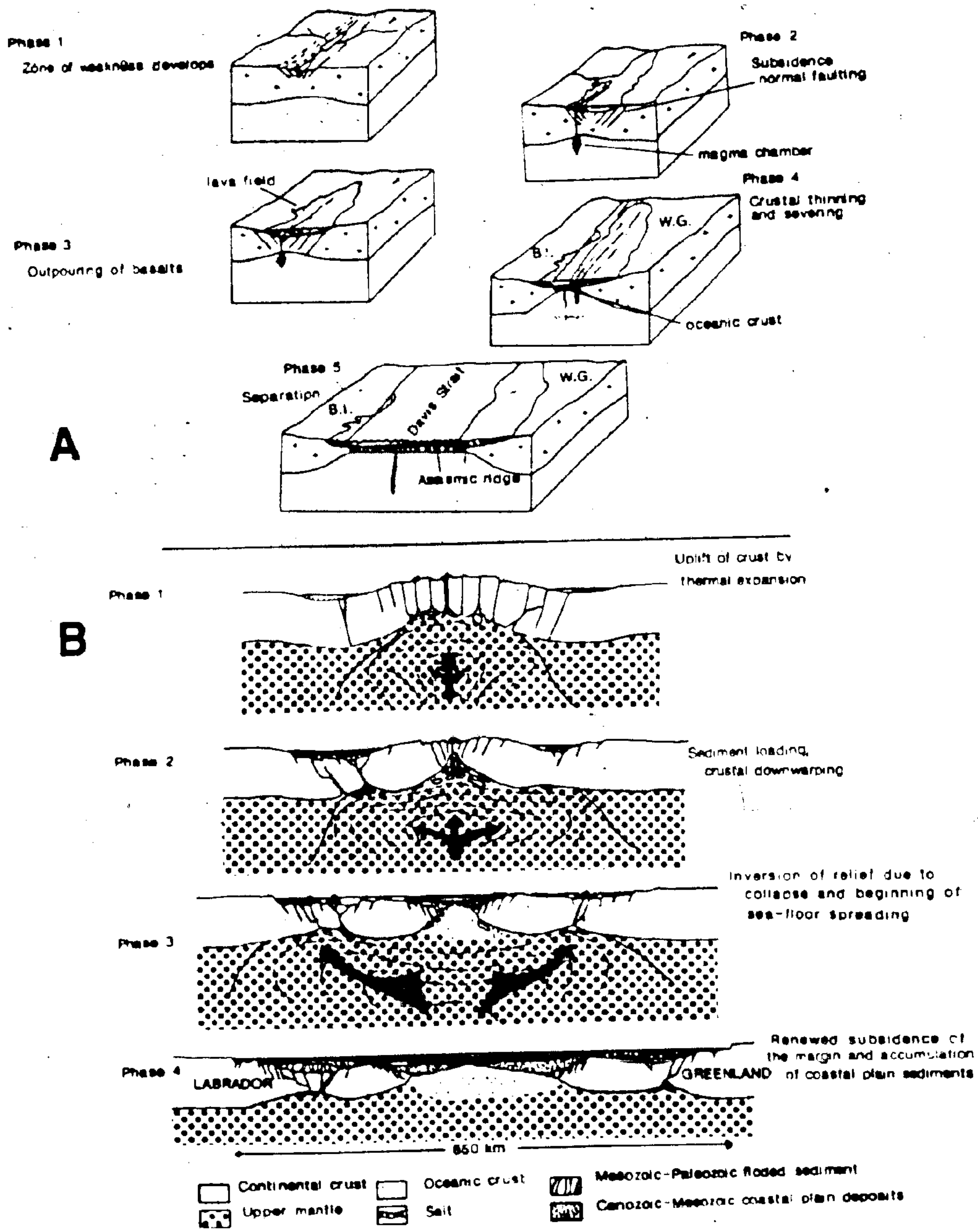



Figure 1.4 (A) Formation of Baffin Bay (after Clarke and Upton, 1971)
(B) Formation of the Labrador Sea (after Van der Linden, 1975).

Late Paleocene-Eocene, respectively.

### 1.4.2 Structural Framework

Numerous northwest-southeast striking, westerly-dipping normal faults (Menzies, 1982) and many fault-related Tertiary-Cretaceous sedimentary basins are located in the Davis Strait-Baffin Bay area (Miall, et al., 1980). Normal faults are visible on offshore seismic sections (Figure 1.5) and in outcrops onshore (Figure 1.6). These strike northwest-southeast and dip towards the west. Throw on these faults is in the order of hundreds of metres with the angle of throw decreasing with depth (listric) (J. Knill an d O. Friedenreich, pers. comm., Shell Canada Resources Ltd). These faults, likely associated with rifting or crustal attenuation of the region, formed half-graben structures, into which continental sediments were deposited.

### 1.4.3 Basement

The regionally extensive Precambrian basement consists of migmatized, amphibolite to granulite facies paragneisses, composed of quartz, feldspar, and biotite, with minor amounts of apatite, muscovite, garnet, epidote, zircon, and magnetite. The gneisses are cut by pegmatite dykes of 1700 m.y. (Clarke and Upton, 1971), and on Durban Island, by an undated muscovite-tourmaline granite. A regolith, usually five to ten metres thick, is commonly observed on basement rock which is covered by sedimentary strata. The regolith consists of weathered bedrock weakly bound in a yellow-orange clay matrix.

### 1.4.4 Sedimentary Rocks

Sedimentary strata, previously described as Cenozoic in age and of fluviodeltaic origin, occur as outliers on the southeast coast of Baffin Island on Quqaluit, Padloping and Durban islands (Clarke and Upton, 1971 and Sears, 1986). Strata consist

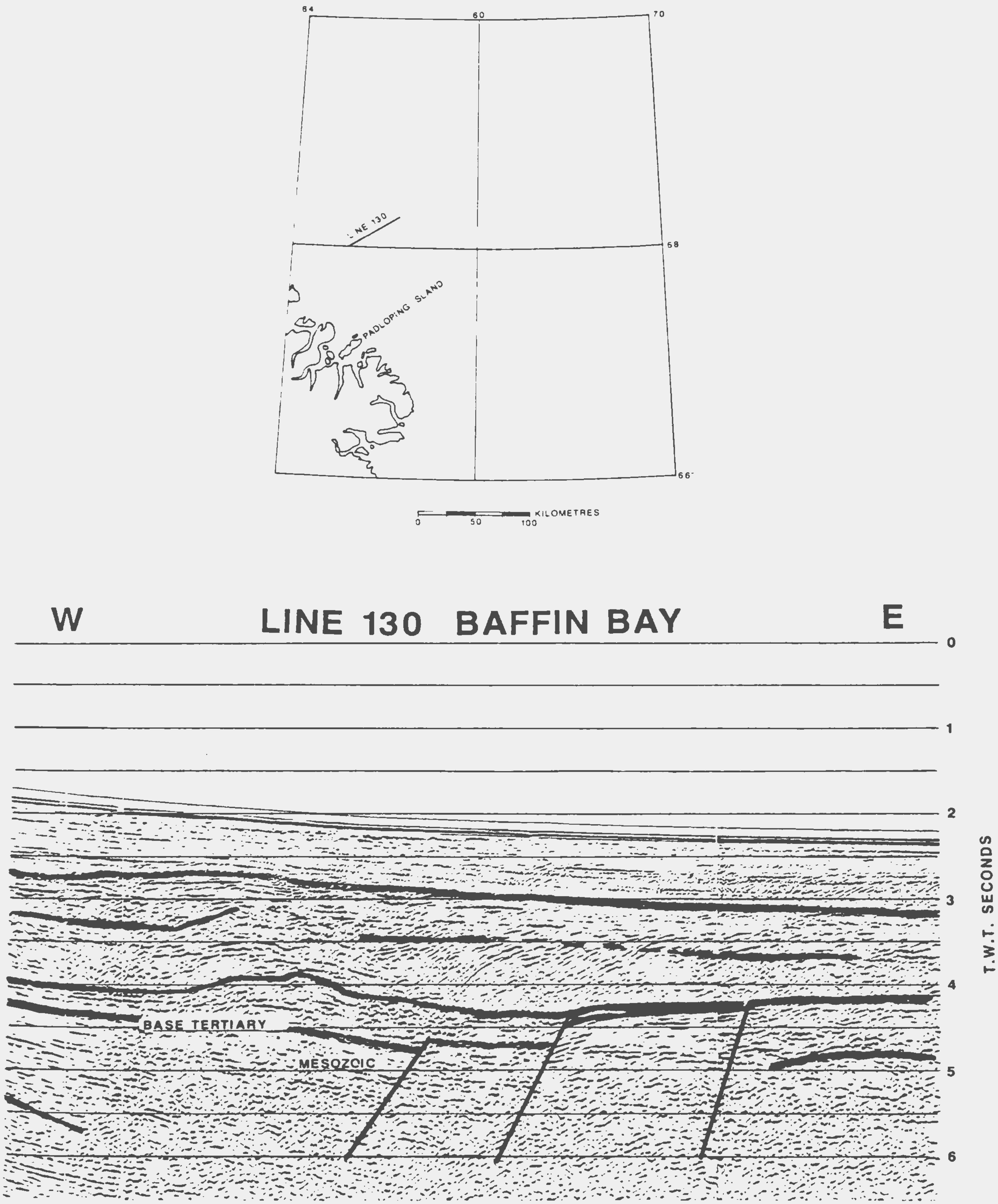



Figure 1.5 Seismic line illustrating normal faults in the subsurface (from Shell Canada Resources Limited).

Figure 1.6 Fault visible on Durban Island.

of poorly lithified sandstones and shales with minor coal which is locally found unconformably overlying the regolithic paragneiss (Sears, 1986). The sandstones are composed of quartz, feldspar, and mica (Clarke and Upton, 1971; Sears, 1986).

The sedimentary strata were deposited in small fault-bounded basins on the migmatized Precambrian paragneissic basement (Sears, 1986). Sections have been disrupted by post-depositional faulting, soft-sediment deformation and cryogenic activity (Sears, 1986).

### 1.4.5 Volcanics

Volcanic strata conformably overlie the sedimentary strata on all the islands examined in Merchants Bay and form high cliffs between Cape Dyer and Quqaluit Island (Figure 1.7). The volcanics consist of subaerial olivine-rich basaltic lava which is underlain, locally, by subaqueous volcanic breccia (Clarke and Upton, 1971). Volcanic ash beds are interbedded with sedimentary strata on both Padloping and Quqaluit islands. The geology of these basalts and volcanic breccias has been discussed in detail by Wilson and Clarke (1965), Clarke (1970) and Clarke and Upton (1971). Clarke and Upton (1971) suggest an age of 58 $\pm$ 2 m.y for the basalts based on potassium-argon dating by Farrar. However Deutsch et al. (1971), and B. Clarke (pers. comm., Dalhousie University) state that the potash content of the rocks is exceptionally low for continental basalts and thereby makes potassium-argon dating very difficult. B. Clarke (pers. comm., Dalhousie University) and E. Deutsch (pers. comm., Memorial University of Newfoundland) question the credibility of the potassium-argon date.

Figure 1.7 Basaltic flows and crossbedded basaltic breccia compose the cliffs at Cape Searle, Quqaluit Island.

# CHAPTER 2 SEDIMENTOLOGY

## 2.1 Introduction

Sedimentary strata, consisting of interbedded sandstones, mudstones and coal are well exposed on the southeast coast of Baffin Island. These strata are excellent research material for facies analyses.

Facies descriptions, spatial distribution, process interpretations, and associations allow the generation of local environment of deposition interpretations. With this framework, the construction of fluvial facies models and the reconstruction of the depositional history for the sedimentary strata exposed on the southeast coast of Baffin Island is achieved.

## 2.2 Facies Descriptions, Distribution and Process Interpretations

Eight facies are described, illustrated and interpreted using the criteria for facies outlined by Reading (1978). Exposed strata of facies are referred to as "units". Mineralogical composition and sorting were determined from the study of thin sections (Section 2.5). Detailed lithological logs (stratigraphic sections) of all facies are provided in appendices $A_1$-$A_3$. The eight facies are:

A: Coarse-Grained Sandstone
B: Mudstone
C: Interbedded Sandstone and Mudstone
D: Subbituminous Coal
E: Medium-Bedded Sandstone
F: Arkosic Sandstone
G: Gravel-Supported Conglomerate
H: Volcanic Ash

Facies A: Coarse-Grained Sandstone

**Description**

Facies A is characterized by beds of medium to coarse-grained subarkosic to quartzarenitic sand, white to greyish-white in color (Figure 2.1). This facies is found in units whose average thickness is 3.5 metres with a minimum of 0.25 metres and a maximum of approximately 6 metres. Bed thickness ranges from centimetre-scale near the base of units to decimetre-scale near the top of units. Bed contacts in Facies A are always scoured.

Trough cross bedding is very common; sets average 10 cm in thickness and 30-40 cm in length. Granules and very coarse sand are common at the base of the sets. Locally, centimetre-scale ripple cross stratification, outlined by organic plant debris, are present in finer beds of this facies. Thin bands of terrestrial organic debris occur between trough cross bed sets. Other rarely observed depositional sedimentary structures include centimetre-scale horizontal lamination and centimetre-scale massive sands. Although fossils are uncommon, some samples from beds of Facies A yield terrestrial palynomorphs and wood.

**Distribution**

This facies occurs at the base of all sections except Section 1 (QU-01A) on Quqaluit Island (Figure 1.1). Beds coarsen upward from medium grained sand to coarse grained sand with granules. Centimetre-scale beds near the base of units thicken to decimetre-scale beds towards the top of units. The lower contact of beds is always scoured and the basal occurrence is unconformable over highly weathered Precambrian migmatized gneiss. The upper contact of the highest beds of Facies A is always sharp to beds of Facies B, D, or C.

**Process Interpretation**

Lithology, grain size, and sedimentary structures indicate that sediments of Facies A were deposited in a high energy setting where currents winnowed silt and clay. Trough cross stratification in medium- to coarse-grained sands has been addressed by many researchers (Harms and Fahnestock, 1965; Miall, 1977). It has generally been accepted that large-scale (depth greater than 10 cm) trough cross stratification is formed by the migration of dunes in the lower flow regime (Harms and Fahnestock, 1965; Miall, 1977). Trough cross beds 10 cm in thickness dictate megaripple amplitudes of 15-20 cm (Cant, 1982). According to the studies of Harms and Fahnestock (1965) water depth would have exceeded 30 cm. Ripple cross stratification, more common in thinner beds of Facies A, occur most commonly near the top of beds where they formed as "small" ripples superimposed on the underlying megaripple.

The coarsening upward (reverse grading) of beds in this facies, is explained by migration of bar heads over bar tails as sand forms migrated downcurrent; this is similar to deposits described by Steel and Aasheim (1978). Preservation of a complete bar deposit may result in a coarsening-upward sequence; however, the more common situation is the preservation of partial sequences consisting of numerous superimposed sets of trough cross bedded sandstones (Miall, 1986). The increase in thickness of beds of Facies A upsection may be a function of increased deposition (higher deposition rates and/or greater availability of sand) thereby creating larger sand forms with time.

Petrologically, the absence of sedimentary rock fragments, the prominence of gneissic and granitic rock fragments and the angularity of clasts in the sandstone samples from Facies A strongly suggests only one cycle of weathering and deposition. These sandstones resemble the first-cycle fluviatile Sioux Quartzite sandstones of southwestern Minnesota (Southwick et al., 1986).

The absence of fine-grained sediment and presence of many indicators of a high energy environment and the stratigraphic position of this facies - at the base of each measured section, where it unconformably overlies the Precambrian migmatized gneiss (not uncommon, e.g. Southwick et al., 1986), combined with information on lithology, grain size, fossils and sedimentary structures, suggests that Facies A represents the deposits of sinuous crested dunes in a terrestrial aquatic depositional environment.

Facies B: Mudstone

**Description**

Facies B consists of grey to black, massive or laminated mudstone. Laminated dark-colored sections, which contain a high concentration of organic matter are present. The thickness of beds varies significantly from 1.5 metres to a maximum of 6.0 metres. Terrestrial plant debris, laminated plant debris and terrestrial palynomorphs (discussed in Chapters 3 and 4) are common. Root traces and faunal remains are not common; only one root trace was identified in this investigation. At some localities there are well preserved coniferous needles and fern fronds on bedding planes.

Two very thick beds (1.5-3.0 m) of structureless, organic rich mudstone are of note; they contain well preserved logs and log debris of ?Metasequoia (Plate 1, Figure 1). These occur in the upper part of Padloping Island Section 1 above beds of Facies H (Volcanic Ash) and in the upper part of Quqaluit Island Section 1 above beds of Facies G (Gravel Conglomerate) (Figure 2.2).

**Distribution**

Facies B makes up only a small percentage of the sections studied; it is present in widely spaced intervals. Upper and lower contacts with beds of other facies (A, $C_2$, $C_3$, D, F and H) are sharp.

**Process Interpretation**

Grain size and lack of traction features indicate that sediment of this facies was deposited from suspension. The dark color of this facies is from high levels of carbon associated with with plant detritus, variations in which have produced laminae (Potter et al., 1980). Siderite concretions may form around nuclei of decaying organic matter under conditions of low Eh and high $H_2S$ levels produced by sulfate-reducing bacteria (Pettijohn, 1975). These concretions commonly form around terrestrial plant rootlets (Collinson and Thompson, 1982) as may be the case in this study.

Based on the sedimentological characteristics it is likely that Facies B (mudstone), formed in pools of standing water. The presence of terrestrial palynomorphs and abundant woody debris suggests a terrestrial origin.

Figure 2.1 Facies A: Coarse-grained sandstone.


Figure 2.2 Extremely organic rich mudstone containing ?Metasequoia logs and voluminous organic debris.

Facies C: Interbedded Sandstone and Mudstone

**Description**

Facies C is characterized by interbedded (cm-scale) fine to very fine-grained poorly lithified sandstones (subarkoses and greywackes) and grey to grey-black mudstones (Figure 2.3). This facies has been divided into three subfacies based on the estimated ratio of sandstone to mudstone in the strata ($C_1$-20% poorly lithified sandstone; $C_2$-50% poorly lithified sandstone; $C_3$-near 100% fine-grained, moderately sorted, poorly lithified feldspathic greywacke).

Subfacies $C_1$ has an average unit thickness of approximately 2 metres and ranges from 0.25 to 20 metres. Beds of bulbous (upper surface of beds) calcite-cemented concretionary sandstone are present in a 20 metre thick unit of $C_1$. These calcite-cemented quartzwackes are medium bedded, generally < 0.40 metres thick, very fine grained and poorly to moderately sorted. Woody plant debris form laminae and are common in the silty and clay-rich strata of this subfacies. Organic plant matter includes coniferous needles, "planthash", fern fronds and terrestrial palynomorphs (discussed in Chapters 3 and 4).

Subfacies $C_2$ ranges in unit thickness from 1.0 to 3 metres with an average of 1.3 metres. Laminae of woody plant debris are common in the silty and clay-rich strata. Plant matter includes coniferous needles and "planthash" with poorly preserved fern fronds. Palynomorphs present in samples from strata of subfacies $C_2$ are terrestrial.

Subfacies $C_3$ is characterized by thinly bedded (3-10 cm), fine-grained, moderately sorted, feldspathic graywackes and well-sorted quartzarenites which are white to yellowish white (cream) in color. Average unit thickness of subfacies $C_3$ is 0.50 metres with a range from 0.25 to 0.60 metres. Horizontal lamination is the dominant sedimentary structure; locally, small-scale ripple cross stratification and massive beds are present. Rip-up clasts (< 3 cm in maximum dimension) of red (oxidized) mudstone are common, particularly along lower contacts. Also present are rare,


Figure 2.3 Facies C: Interbedded sandstone and mudstone (subfacies $C_1$, $C_2$ and $C_3$ are indicated; total thickness of $C_3$-$C_2$ is 10 m).

small (< 2 cm in diameter) siderite concretions.

**Distribution**

Beds of this facies are common and occur in all sections examined in this study. The internal and lower contacts between beds of subfacies $C_1$, subfacies $C_2$ and subfacies $C_3$ are gradational. The upper contact of beds of subfacies $C_1$ to beds of subfacies $C_3$ are usually scoured and sharp, however, all other upper contacts of beds of these subfacies to overlying strata are gradational, except when overlain by beds of Facies A or E, in which case the contact is sharp and erosional.

**Process Interpretation**

The predominance of very fine sandstone and mudstone in subfacies $C_1$ suggests that these units were deposited in a relatively low-energy environment, such as abandoned channels and other topographic lows, with periodic interruption by a higher energy deposition medium; similar to deposits discussed by Williams and Rust (1969). Thin laminae of mud in subfacies $C_1$ represent suspension sedimentation in pools of standing water like those discussed by Miall (1977) and Tunbridge (1981). Based on the data presented, including terrestrial organic matter and palynomorphs, subfacies $C_1$ most likely represents continental deposits which formed in pools of shallow water.

Subfacies $C_2$ is very similar to subfacies $C_1$ and the processes of deposition are intimately related. In comparison to subfacies $C_1$ this subfacies contains more sand-sized particles and a greater amount of horizontal lamination. Higher sand content, and the dominance of horizontal lamination is interpreted to represent higher-energy conditions in similar processes of deposition.

Subfacies $C_3$ is interpreted as having formed at higher energy conditions than either $C_1$ or $C_2$. The grain size, bed thickness, dominance of horizontal lamination (upper flow regime plane bed), suggests that this deposit likely formed at high flow velocities in shallow water. Abundant terrestrial organic matter along with lithologic type and sedimentary structures suggests a terrestrial origin similar to subfacies $C_2$, however, higher energy.

Facies D: Subbituminous Coal

**Description**

Coal found in eight laterally restricted (presumed < 50 metres long), thin (max. thickness = 1.5 m) seams on Padloping Island is black and blocky with thin (mm-scale) bright bands. Lithotypes, associations of different macerals and mineral matter giving the coal a distinct banded or stripped aspect, have been estimated according to terminology from McCabe (1984) and Bustin et al. (1983). The coal consists of approximately 60% vitrain and 40% durain; resin in the form of amber is present in minor amounts (1-2%). Padloping Island coals contain a rich assemblage of terrestrial fossil palynomorphs (discussed in Chapters 3 and 4).

Proximate analyses (Bonnell, 1986; Cape Breton Coal Research) of the coal show wide ranging values of % moisture, % ash, % volatile matter, % fixed carbon, and BTU/lb (Table 2.1). The sulphur values are consistently low (0.34% to 0.53%).

**Distribution**

Coal is restricted in its occurrence; it is found only in Padloping Island Section 1. Facies D is overlain by beds of mudstone (Facies B) in all but two cases where the coal is overlain by beds of Facies E and subfacies $C_1$, respectively. Upper and lower contacts of the coals are sharp, however, scour surfaces are not present. Rooted horizons below the coals were not observed. However, six out of the eight coal occurrences lie directly over beds of Facies A or Facies E, quartz-rich sandstones; other coals occur associated in sequences of Facies B. Splits in the coal are common.

**Process Interpretation**

According to Bustin et al. (1983) the initial stage of coal formation is the deposi-

TABLE 2.1

PROXIMATE ANALYSES OF COALS

(from Bonnell; 1986)

| | Sample Numbers | | | |
|---|---|---|---|---|
| | PD-01C-19A | PD-01A-00 | PD-01C-11 | PD-01C-15 |
| Moisture | 7.23 | 8.53 | 10.29 | 14.09 |
| Ash | 11.28 | 8.63 | 24.92 | 20.91 |
| Volatile Matter | 43.67 | 41.13 | 33.93 | 33.12 |
| Fixed Carbon | 37.82 | 41.71 | 30.86 | 31.88 |
| Sulfur | .45 | .47 | .34 | .53 |

tion of peat in quiet shallow water settings, isolated from clastic input. Bright bands in the coal, vitrain, form from undegraded peats. The absence of fusinite in coals suggests an even precipitation pattern with a high water table (McCabe, 1984). However, banding in the coal (vitrain and durain), may indicate subtle variations (energy level and/or supply of organics) in the depositional environment at the time of peat accumulation. High ash content in coals (> 8% for coals from Padloping Island) may be attributed to clastic input in the area of peat accumulation (Fielding, 1985; Bustin, et al., 1983; McCabe, 1984); swamps must be isolated from active clastic deposition for peat accumulation to reach sufficient levels for the formation of coal (McCabe, 1984). Thin coal seams (< 1.5 m) with numerous thin interbeds of mud (splits) are formed by frequent contemporaneous progradation of overbank fines into swamps combined with locally rapid basin subsidence or flooding (Falini, 1965; Fielding, 1985). This scenario of an uneven subsidence rate is applicable to the coal seams on Padloping Island. Peat growth may have been periodically terminated by a rapid rise of the water table caused by floods, avulsions or subsidence, which drowned the bogs and allowed only mud deposition. Therefore it seems likely that the coal seam thinness is related to poor peat development conditions rather than erosion (scours at the top of coal seams were not observed).

Coal on Padloping Island has low sulphur values with a very limited range. Hunt and Hobday (1984), in a study examining the petrographic composition and sulphur content of some coals from eastern Australia, conclude that fluvial coals usually contain < 0.55% sulphur. They, as do Casagrande et al. (1977) and Horne et al. (1978), attribute higher sulphur values in lower delta plain coals to higher concentrations of sulphate in marine waters. Cecil et al.(1985) state that pH, rather than the simple presence of marine water, is the underlying factor controlling the concentration of sulphur. Low pH will result in coals with low sulphur and ash (from mineral leaching) values.

The absence of root traces and stumps in growth position suggests, according to work by Bustin et al. (1983) that these coals are neither autochthonous nor hypautochthonous. The absence of root traces below the coal beds is likely related to the Eh of the environment. However, Nye and Tinker (1977) propose that the pH in the immediate environment of the roots may rise and cause disintegration of the roots. Fluids present during or after the formation of the coal may have destroyed any root traces which might have been present. Alternatively, the initial organic matter forming the base of the coal deposit may not have been rooted at all, suggesting that the initial vegetative materials were allochthonous.

Peat associated with the coal found on Padloping Island probably accumulated in a backswamp environment. The backswamp coals in the meandering river deposits of the Port Hood Formation (Gersib and McCabe, 1981) are an excellent analog to the coal found on Padloping Island.

Facies E: Medium-Bedded Sandstone

**Description**

Facies E is characterized by beds of fine-grained poorly lithified sandstone, subarkosic to quartzwacke in composition, white to yellowish-white in color (Figures 2.4-2.7). Grain size of individual beds ranges from medium-fine to fine, however, very rare coarse lenses occur. Bedding is decimetre scale with an average bed thickness of approximately 1 dm. Unit thickness of Facies E averages 5 metres with a range of 1.5 to 12 metres. Sedimentary structures include large-scale cross stratification in the form of epsilon cross bed sets (Figure 2.4). These cross beds tend to dip 10-15 degrees in an easterly direction, depending on local variations. Foresets are usually highlighted by variations in very fine sandstones, mudstones and terrestrial organic debris. A localized occurrence (near base of Section 1 on Quqaluit Island) of Facies E exhibits scour-and-fill structures (Figure 2.5). Scours (channels) are 2 metres deep and approximately 10-15 metres wide. Other less common depositional structures include isolated small-scale trough cross beds, ripple cross stratification (most common near the upper contact of beds), and a few thin (<3-5 cm) horizontally laminated beds.

At some localities there are convolute laminae present in the upper 1-3 metres of units of Facies E (Figure 2.6). Convolutions, outlined by fine sediment and terrestrial organic debris are defined by broad folds. Small, (< 3-5 cm in diameter) red, mudstone rip-up clasts, which imply local erosion of poorly lithified substrate, are common in beds located at the base of units of Facies E. Their abundance generally decreases upsection within each unit of Facies E. Siderite concretions (3-6 cm in diameter) occur sporadically in units of Facies E. Bulbous calcite-cemented concretionary sandstone (< 1 m thick) occurs rarely in beds of Facies E (Figure 2.7). Fossils in beds of Facies E include well-preserved ?Metasequoia logs (located above the first volcanic ash on Padloping Island), terrestrial plant debris and a rich assemblage of terrestrial palynomorphs (discussed in Chapters 3 and 4).

**Distribution**

Facies E is observed in all the stratigraphic sections except that measured on Durban Island. The basal contact of beds in this facies is always sharp with erosional evidence, rip up clasts, present. The upper contact is usually gradational to beds of subfacies $C_1$ or $C_2$. However, when overlain by beds of Facies B or D the upper contact is sharp. The single unit of Facies E containing fossil logs and log debris (located above Facies H on Padloping Island) has both a sharp upper and lower contact with ~~beds of volcanic breccia and~~ Facies B, respectively.

**Process Interpretation**

Deposition in channels by laterally migrating bars commonly produces sand deposits with lateral accretion surfaces - epsilon cross stratification (Walker and Cant, 1984; Allen, 1964). However, Allen (1964) states that lateral accretion may also form

Figure 2.4 Facies E: Fine grained sandstone; epsilon cross sets dip 10-15 degree to the east (staff is marked in 0.5 m intervals) (Quqaluit Is.).

Figure 2.5 Channel cut-and-fill and epsilon cross sets in Facies E (Quqaluit Is.).

Figure 2.6 Convolute lamination in Facies E.

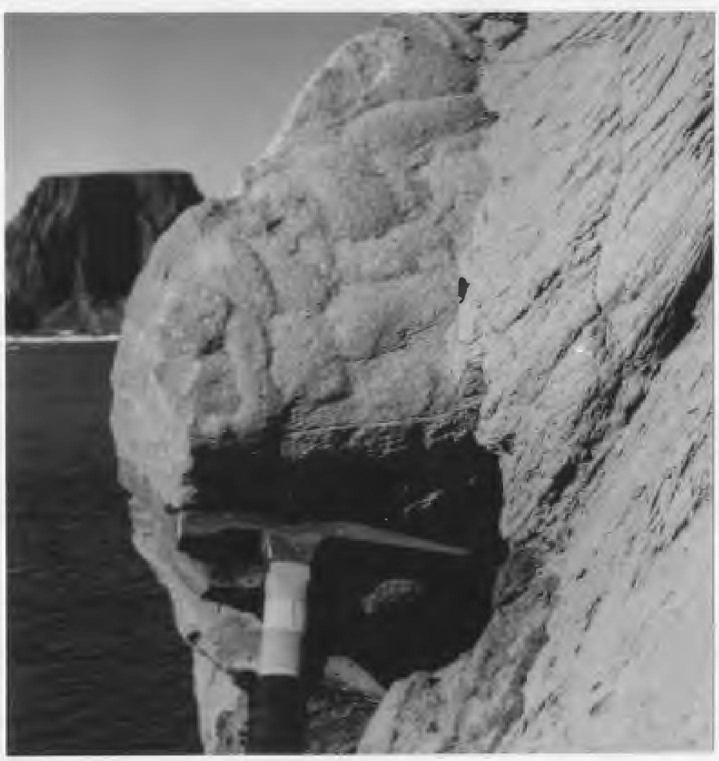


Figure 2.7 Bulbous concretionary sandstone in Facies E.

by the downcurrent, and lateral spreading, of channel bars by foreset addition. The scant presence of scour-and-fill structures in Facies E is supportive of bar migration(e.g. Allen, 1964).

According to Gersib and McCabe (1981) channel sand thickness is roughly equivalent to channel depth. Channels representing Facies E were approximately 2 metres deep and were commonly eroding into previously deposited channel-fills to form stacked sands (Figure 2.5).

Horizontally laminated sands within this facies formed at high velocities (high flow regime). Rare small-scale ripple cross stratification near the top of beds of Facies E are related to the migration of ripples as flow velocities decreased to lower flow regime. Small-scale cross stratification in the middle of beds of Facies E is related to small asymmetrical ripples formed by low intensity currents. Normal grading within the sandstones of Facies E is a reflection of the decreased ability of the depositing medium to carry sediment during channel abandonment (e.g. Howell and Ferm, 1980).

Contorted and convoluted bedding, caused by either syn-depositional or early post-depositional liquefaction (producing sediment which acts thixotropically), suggests that Facies E sands may have formed by extremely rapid deposition with relatively high pore pressures (Ayers, 1986; Collinson and Thompson, 1982; Gersib and McCabe, 1981; Miall, 1977; and Ray, 1976). Liquefaction can be triggered by external forces such as sudden uplift or earthquake activity possibly related to regional tectonic activity (Collinson and Thompson, 1982; Gersib and McCabe, 1981). Calcite-cemented concretionary sandstone beds present in Facies E form as a result of cementation by downward percolating fluids (saturated with respect to $CaCO_3$); stratigraphically controlled by fine-grained horizons, which acted as impermeable layers stopping the flow of fluids downward. Sandstones of Facies E represent terrestrial, moderate to high energy, channelized deposition.

Facies F: Arkosic Sandstone

**Description**

Facies F is a medium- to coarse-grained, arkosic to subarkosic light pink sandstone (Figure 2.8); bedding is massive. The only sedimentary structures present were, rare small-scale trough cross beds found near the top of the section on Durban Island. Strata in the upper 9 metres of section on Durban Island coarsen upward. Organic matter present in beds of Facies F includes coniferous needles, terrestrial palynomorphs and terrestrial "planthash".

**Distribution**

The only in situ occurrence of Facies F is on Durban Island where it is very poorly exposed due to internal slumping and surface erosion. This facies apparently makes up more than 80% of the sedimentary strata on Durban Island. Very thickly bedded strata of Facies F are well exposed in the upper 9 metres of the stratigraphic section. Float samples (isolated cobbles) of Facies F are present on high cliffs above the sedimentary strata on both Padloping and Quqaluit islands. The lower contact of the single unit of Facies F, over beds of Facies B (mudstone) is sharp. The section examined is not overlain by any other strata. Clarke and Upton (1971), cite this unit of Facies F as being upwards of 250 metres thick. However, this author's investigation indicates a thickness of only 86 metres; Clarke and Upton (1971) may have measured repeat section caused by faulting.

**Process Interpretation**

The characteristics of this facies may suggest a very high energy deposit, however the single outcrop observed is very poorly exposed (only tentative interpretations are implied). Granitic rocks are common sources for arkosic sediments (Pettijohn, 1975); the strata of Facies F appear to occur as a thick wedge-shaped deposit which is fault-bounded to the east against a ?granite. Coarsening upward in the upper 9 metres of the section on Durban Island may be in response to basinal tectonics. Progradation of sand bodies down-slope in an attempt to retain equilibrium in a subsiding basin will result in a deposit which coarsens upward (Rust and Koster, 1984; Ethridge, 1985b, Heward, 1978). Facies F represents a high energy continental deposit.

Facies G: Gravel-Supported Conglomerate

**Description**

A single outcrop (6 metres thick) of very poorly sorted, polymodal, gravel-supported conglomerate occurs in Quqaluit Island Section 1 (Figure 2.9). This yellow-brown weathering conglomerate is composed of sub-rounded gneiss and granite boulders (approximately 20% of total volume) up to 0.75 metres in diameter, and a gravel matrix composed of similar material and quartz pebbles. No sedimentary structures or organic matter were observed in the conglomerate.

**Distribution**

This facies comprises approximately 20% of Quqaluit Island Section 1 (QU-01A). The lower contact of the only occurrence of the facies, over beds of what may be Facies E (?), was not observed directly. Although lateral relationships could not be observed in detail, it appears that the conglomeratic body pinches to the west and may be lensoid in shape. The upper contact of this unit is sharp with beds of Facies B (mudstone) which contain logs and organic debris of ?Metasequoia.

**Process Interpretation**

According to Harms, Southard, and Walker (1982), polymodal, matrix-supported gravel conglomerates with boulders and no obvious preferred clast orientations, like Facies G, are deposited in extremely high-energy environments. Absence of grading, lamination, imbrication, and any internal sedimentary structures, along with the matrix-supported nature of the gravel, according to Miall (1977) indicates deposition in a very high energy setting, possibly, debris flows.

Figure 2.8 Facies F: Arkosic sandstone.

Figure 2.9 Facies G: Gravel-supported conglomerate.

Facies H: Volcanic Ash

**Description**

Moderate to well-sorted volcanic ash beds (Figure 2.10), consisting of volcanic glass, minor quartz crystals and grains, feldspar and biotite crystals, and scattered lithic fragments (gneissic), constitute Facies H. The only sedimentary structure present in Facies H is slight normal grading, observed microscopically. Two petrologically distinct volcanic ashes have been recognized. The ash on Padloping Island is dacitic, whereas the ash on Quqaluit Island is basaltic and contains marine palynomorphs.

**Distribution**

Volcanic ash occurs at the upper contact of Padloping Island Section 1 and Quqaluit Island Section 1. The volcanic ash is found on Padloping Island in beds slightly over 2 metres in thickness separated by beds of Facies B (mudstone). Medium bedded (10-20 cm) volcanic ash is also present in Padloping Island Section 1 (located at approximately the same stratigraphic level as the "main" volcanic ash beds). Upper and lower contacts of the ash beds are sharp; no internal scour surfaces were noted.

**Process Interpretation**

Facies H (Volcanic Ash) is interpreted as an air-fall ash. This is supported by lithology, sorting and graded bedding. Air-fall ashes are composed of at least 50% ash-sized particles (< 2 mm) that are usually well sorted (Best, 1982; Williams and McBirney, 1979). Based on the two petrologically different ashes, more than one phase of "air-fall" occurred in the study area. The presence of marine palynomorphs indicates marine conditions at the time of basaltic "air-fall" in the region.

## 2.3 Facies Associations

Five facies associations (groups of facies that tend to occur together and which

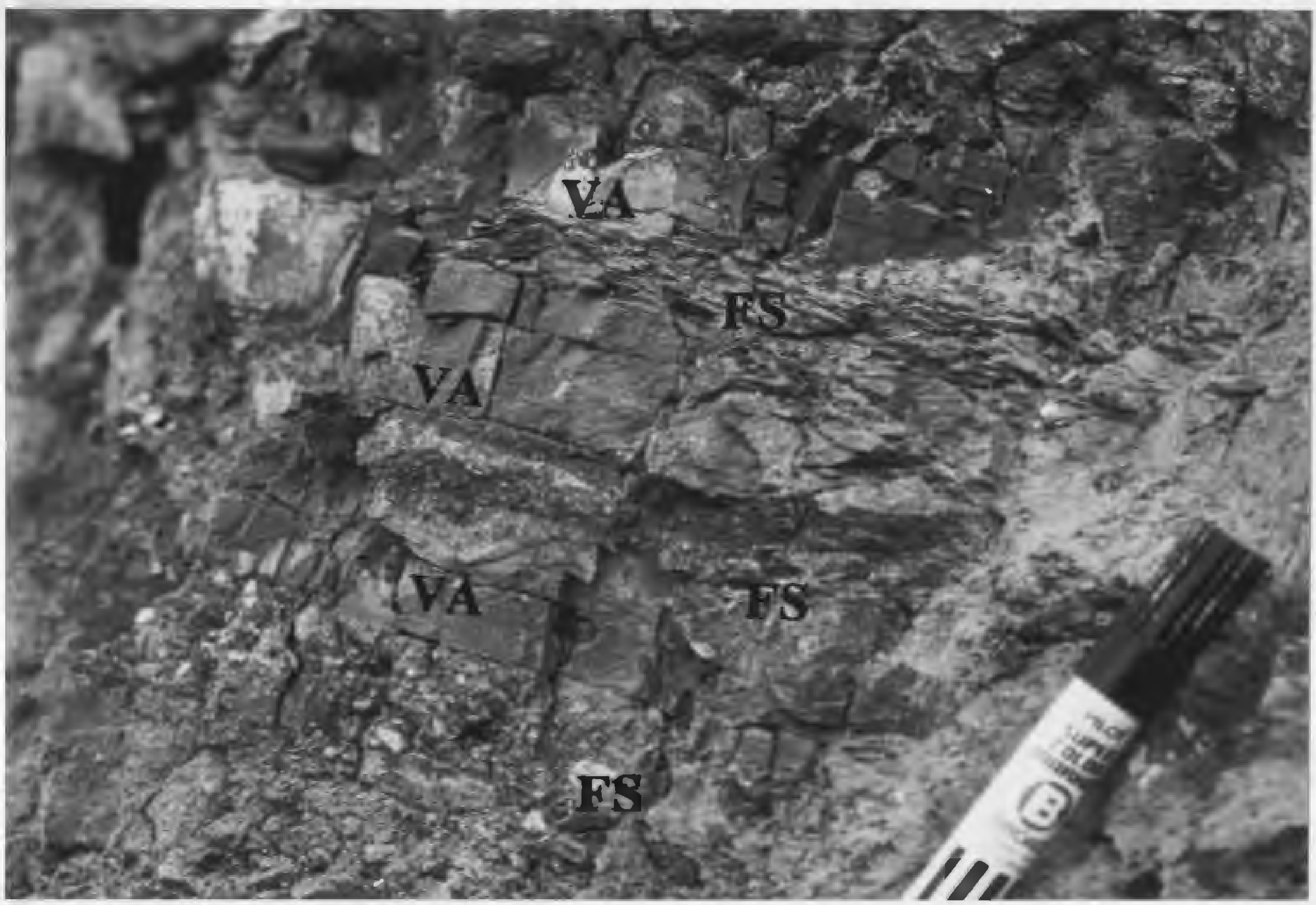



Figure 2.10 Facies H: Thin beds of Volcanic Ash interbedded with fine grained sediment on Padloping Island.

are genetically or environmentally related (Reading, 1978)) are identified and summarized in Table 2.2.

Facies Association 1: Facies A (Coarse-Grained Sandstone, terrestrial deposits of sinuous-crested dunes) and C (Interbedded Sandstone and Mudstone, overbank deposits) constitute Facies Association 1. A number of terrestrial environments may represent Facies A. Given the lack of fine-grained sediment and many characteristics of a terrestrial high energy environment, the possibilities include (a) alluvial fans, (b) braided streams or (C) meandering streams. However, the abundance of trough cross beds suggests a subaqueous origin in well confined channels, thereby ruling out (a).

Miall's (1977) classification of the various fluvial facies in a braided depositional environment states that a medium to very coarse-grained sand, which may have pebbles and sets of trough cross beds, forms by the migration of dunes in the lower flow regime, and is common in braided streams. Williams and Rust (1969) point out that pebbly beds and pebbly sands are commonly formed in high energy channel-bar complexes. The occurrence of Facies A directly on the Precambrian basement aids in ruling out possibility (c) listed above. Facies A represents deposits of sinuous crested dunes, possibly, in a braided stream environment.

According to Williams and Rust (1969) deposits like subfacies $C_1$ are commonly formed in relatively low-energy environments, such as abandoned fluvial channels. Change in grain size from sand to silt and clay indicates waning flows, which combined with lack of evidence for traction deposition, is most consistent with deposition as overbank deposits on a floodplain (Elliott, 1974; Miall, 1977; and Steel and Aasheim, 1978). Thin laminae of mud represent suspension sedimentation occurring during the final stages of a flood cycle in pools of standing water in a fluvial environment (Miall, 1977; Tunbridge, 1981). Subfacies $C_1$ represents floodplain deposits which were periodically interrupted by higher energy deposits.

TABLE 2.2

FACIES ASSOCIATIONS

| FACIES ASSOCIATION | MAIN FACIES | | INTERPRETATION |
|---|---|---|---|
| 1 | **A** (Coarse Grained Sandstone [Deposits of Sinuous Crested Dunes])<br><br>**C** (Interbedded Sandstone and Mud-stone [Overbank Deposits]) | | BRAIDED<br>STREAM<br>DEPOSITS |
| 2 | **B** (Mudstone [Pond Deposits])<br><br>**D** (Coal [Deposits of Peat Swamps])<br><br>**C** (as above) | | BACKSWAMP<br>DEPOSITS |
| 3 | **E** (Medium Bedded Sandstone [Point Bar Deposits])<br><br>**C** (as above) | | MEANDERING<br>STREAM<br>DEPOSITS |
| 4 | **F** (Arkosic Sand [Alluvial Fan]) | ?<br>?<br>? | DISTAL<br>ALLUVIAL FAN<br>DEPOSIT |
| 5 | **G** (Gravel Supported Conglomerate [Debris Flow])<br><br>**H** (Volcanic Ash [Air-fall Volcanic Ash]) | | VOLCANI-<br>CLASTIC<br>DEPOSITS |

Subfacies $C_2$ is very similar to subfacies $C_1$ and also represents overbank deposits. According to Tunbridge (1981) and Harms and Fahnestock (1965) horizontally laminated sands may represent deposits of high energy sheet flood deposits. However, Elliott (1974) points out that rapidly alternating sands and muds of varying thickness implies deposition on levees of river or stream banks. Levee deposits (subfacies $C_2$ ?) are finer than channel deposits and are composed of very fine sand and silt with minor thin laminae of organic debris or clay (Coleman and Gagliano, 1964).

Grain size, bed thickness, dominance of horizontal lamination, and stratigraphic relationships, suggest that strata of subfacies $C_3$ were deposited as fluvial overbank flows (crevasse splays), similar to those described by Harms and Fahnestock (1965), Tunbridge (1981) and Walker and Cant (1984). Crevasse splay deposits form at high flow velocities, shallow depth, and are typically sandy, fairly well sorted, and well stratified (Nilsen, 1982).

Based on the stratigraphic position of Facies Association 1 (base of each measured section, where it unconformably overlies the Precambrian basement), lithology, terrestrial fossils, organic debris, grain size and sedimentary structures, it is suggested that it represents the deposits of sinuous crested dunes (Facies A) and minor overbank fines (Facies C) in a braided stream environment. Facies Association 1 is termed the "Braided Stream Complex".

Facies Association 2: This facies association consists of mainly Facies B (Mudstone, pond deposits), D (Coal, organic accumulations) and minor amounts of C (Interbedded Sandstone and Mudstone, overbank deposits, discussed above). Based on sedimentological and paleotological characteristics, Facies B (Mudstone), formed in pools of standing water, in backswamp regions of a fluvial depositional environment, like Facies "Fsc" in Miall's (1977) classification of fluvial facies. Facies D (Coal) formed from organic accumulations in peat swamps isolated from clastic input.

The association of ponds, peat swamps and minor overbank sediments (quiet water deposition), absence of high energy deposits (i.e. Facies A or E), and abundance of terrestrial organic matter and terrestrial fossils, suggests that Facies Association 2 most likely formed in backswamp regions of a fluvial depositional system. Facies Association 2 is termed the "Backswamp Complex".

Facies Association 3: Facies E (Medium-Bedded Sandstone, terrestrial channel deposits) and Facies C (Interbedded Sandstone and Mudstone, overbank deposits, discussed above) constitute Facies Association 3. Epsilon cross stratification in Facies E represents the lateral migration of channels in a terrestrial environment; most likely in a fluvial setting. Small-scale cross stratification in the middle of beds of Facies E is related to small asymmetrical ripples formed by low intensity currents; these are sometimes found in the middle part of point bar deposits (Ray, 1976; Hobday et al., 1981). Fining-upward sequences, like beds of Facies E, are characteristic of fine-grained fluvial deposits and most likely formed by point bar migration (McGowen and Garner, 1970; Steel and Aasheim, 1978). The upward fining in units of Facies E is the result of the lateral migration of environments (i.e. channel floor, point bar, flood plain) characterized by different grain sizes. The relatively thick, massive sands of Facies E that do not exhibit sedimentary structures, are interpreted as point bar deposits similar those described by Plint and Van de Poll (1982). Their explanation for the lack of sedimentary structures, like beds decribed by Gersib and McCabe (1981), is due to relatively uniform grain size and post-deposition in situ liquefaction. Exposure and oxidation of overbank sediments (Facies C) produced small siderite concretions, which according to Hobday et al. (1981) are abundant in point bar sands (Facies E). According to Ray (1976) convolute lamination can occur during the waning phase of a flood, in fluvial depositional settings. This author concludes that Facies E represents deposits of point-bars in a fluvial environment.

The anomalously thick (20 metres) unit of subfacies $C_1$ in Padloping Island Section 2 likely represents a sequence of vertical accretion deposits (overbank fines) which accumulated adjacent to stacked sand bodies (Facies E) that were being deposited in a confined meander belt (e.g. Walker and Cant, 1984).

The presence of point-bar and overbank deposits in Facies Association 3 suggests a fluvial setting; most likely a meandering stream environment. Facies Association 3 is termed the "Meandering Stream Complex".

Facies Association 4: Facies Association 4 consists of Facies F (Arkosic Sandstone, high energy terrestrial deposit) and minor amounts ? of Facies C (Interbedded Sandstone and Mudstone, overbank deposits, discussed above). The characteristics of Facies F suggest a very high energy deposit, however the only section of Facies F is very poorly exposed. Possibilites for processes producing such a deposit include (a) debris flows, (b) braided stream deposits, (c) alluvial fan deposits. The presumed small percentage of mud and sedimentary structures, isolated occurrence, and strata thickness may suggest that Facies Association 4 represents a mid to distal deposit of an alluvial fan. The presumed lack of sedimentary structures and the sediment sorting (moderate to well) rule out possibilities (a) and (b) respectively. According to Rust (1979) deposits of this type are of tectonic significance and indicate sharp terrestrial relief at the time of deposition. Facies Association 4 is termed the "Distal Alluvial Fan".

Facies Association 5: Facies G (Gravel-Supported Conglomerate, very high energy deposit, possibly a debris flow) and Facies H (Volcanic Ash, air-fall ash) constitute Facies Association 5. Facies G, a very high energy deposit, may be a debris flow. A number of criteria for debris flows, outlined by Nilsen (1982), apply to Facies G: (a) the composition of the conglomerate dictates that the source was near (i.e. the Precambrian gneiss and the granitic body on Durban Island); (b) the deposit exhibits characteristics of a very high energy depositional environment; (c) poor sorting with a wide range of clast sizes; (d) sub-rounded clasts, indicating a short period of transport prior to deposition; (e) yellow color and lack of organics and fossils suggesting deposition in subareal oxidizing conditions; (f) absence of sedimentary structures; and (g) association with a fault-bounded sedimentary basin. Facies H (Volcanic Ash) is hydrodynamically interpreted as an air-fall ash.

The association of two facies which indicate high energy and tectonic activity in the region suggests a volcaniclastic-related origin. Facies Association 5 is termed the "Volcaniclastic Complex".

## 2.4 Synthesis of Environments of Deposition

The stratigraphic sequence on Padloping, Quqaluit and Durban islands indicates initial deposition in a braided fluvial environment (Figure 2.11) which, on Quqaluit and Padloping islands, is followed by deposition in a meandering fluvial environment (Figure 2.12). Paleocurrent direction was approximately to the north, based on cross bed measurements (Facies A and E) and the increase in thickness of braided and meandering stream deposits northward towards Quqaluit Island. This change from braided to meandering deposition pattern is not uncommon in other similar sequences (e.g. the Fort Union Formation; Beaumont ,1979). In the Scalby Formation (M. Jurassic) of Yorkshire a similar change from braided stream deposits to meandering stream deposits was attributed by Nami and Leeder (1978) to the reduction of stream gradients during the initial deposition stages following uplift.

An important consideration in this context is that vertical sequences may not be due entirely to the migration of laterally adjacent facies within a particular depositional system (i.e. coal overlying pointbar sands), but rather to major changes in depositional systems through time (McCabe, 1984). The change in river system (braided to meandering) reflects changes in discharge of the river, or of slope, originating from tectonic, climatic or eustatic changes. Tectonic movements in the local

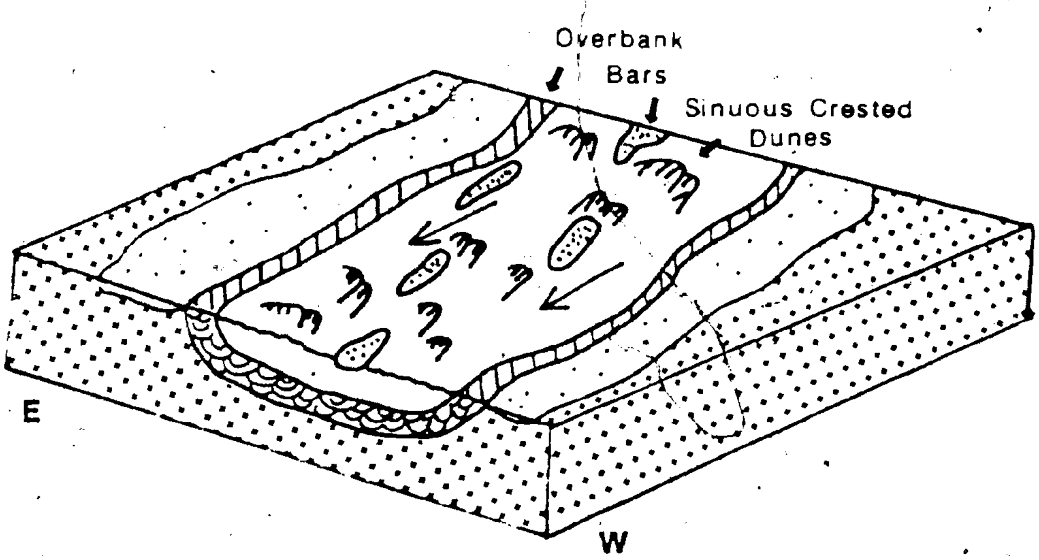



Figure 2.11 Braided stream depositional environment.

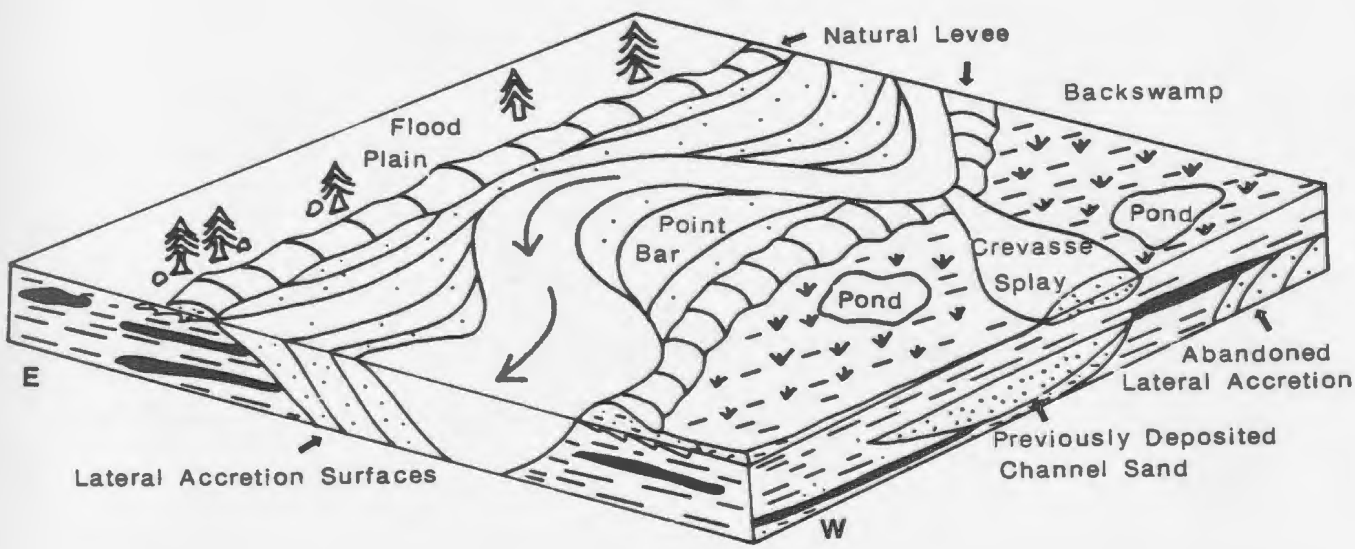



Figure 2.12 Meandering stream depositional environment.

source area may have resulted in lowering the source rocks relative to the drainage region or a lowering of gradient through time in the sedimentary basin and a change in fluvial pattern from braided to meandering.

Strata from all three islands have been correlated in stratigraphic sections which use the upper contact (with basaltic breccia) as a datum (Figure 2.13). This was chosen because of the likelihood that these beds represent a geologically instantaneous event. Upper strata (Facies F) on Durban Island are anomalous and represent deposition in a separate depositional basin. Facies F (Distal Alluvial Fan) is of tectonic significance and may represent a local deposit formed proximal to an uplifted area.

## 2.5 Sandstone Petrology

Twenty-eight samples of sandstones from outcrops on Padloping, Quqaluit, and Durban islands were thin-sectioned and stained for a variety of carbonate species (High Fe, Low Fe Calcite and Dolomite) using Alizarin Red S and potassium ferricyanide following a staining method as stated in Adams et al. (1984). In these samples only low Fe calcite was found. Many samples were very poorly consolidated and were therefore impregnated using blue epoxy before thin sectioning. The blue dye facilitates recognition of pore space. A minimum of 500 points per thin section supplied data on mineralogical composition. This number insures that for major constituents, the volume of observed constituents is within ± 4.5% of the actual volume with a 95% level of confidence (Van der Plas and Tobi, 1965). Grain size and/or thin section condition allowed only 250 points for three samples (PD-01A-BASE, PD-01B-09, and PD-02A-58). Fragments counted in the analyses include: quartz, feldspar, mica, tourmaline, garnet, magnetite, organics, and lithic rock clasts (only granitic and gneissic rock clasts were present). Clay matrix, calcite cement, hematite cement, and pore space were also counted (Appendix $B_1$).

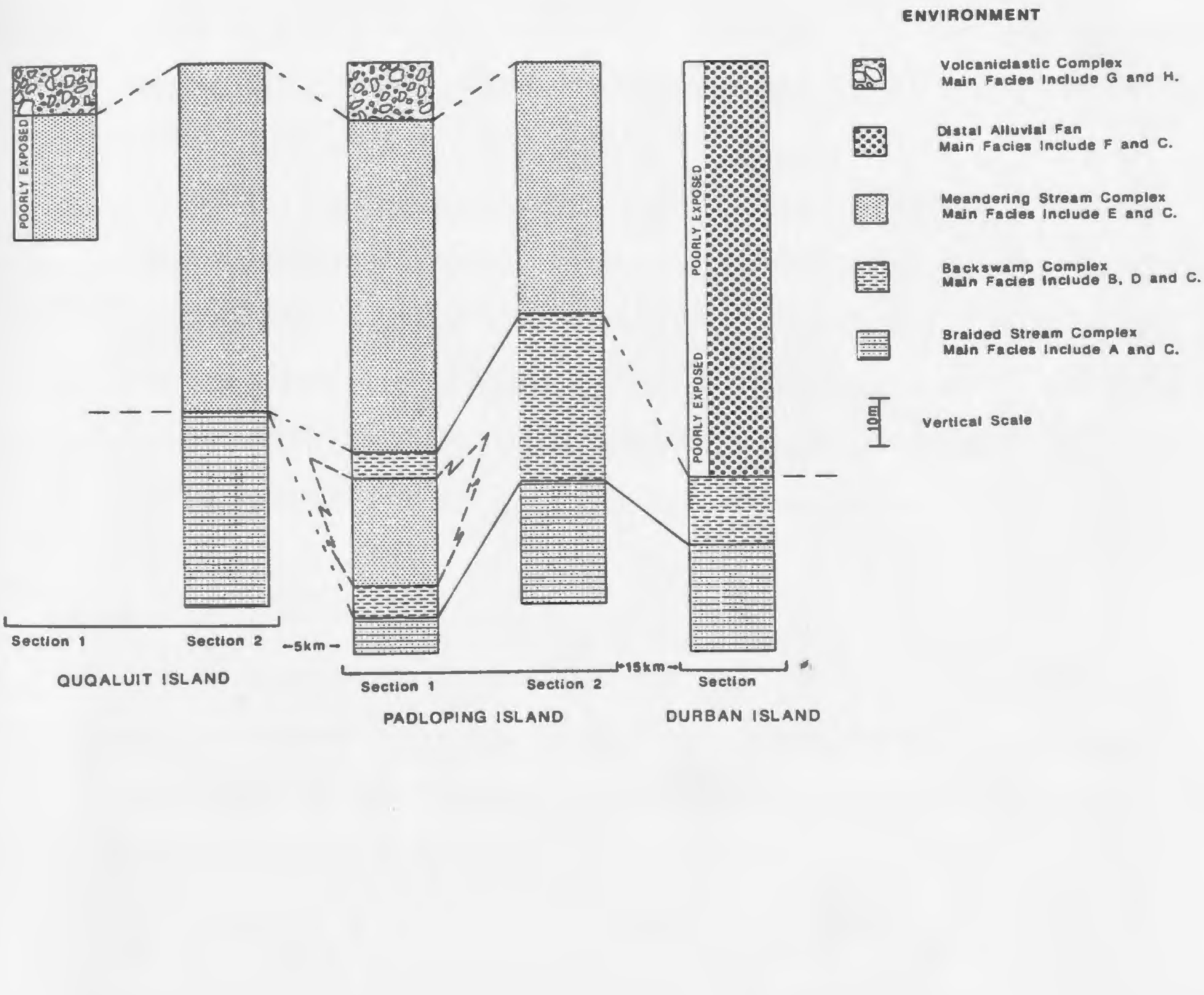



Figure 2.13 Correlation of depositional complexes.

### 2.5.1 Detrital Modes

Sandstone samples have been classified according to McBride (1963). Wackes, those samples containing more than 15% matrix are classified according to Folk (1980). This classification allows best representation of data (referring to apices of triangles for plotting detrital mode data) since the only lithic rock fragments present are granitic or gneissic. Granite and gneiss are the two rock types presumed to be the source for the sandstones. In McBride's (1963) classification, the majority of the sandstones from this study fall in the arkose and subarkose fields. Sandstones from Durban Island (Facies F) fall in the subarkose and arkose categories (Figure 2.14). Sandstones from Quqaluit Island (only 3 samples) fall in three separate categories, quartzarenite (Facies E), subarkose and lithic subarkose (Facies A), with the mean composition falling in the subarkose field (Figure 2.14). Padloping Island sandstones have varied compositions, most plotting near the quartz pole (Figure 2.14); the mean composition of these sands is subarkosic. Padloping Island sandstones with >15% clay matrix (Figure 2.15) include quartzwackes, and more commonly, quartz-rich feldspathic greywackes (subfacies $C_3$ and Facies A and E).

### 2.5.2 Framework Grains

Quartz is the most abundant framework grain present in all the sandstones; it ranges from 37% to 89% of the total rock volume (Appendix $B_1$). Monocrystalline quartz is dominant with polycrystalline quartz found in only very small percentages (< 3% rock volume).

Feldspar, both alkali and plagioclase, is common; plagioclase is far more common than orthoclase. Carlsbad and albite twinning are common in the plagioclase feldspars. Microcline, exhibiting polysynthetic twinning, is the most common alkali feldspar.

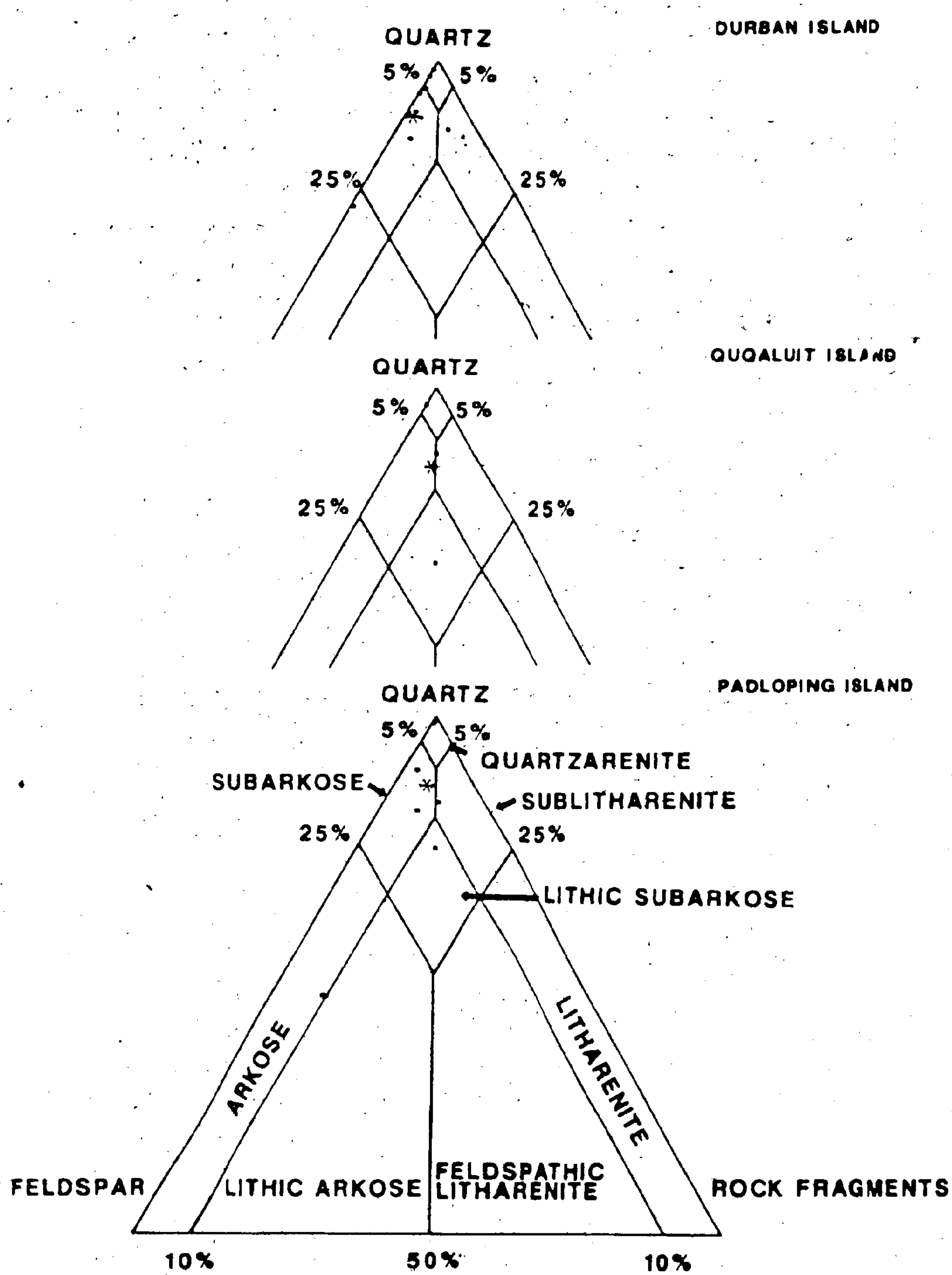



Figure 2.14 Detrital plots for sandstones (*= mean composition).

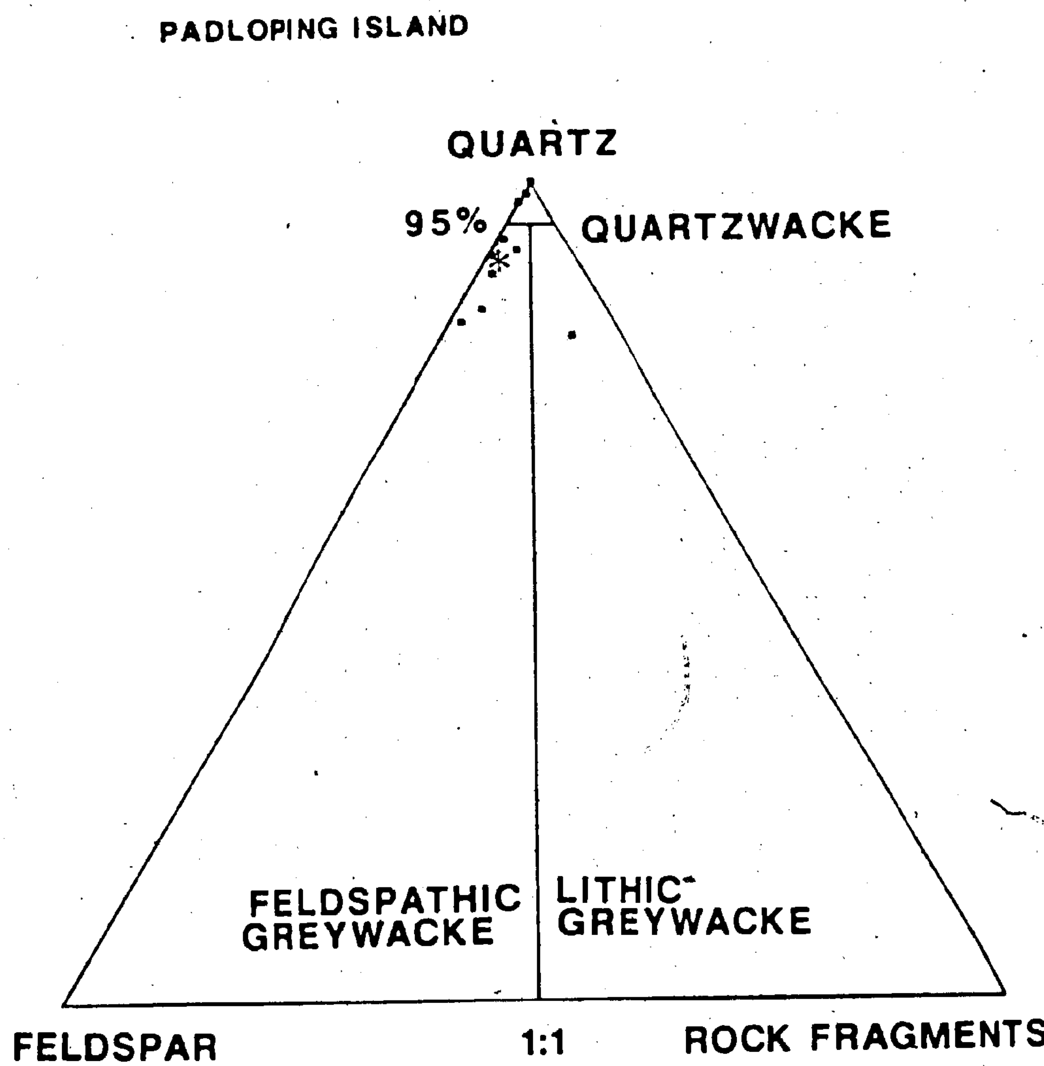



Figure 2.15 Detrital plot for Padloping Island sandstones with >15% clay matrix; (*= mean composition).

Rock fragments consist of clasts of weathered granite and gneiss; both are suspected source rocks for the sediments. Detrital heavy minerals include tourmaline, garnet, and magnetite. Biotite and muscovite compose < 5% of total rock volume (muscovite is more common than biotite).

### 2.5.3 Matrix and Cement

Sandstones which contain > 15% clay matrix are termed wackes (Folk, 1980). The only wackes identified during the study were from Padloping Island. Many of the unconsolidated sands from Quqaluit Island appear to be wackes, however, inability to sample precluded thin section determination.

Cements (calcite, hematite, and quartz overgrowths) contribute from 0% to 44% of total rock volume. Hematite cement is found only in sandstones from Durban Island. Secondary calcite cement is observed only in sandstones from Padloping Island and represents precipitation under diagenetic conditions that were unusual for the sediments in this study. Quartz overgrowths were observed in some samples; however, they were difficult to discern and so their abundance is probably underestimated.

### 2.5.4 Grain Size, Sorting and Texture

The grain sizes (visual estimation) of the samples studied in thin section are: medium to very coarse for Facies A, very fine to medium for Facies C, very fine to very coarse for Facies E (only three samples), and medium to very coarse for Facies F. Sorting of these sandstones varies considerably (very poor to well), however, the majority of the sandstones are poorly sorted. All samples exhibit subangular to angular grain shapes.

### 2.5.5 Petrologic Summary

The higher percentages of heavy minerals in the Durban Island sandstones (no finer than other sandstones from other areas in this study) probably represents closer proximity to the granitic source. Hematite cement found in Durban Island samples, forms from the removal of approximately 1% $Fe_2O_3$ by intense weathering and leaching of the common iron-rich minerals such as magnetite, ilmenite, biotite, and hornblende (Greensmith, 1979). In this case from the local granitic source rock located adjacent to the sediments.

The absence of sedimentary rock fragments, the prominence of gneissic and granitic rock fragments and the angularity of clasts in the sandstones of this study strongly suggests only one cycle of weathering and deposition. The prominent lithology represented lies in the quartz-rich subarkose to arkose category. However, as in the fluvial facies of the Port Hood Formation (e.g. Gersib and McCabe, 1981) few differences in composition between sandstones of different facies are present.

### 2.6 Reservoir Rock Potential

The environments of deposition for the strata in this study are mainly fluviatile. Fluvial sedimentary sequences often constitute significant hosts for hydrocarbons (Ethridge, 1985a); the largest oil producing field in North America, Prudhoe Bay, is reservoired in braided stream deposits.

Fluvial depositional systems produce hydrocarbon reservoirs which are highly variable. Galloway and Hobday (1983) state that braided river deposits produce abundant potential reservoir rocks but lack good seals; meandering deposits, on the other hand, have smaller reservoirs with adequate sealing rocks present.

Porosity estimates have been made for all sandstones on Quqaluit, Padloping, and Durban islands. During point counts for sandstone petrology, pore spaces were counted taking great care not to include voids due to plucking. Appendix $B_1$ expresses pore percentages in terms of total rock volume. Porosities range from 0% to more than 24% in sandstones varying in grain size and composition. According to

Levorsen's (1967) classification, porosities of 5-10% are poor, 10-15% fair, 15-20% good, and 20-25% very good. Some sandstones, especially on Durbán Island, have good to very good intergranular porosity.

Detailed measurements for permeability have not been made, however, using the porosity values for these samples, general estimates of permeability have been made; the majority of the sandstones have good (10-100 millidarcys) permeabilities.

# CHAPTER 3

# PALEOBOTANY, PALYNOLOGY AND OTHER ORGANIC MATTER

## 3.1 Introduction

Paleobotany and palynology have been employed for age determination of the strata exposed on the southeast coast of Baffin Island. Previous works, based solely on paleobotany report these sediments as Paleocene in age (McMillan, 1910; Clarke and Upton, 1971).

It is a long and well understood fact that oil and gas are formed by the thermal maturation of organic matter (Levorsen, 1967). Information concerning the type of organic matter leads to conclusions about the type of hydrocarbons that potential source rocks may provide. Organic matter observed in polished blocks of coal and mudstone samples and in palynology strews has been utilized for organic matter typing and organic maturation assessment.

A source rock is defined as any fine-grained rock which, on the basis of organic richness and maturity is believed to be presently, or formerly, capable of expelling petroleum (Levorsen, 1967). The basic requirements for a source rock are: (1) organic richness, (2) organic type, and (3) maturity (Tissot and Welte, 1978). Source rocks are commonly classified on the basis of chemical composition and ratio of H/C to O/C (Gutjahr, 1983); however, these chemical analyses are very time consuming and expensive. Microscopic techniques also permit recognition of source rock quality.

According to Waples (1982) the two most commonly used parameters for measuring thermal maturity of potential source rocks are thermal alteration index (TAI) and vitrinite reflectance (%Ro). However, Dembicki (1984) points out, in an interlaboratory comparison of source rock data, that most methods of source rock analyses are subject to much error. Also, Heroux, et al. (1979) state that there is no known thermal parameter which is self-sufficient in hydrocarbon exploration. TAI and %Ro are employed for organic maturity assessment.

### 3.2 Paleobotany

Samples of tree bark, woody detritus, petrified wood, coniferous needs, and fern impressions were analysed by J. Bassinger (University of Saskatchewan) for taxonomic affinities and age determination (Table 3.1).

Logs of ?Metasequoia are preserved as wood, some lignitic, and locally by permineralization through silica replacement. Organic matter of this type, coniferous needles, fern frond impressions, and "planthash" is present in beds of Facies C, B and D (overbank and backswamp), however, fossil logs are only found above the debris flow on Quqaluit Island and above the first volcanic ash on Padloping Island.

### 3.3 Palynology

#### 3.3.1 Methods

**Processing**

Over 150 samples were collected from freshly exposed strata on Padloping, Quqaluit and Durban islands; fifty samples, representing the various lithologies and facies of the section, have been processed and examined for palynomorphs and other organic debris (Appendix $C_1$).

Before preparation, all samples received a five digit laboratory number (Appendix $C_1$) identifying the sample and year of processing. Consolidated samples were washed in distilled water, scrubbed with a wire brush, and air dried for approximately twelve hours; many of the samples were poorly consolidated and washing was not possible. Samples were then wrapped in aluminum foil, crushed to millimeter size, weighed (15 gm for shales, siltstones and coals, 30 gm for sands and sandstones, and 60 gm for volcanic ash) and placed in labelled 250 ml beakers. Before chemical treatment four tablets each containing 12,100 ± 400 Lycopodium grains (Stockmarr, 1971) were added to each crushed sample to provide an estimate of

TABLE 3.1

SUMMARY OF PALEOBOTANICAL ANALYSES
(* indicates samples located above the first volcanic ash)

| Sample | Description | Affinity | Possible Age |
|---|---|---|---|
| PD-01B03<br>Pl.1 Fig. 2 | Coniferous needles | ?*Elatides* | Aptian-Albian |
| *PD-01B-15 | Tree bark | Taxodiaceae | Cretaceous - Tertiary |
| *PD-LOG<br>Pl.1 Fig. 1 | Permineral - ized wood | ?*Metasequoia ocelon*<br>?*Glyptostrobus* | Paleocene - Eocene |
| QU-2<br>Pl.1 Fig. 4 | Root | unidentifiable | |
| QU-5<br>Pl.1 Fig. 7 | Fern Frond | ?*Gleichenites* | Early Cretaceous |
| QU-6<br>Pl.1 Fig. 6 | Fern Frond | ?*Cladophlebis* | Early Cretaceous |
| PD-2a<br>Pl.1 Fig. 3 | Leaflets | ?*Podozamites* | Early Cretaceous |
| PD-2b<br>Pl.1 Fig. 5 | Fern Frond | ?*Gleichenites* | Early Cretaceous |

palynomorph concentrations.

To remove carbonates 100-150 ml of 20% hydrochloric acid was added to each sample. Methanol was used to control any excessive effervescence. The sample was left for approximately 8-10 hours until the reaction was complete. Samples were centrifuged and the acid decanted. Distilled water was added, centrifuged and decanted to remove all remaining hydrochloric acid. At least three washings were necessary to neutralize the sample.

Hydrofluoric (HF) acid was used to remove silicates in the samples. Samples were left in 150 ml of HF for 8 to 12 hours then washed in distilled water, centrifuged and decanted three times. Residues were then examined to determine the quantity of organic and remaining mineral matter. Prior to sieving, a slide (1 of 5) of this unoxidized, unsieved sample was prepared. Darvan (100 ml) was added to particularly mud-rich samples prior to sieving. Darvan removes the < 3 um particles and speeds up processing. Few samples required this step and no noticeable difference in the percentage of total organic matter in treated samples was detected. A slide of the darvan residue contained 99% clay matter and very fine organic matter; no palynomorphs were present in the darvan residue.

Samples were then sieved through a 10 um screen using a technique described by Cwynar et al. (1979). Prior to oxidizing, a slide (2 of 5) was mounted of this sieved, but unoxidized, sample. In addition, about 5 ml of the residue was placed in a labelled vial with 2 drops of phenol. Wet mounts of samples were microscopically examined to determine the amount of time required for oxidation in "Schultz" solution. The time limitations were based upon the color of the palynomorphs present in each sample. If the palynomorphs were black the sample was placed in Schultz solution for 5 minutes; if they were brown, 3 minutes; and if yellow only 1 minute.

About 20 ml of Schultz solution was added to samples in a 50 ml test tube and then stirred. Samples were washed and centrifuged three times. While washing and sieving for the final time 10% potassium carbonate was added to the oxidized samples briefly and then washed out with distilled water. The sample was then re-examined under a microscope. If too sandy, heavy liquid was employed to separate the organic fraction followed by decanting as outlined above. Samples (3, 4 and 5 of 5) were mounted.

To mount slides one drop of sample was placed upon a glass coverslip with three drops of polyvinyl alcohol and spread evenly with a toothpick. The sample was left to dry for approximately 2 hours. Once dry, two drops of Elvacite (Dupont) were placed upon the residue on the coverslip and then turned over onto the glass slide. The coverslip was allowed to settle on the slide where it was left to dry for approximately 8 hours. To preserve residues, 2 drops of phenol were placed in a labelled vial with remaining sample.

## Identification and Statistics

A Reichert Zetopan microscope, serial number 341717, with a Reichert Photo-automatic camera was used for strew examination and palynomorph identifications. Photographs were taken using black and white, Kodak, PX 135, ISO 125 film, with the optics set for interference contrast.

Slides were scanned on at least ten horizontal traverses; total counts of palynomorphs were taken to 200 grains not including the grains of the Lycopodium tracer. The abundance, type and condition of organic matter other than palynomorphs were also noted.

Confidence limits (0.95 confidence level) (error bars on pollen diagrams, Figures 3.1-3.5, in pocket) for relative frequency abundance are calculated from equation:

$$p(0.95_{limit}) = \frac{(Z + (K^2/2N) \pm K \sqrt{(Z(1-Z)/N + (K^2/4N^2))}}{1 + (K^2/N)}$$

(N = the number of grains in the count)

where Z is the relative percent abundance of a taxon and K is a constant equal to 1.96 (Maher 1972).

Statistics have been calculated to determine the diversity and evenness of species contained in each sample (Appendix $C_2$). Beerbower and Jordan (1969, p. 1186) define diversity as the "number of equally common taxa" and they state (p. 1196) "reflect both the number of taxa present and their proportional abundance."

Diversity, H', is given by the formula for the "Shannon-Wiener Index" (Pielou, 1966; p. 290);

$$H' = -\sum_{i=1}^{s} p_i \ln(p_i)$$

"where $p_i$ is the proportion of the community that belongs to the $i^{th}$ species." S equals the number of species in the assemblage. The units given here are not important as long as consistancy is practiced in the base of the logs (Pielou, 1966).

The sampling variance of diversity is given by;

$$\sigma H^2 = 1/N \left( \sum_{i=1}^{s} p_i (\ln p_i)^2 - H'^2 \right)$$

where $n_i$ is the number of individuals in taxon i and s' is the number of species counted in a count of N grains and $p_i = n_i/N$ (Pielou 1966).

Evenness, which is dependant upon diversity, is a measure of the equitability of probabilities for palynomorphs in a particular sample (Burden 1982). Evenness may be expressed as a ratio between the previously calculated diversity H' and the number of species in a sample. Evenness, E, is represented by;

$$E = H'/\ln s$$

and the sampling variance of evenness is represented by;

$$\sigma E^2 = \sigma H^2/(\ln s)^2$$

This statistical information (Appendix $C_2$, Figures 3.1-3.5) can be used in paleoecologic analysis as an aid for defining environmental boundaries. However, due to transportation and selective preservation these statistics may not directly relate to the sites where plants grow.

### 3.3.2 Systematics

As the phyletic affinities of fossil palynomorphs can rarely be determined with certainty, most classification schemes (morphological) are somewhat artificial.

A morphological classification system is used in this study. Paleoecological or phyletic affinities are not inferred. This classification scheme is that of Burden (1982) and Burden and Hills (in prep.) and is based on the taxonomic key of Burden and Hills (in prep.) of the Lower Cretaceous of western Canada. Palynomorphs are subdivided into the following groups and subgroups:

TERRESTRIAL PALYNOMORPHS

- Trilete Spores
- Monolete Spores
- Inaperturate Pollen
- Bisaccate Pollen
- Monosulcate Pollen
- Tricolpate Pollen
- Tricolporate Pollen
- Triporate Pollen
- Periporate Pollen

FUNGAL REMAINS

MARINE MICROPLANKTON

Chorate Dinoflagellates

Proximate Dinoflagellates

Cavate Dinoflagellates

The entry for each taxon includes a photograph, selected synonymy, a short description for some specimens classified only to the generic level, worldwide range, occurrence in this study, relative abundance, and any specialized characteristics unique to this study.

The species from Padloping, Quqaluit and Durban islands, are illustrated as palynomorph counts in Appendix D.

TERRESTRIAL PALYNOMORPHS

Trilete Spores

Genus Polycingulatisporites Simoncsics and Kedves
emend. Playford and Dettmann, 1965

Type Species: Polycingulatisporites circulus Simoncsics and Kedves, 1961.

Polycingulatisporites sp. cf. P. radiatus Singh, 1971

Pl. 2 Fig. 1

Selected Synonymy:

1971 Polycingulatisporites radiatus Singh, p. 131, pl. 18, figs. 4-7.

Remarks: The single specimen observed, resembles Polycingulatisporites radiatus, however, it is corroded and therefore assignment to this species is questionable. P. radiatus is reported from the early Aptian to late Albian (Burden and Hills, in prep.). The single occurrence of this taxon is in a sample from a bed of Facies C (overbank) located below the debris flow on Quqaluit Island.

Genus Distaltriangulisporites Singh, 1971

Type Species: Distaltriangulisporites perplexus (Singh) Singh, 1971.

Distaltriangulisporites perplexus (Singh) Singh, 1971

Pl. 2 Fig. 2

Selected Synonymy:

1964 Appendicisporites perplexus Singh, p. 55, pl. 5, figs. 6-9.

1971 Distaltriangulisporites perplexus (Singh) Singh, p. 89, pl. 12, figs. 1-6.

1975 Distaltriangulisporites perplexus (Singh) Singh; Brideaux and McIntyre, p. 16, pl. 2, fig. 40.

1982 Distaltriangulisporites perplexus (Singh) Singh; Burden, p. 183, pl. 9, figs. 17-20.

Remarks: The reported range for this species is Valanginian to late Albian (Burden, 1982). Specimens in this study are 5-8µm larger than Singh's (1964) maximum size (45µm) for the species. This taxon is present (in very low abundance; 2 specimens) in a sample from a bed of Facies C (overbank) from below the debris flow on Quqaluit Island.

Distaltriangulisporites irregularis Singh, 1971

Pl. 2 Fig. 3

Selected Synonymy:

1971 Distaltriangulisporites irregularis Singh, p. 91, pl. 12, figs. 10-13.

1982 Distaltriangulisporites irregularis Singh; Burden, p. 185, pl. 9, figs. 23-26.

Remarks: Burden (1982) reports a range of late Berriasian to Albian for Distaltriangulisporites irregularis. Only two specimens, each in a sample from a bed of Facies C (overbank) located below the debris flow on Quqaluit Island were observed.

Genus Densoisporites Weyland and Krieger emend.

Dettmann, 1963

Type species: Densoisporites velatus Weyland and Kreiger, 1953.

Densoisporites microrugulatus Brenner, 1963

Pl. 2 Fig. 4

Selected Synonymy:

1966 Densoisporites microrugulatus Brenner; Burger,
p. 253, pl. 22, figs. 1, 2; pl. 23, fig. 1.

1971 Densoisporites microrugulatus Brenner; Singh,
p. 46, pl. 3, figs. 11, 12.

1975 Densoisporites microrugulatus Brenner; Brideaux and McIntyre,
p. 16, pl. 3, fig. 4.

1980 Densoisporites microrugulatus Brenner; Wingate, p. 11, pl. 2, fig. 9.

1982 Densoisporites microrugulatus Brenner; Burden, p. 306, pl. 24, figs. 12, 13.

Remarks: According to Burden (1982) the range for Densoisporites microrugulatus is Berriasian to Albian. This species occurs (1-3 specimens/sample) in samples from beds of Facies C, B and D (overbank and backswamp) on all three islands. It occurs once (corroded) in a sample from a bed of Facies B (backswamp) located above the debris flow on Quqaluit Island.

Genus Appendicisporites Weyland and Krieger, 1953

Type Species: Appendicisporites tricuspidatus Weyland and Greifeld, 1953.

Appendicisporites bifurcatus Singh, 1964

Pl. 2 Fig. 5

Selected Synonymy:

1964 Appendicisporites bifurcatus Singh, p. 54, pl. 5, figs. 1-5.

1971 Appendicisporites bifurcatus Singh; Singh, p. 56, pl. 4, figs. 3-5.

1975 Appendicisporites bifurcatus Singh; Brideaux and McIntyre, p. 15, pl. 2, fig. 10.

1975 Appendicisporites bifurcatus Singh; Srivastava, p. 12, pl. 3, figs. 8-10, pl. 4, figs. 1-8, pl. 5, figs. 1-3.

Remarks: Specimens in this study resemble more closely Singh's (1971) assignment than his earlier 1964 assignment. Appendicisporites bifurcatus is restricted to the middle and late Albian of Western Canada (Singh, 1964). Srivastava (1975) reports a North American range of Barremian-Cenomanian. This species is rare in the samples examined from the study area and occurs only three times in samples from beds of Facies D and C (backswamp and overbank) located below the first volcanic ash on Padloping Island and below the debris flow on Quqaluit Island.

Appendicisporites problematicus (Burger) Singh, 1971

Pl. 2 Fig. 6

Selected Synonymy:

1966 Plicatella problematica Burger; p. 245, pl. 10, fig. 3.

1971 Appendicisporites problematicus (Burger) Singh, p. 63, pl. 6, figs. 1-6.

1975 Appendicisporites problematicus (Burger) Singh; Srivastava, p. 17, pl. 9, figs. 3, 4.

1982 Appendicisporites problematicus (Burger) Singh; Burden, p. 206, pl. 11, figs. 9, 10.

Remarks: Like Appendicisporites bifurcatus Singh, Appendicisporites problematicus (Burger) Singh is well preserved. However, A. problematicus is much more frequent than A. bilateralis occurring in samples from beds of Facies D and C (backswamp and overbank) from Padloping and Quqaluit islands and a single occurrence in a sample from a bed of Facies F (distal alluvial fan). Corroded specimens (1-2 specimens/samples) occur in a sample from a bed of Facies B (backswamp) located above the debris flow on Quqaluit Island. A. problematicus is found in Berriasian to Albian strata of Western Canada (Singh, 1971) and in Berriasian and Valanginian strata of Holland (Burger, 1966).

Genus Murospora Somers, 1952

Type Species: Murospora kosankei Somers, 1952.

Murospora mesozoica Pocock, 1961

Pl. 2 Fig. 7

Selected Synonymy:

1961 Murospora mesozoica Pocock, p. 1233, text-fig. 1, figs. 3-5.

1982 Murospora mesozoica Pocock; Burden, p. 210, pl. 11, figs. 13, 14.

Remarks: The North American range for Murospora mesozoica is Portlandian to Albian (Burden, 1982). This species occurs in only two samples in the study area. Both occurrences are below the first volcanic ash and are in a coal sample (Facies D) (2 specimens) and a sample from a bed of Facies B (backswamp mudstone) (1 specimen) located on Padloping Island.

Genus Trilobosporites Pant. 1954 ex. Potonie', 1956

Type Species: Trilobosporites hannonicus (Delcourt and Sprumont) Potonie', 1956.

Trilobosporites hannonicus (Delcourt and Sprumont) Potonie', 1956

Pl. 2 Fig. 8

Selected Synonymy:

1963 Trilobosporites hannonicus (Delcourt and Sprumont) Potonie'; Delcourt, Dettmann and Hughes, p. 288, pl. 43, figs. 9, 10.

1982 Trilobosporites hannonicus (Delcourt and Sprumont) Potonie'; Burden, p. 211, pl. 11, figs. 15-16.

1984 Trilobosporites hannonicus (Delcourt and Sprumont) Potonie'; Burden, p. 265, fig. 11e.

Remarks: This species occurs in Valanginian to middle Albian strata (Burden and Hills, in prep.). Trilobosporites hannonicus is very rare; only three specimens in three separate samples from beds of Facies B (backswamp) and Facies C (overbank)) located below the first volcanic ash on Padloping Island were observed.

Genus Impardecispora Venkatachala, Kar and Raza, 1968

Type Species: Impardecispora apiverrucata (Couper) Venkatachala, Kar and Raza, 1968.

Impardecispora tribotrys (Dettmann) Venkatachala, Kar and Raza, 1968

Pl. 2 Fig. 9

Selected Synonymy:

1963 Trilobosporites tribotrys Dettmann, p. 61, pl. 12, figs. 10-14.

1982 Impardecispora tribotrys (Dettmann) Venkatachala, Kar and Raza; Burden, p. 221, pl. 13, figs. 10-11.

Remarks: According to Burden (1982) the range of this species is not well defined. It occurs in the middle to late Albian in northwestern Alberta (Singh, 1971), however it also occurs in both younger and older strata from Australia and Siberia (Dettmann, 1963). This species occurs only once (highly corroded) in a sample of Facies B (backswamp) taken from a bed located above the debris flow on Quqaluit Island.

Genus Sestrosporites Dettmann, 1963

Type Species: Sestrosporites irregulatus (Couper) Dettmann, 1963.

Sestrosporites pseudoalveolatus (Couper) Dettmann, 1963

Pl. 2 Fig. 10

Selected Synoymy:

1958 Cingulatisporites pseudoalveolatus Couper, p. 147, pl. 25, figs. 5, 6.

1963 Sestrosporites pseudoalveolatus (Couper) Dettmann, p. 66, pl. 13, figs. 11-16.

1964 Hymenozonotriletes pseudoalveolatus (Couper) Singh, p. 83, pl. 10, figs. 1-3.

1971 Sestrosporites pseudoalveolatus (Couper) Dettmann; Singh, p. 44, pl. 3, figs. 3-7.

1982 Sestrosporites pseudoalveolatus (Couper) Dettmann; Burden, p. 222, pl. 13, figs. 14-15.

Remarks: Singh (1971) reports a composite worldwide range of Bajocian to early Cenomanian for Sestrosporites pseudoalveolatus. Only two specimens were observed in this study. Both specimens of are in a sample from a bed of Facies C (overbank) located below the debris flow on Quqaluit Island.

Genus Gleicheniidites Ross 1949 ex Delcourt and Sprumont emend. Dettmann, 1963

Type Species: Gleicheniidites senonicus Ross, 1949.

Gleicheniidites senonicus Ross, 1949

Pl. 2 Fig. 11

Selected Synonymy:

1958 Gleicheniidites senonicus Ross; Couper, p. 138, pl. 19, figs. 13-15.

1964 Gleicheniidites senonicus Ross; Singh, p. 69, pl. 8, figs. 10, 11.

1965 Gleicheniidites senonicus Ross; McGregor, p. 30, pl. 10, fig. 6.

1966 Gleicheniidites senonicus Ross; Burger, p. 239, pl. 3, fig. 5.

1971 Gleicheniidites senonicus Ross; Singh, p. 97, pl. 14, fig. 1.

1973 Gleicheniidites senonicus Ross; Hopkins and Balkwill, p. 14, pl. 1, fig. 23.

1974 Gleicheniidites senonicus Ross; Hopkins, p. 12, pl. 2, fig. 22.

1975 Gleicheniidites senonicus Ross; Srivastava, p. 41, pl. 18, figs. 7-15.

1980 Gleicheniidites senonicus Ross; Wingate, p. 21, pl. 8, fig. 10.

1982 Gleicheniidites senonicus Ross; Burden, p. 223, pl. 13, fig. 20.

Remarks: The range for this cosmopolitan taxon is Jurassic and Cretaceous world-wide (Burden, 1982). This spore occurs (1-15 specimens/sample) in almost every sample, both above and below the first volcanic ash on Padloping Island and both above and below the debris flow on Quqaluit Island. It is very abundant (up to 25 specimens present) in samples from beds of Facies B and D (backswamp).

Genus Foveogleicheniidites Burger, 1976

Type species: Foveogleicheniidites confossus (Hedlund) Burger, 1976.

Foveogleicheniidites confossus (Hedlund) Burger, 1976

Pl. 2 Fig. 12

Selected Synonymy:

1983 Foveogleicheniidites confossus (Hedlund) Burger; Singh, p. 39, pl. 4, fig. 3.

Remarks: According to Singh (1983) the range of this taxon is Albian and Cenomanian. The single specimen observed, in a sample from a bed of Facies B (backswamp), located below the debris flow on Quqaluit Island, is 9 μm larger than Singh's (1983) specimens (Singh's (1983) specimens measure 30 μm in maximum equatorial diameter).

Genus *Lycopodiacidites* Couper emend. Potonie', 1956

Type Species: *Lycopodiacidites bullerensis* Couper, 1953.

*Lycopodiacidites canaliculatus* Singh, 1971

Pl. 2 Fig. 13

Selected Synonymy:

1971 *Lycopodiacidites canaliculatus* Singh, p. 38, pl. 1, fig. 15.

Remarks: Singh (1971) reported this species from the middle and late Albian in the Peace River area of Alberta. Only two specimens, each in two separate samples from beds of Facies C (overbank) located below the debris flow on Quqaluit Island, were observed.

Genus *Hamulatisporis* Krtuzsch, 1959

Type Species: *Hamulatisporis hamulatis* Krutzsch, 1959.

*Hamulatisporis* sp. ?

Pl. 2 Fig. 14

Remarks: The single broken specimen in this study does not have a proximal face, therefore accurate species assignment cannot be made. The specimen occurs in a sample from a bed of Facies B (backswamp) located above the debris flow on Quqaluit Island. Stone (1973) and Wilson (1978) state that *Hamulatisporis hamulatis* oc- occurs in upper Campanian to Eocene strata in both Europe and North America.

Genus *Cicatricosisporites* Pflug and Thomson, 1953

Type Species: *Cicatricosisporites dorogensis* Potonie' and Gelletich, 1933.

*Cicatricosisporites annulatus* Archangelsky and Gamerro, 1966

Pl. 2 Fig. 15

Selected Synonymy:

1964 Cicatricosisporites sp. B; Singh, p. 60, pl. 7, figs. 4-6.

1971 Cicatricosisporites annulatus Archangelsky and Gamerro; Singh, p. 67, pl. 6, figs. 13-15; pl. 7, figs. 1, 2.

1975 Cicatricosisporites annulatus Archangelsky and Gamerro; Brideaux and McIntyre, p. 15, pl. 1, fig. 33, 34.

1982 Cicatricosisporites annulatus Archangelsky and Gamerro; Burden, p. 235, pl. 14, figs. 14-18.

Remarks: According to Singh (1971) the range of Cicatricosisporites annulatus is Cretaceous. This spore is extremely rare in the study area; it occurs only three times in a coal sample from Padloping Island.

Cicatricosisporites australiensis (Cookson) Potonie', 1956

Pl. 3 Fig. 1

Selected Synonymy:

1963 Cicatricosisporites australiensis (Cookson) Potonie'; Dettmann, p. 53, pl. 9, figs. 10-16.

1971 Cicatricosisporites australiensis (Cookson) Potonie'; Singh, p. 69, pl. 7, figs. 12-15.

1974 Cicatricosisporites australiensis (Cookson) Potonie'; Hopkins, p. 15, pl. 3, fig. 32.

1975 Cicatricosisporites australiensis (Cookson) Potonie'; Brideaux and McIntyre, p. 15, pl. 1, fig. 37.

1982 Cicatricosisporites australiensis (Cookson) Potonie'; Burden, p. 239, pl. 14, figs. 21, 22.

Remarks: As with Appendicisporites Weyland and Krieger, this genus also exhibits excellent preservation compared with the total assemblage in this study. This taxon occurs only once, in a sample from a bed of Facies C (overbank) located below the debris flow on Quqaluit Island. The range of Cicatricosisporites australiensis is Cretaceous worldwide (Singh, 1971).

Cicatricosisporites hallei Delcourt and Sprumont, 1955

Pl. 3 Fig. 2

Selected Synonymy:

1964 Cicatricosisporites mediostriatus (Bolkhovitina) Pocock; Singh,
p. 59, pl. 6, fig. 8.

1966 Cicatricosisporites hallei Delcourt and Sprumont; Burger, p. 244, pl. 9, fig. 2.

1971 Cicatricosisporites hallei Delcourt and Sprumont; Singh, p. 71, pl. 8, figs. 7-11.

1975 Cicatricosisporites hallei Delcourt and Sprumont; Brideaux and McIntyre,
p. 15, pl. 1, fig. 38.

1975 Cicatricosisporites hallei Delcourt and Sprumont; Srivastava,
p. 27, pl. 11, figs. 5, 6.

1982 Cicatricosisporites hallei Delcourt and Sprumont; Burden,
p. 239, pl. 14, figs. 25, 26.

Remarks: According to Burden (1982) this cosmopolitan taxon is distributed in Kimmeridgian to Santonian strata. Cicatricosisporites hallei is the most abundant species of Cicatricosisporites present in this study. It occurs in samples from all three islands. It is found in low abundance (1-3 specimens/sample) both above and below the first volcanic ash on Padloping Island and both above and below the debris flow on Quqaluit Island. Specimens found in samples from above the ash or debris flow are corroded.

Cicatricosisporites hughesi Dettmann, 1963

Pl. 3 Fig. 3

Selected Synonymy:

1963 Cicatricosisporites hughesi Dettmann, p. 55, pl. 10, figs. 6-16.

1971 Cicatricosisporites hughesi Dettmann; Singh,
p. 72, pl. 8, figs. 12, 13; pl. 9, figs. 1, 2.

1975 Cicatricosisporites hughesi Dettmann; Brideaux and McIntyre,
p. 15, pl. 1, fig. 42.

1982 Cicatricosisporites hughesi Dettmann; Burden,
p. 240, pl. 14, figs. 27-31.

Remarks: Burden (1982) reports Cicatricosisporites hughesi as a cosmopolitan species which ranges from the Berriasian to the Danian. This species occurs only twice in a sample from a bed of Facies C (overbank), taken from below the debris flow on Quqaluit Island.

Cicatricosisporites imbricatus (Markova) Singh; 1971

Pl. 3 Fig. 4

Selected Synonymy:

1966 Cicatricosisporites striatus Rouse; Burger, p. 244, pl. 6, figs. 1, 2.

1967 Appendicisporites potomacensis Brenner; Norris, p. 94, pl. 13, fig. 1.

1982 Cicatricosisporites imbricatus (Markova) Singh; Burden,
p. 240, pl. 14, figs. 32-35.

Remarks: The range of Cicatricosisporites imbricatus is Berriasian and Cenomanian of Europe and Siberia and middle and late Albian of Alberta (Burden, 1982). Two specimens are present in a sample from a bed of Facies C (overbank) located below the debris flow on Quqaluit Island.

Genus Chomotriletes (Naumova) ex Naumova, 1953 emend. Hart 1964

Type Species: Chomotriletes vedugensis Naumova, 1953.

Chomotriletes minor (Kedves) Pocock, 1970

Pl. 3 Fig. 5

Selected Synonymy:

1977 Chomotriletes minor (Kedves); Do"rho"fer and Norris, p. 88, pl. 1, fig. 32.

1982 Chomotriletes minor (Kedves) Pocock; Burden, p. 296, pl. 23, figs. 1-3.

1983 Chomotriletes minor (Kedves) Pocock; Singh, p. 34, pl. 2, fig. 8.

1986 Chomotriletes minor (Kedves) Pocock; Boland, p. 137, pl. 3, fig. 5.

Remarks: According to Burden (1982) this species is widespread in the northern hemisphere occuring in Upper Jurassic and Cretaceous strata. The single specimen present in this study occurs in a sample from a bed of Facies C (overbank) located below the debris flow on Quqaluit Island.

Genus Retitriletes Van der Hammen, 1956, ex Pierce
emend. Do"ring, Krutzsch, Mai and Schulz, 1963

Type Species: Retitriletes globosus Pierce, 1961.

Retitriletes singhii Srivastava, 1972

Pl. 3 Fig. 6

Selected Synonymy:

1964 Lycopodiumsporites marginatus Singh, p. 41, pl. 1, figs. 7-10.

1971 Lycopodiumsporites marginatus Singh; Singh, p. 43, pl. 2, figs. 12-14.

1975 Lycopodiumsporites marginatus Singh; Brideaux and McIntyre, p. 15, pl. 1, fig. 22.

1975 Retitriletes singhii Srivastava; Srivastava, p. 59, pl. 27, figs. 4-8; pl. 28, figs. 1, 2.

Remarks: According to Burden and Hills (in prep.) the range for this species is Valanginian-Maastrichtian. Only two specimens of _Retitriletes singhii_ were observed in this study. Both specimens occurred in a sample from a bed of Facies C (overbank) located below the debris flow on Quqaluit Island.

Genus _Reticulisporites_ Potonie' and Kremp, 1953

Type Species: _Reticulisporites parvogranulatus_ Weyland and Krieger, 1953.

_Reticulisporites elongatus_ Singh, 1971

Pl. 3 Fig. 7

Selected Synonymy:

1971 _Reticulisporites elongatus_ Singh, p. 134, pl. 18, figs. 11, 12.

Remarks: Recent unpublished work by Fensome (1983) suggests that this species should be transferred to the genus _Saxetia_. Basis of this transfer is its possession of an indistinct distal polar crassitude. This species is reported from the middle and late Albian of Alberta (Singh, 1971) and from the Oxfordian-Hauterivian strata of the Aklavik range, N.W.T. (Fensome, 1983). A composite range of Oxfordian-late Albian is inferred. _Reticulisporites elongatus_ occurs only occassionally (1-2 specimens/ sample) in samples from beds of Facies C (overbank) located below the first volcanic ash on Padloping Island and below the debris flow on Quqaluit Island.

Genus _Tappanispora_ Srivastava, 1972

Type Species: _Tappanispora loeblichii_ Srivastava, 1972.

_Tappanispora reticulata_ (Singh) Srivastava, 1975

Pl. 3 Fig. 8

Selected Synonymy:

1971 _Tigrisporites reticulatus_ Singh, p. 139, pl. 18, figs. 17, 18.

1975 Tappanispora reticulata (Singh) Srivastava, p. 64, pl. 29, figs. 7-9.

Remarks: The reported range for Tappanispora reticulata is early Barremian to early Cenomanian (Burden and Hills, in prep.). T. reticulata is rare in the study area; only four specimens were observed. Samples which yielded this species were collected on Quqaluit Island from beds of Facies C (overbank) located below the debris flow.

Genus Foveosporites Balme, 1957

Type Species: Foveosporites canalis Balme, 1957.

Foveosporites labiosus Singh, 1971

Pl. 3 Fig. 9

Selected Synonymy:

1971 Foveosporites labiosus Singh, p. 121, pl. 17, figs. 1-3.

Remarks: Two specimens of Foveosporites labiosus are present in separate samples from beds of Facies C (overbank) located below the debris flow on Quqaluit Island and first volcanic ash on Padloping Island. The range for this taxon is Hauterivian to late Albian (Burden and Hills, in prep.).

Genus Klukisporites Couper, 1958

Type Species: Klukisporites variegatus Couper, 1958.

Klukisporites pseudoreticulatus Couper, 1958

Pl. 3 Fig. 10

Selected Synonymy:

1958 Klukisporites pseudoreticulatus Couper, p. 138, pl. 19, figs. 8-10.

1971 Klukisporites pseudoreticulatus Couper; Singh, p. 96, pl. 13, figs. 12-15.

1975 Klukisporites pseudoreticulatus Couper; Brideaux and McIntyre,

p. 15, pl. 1, fig. 28.

1977 Klukisporites pseudoreticulatus Couper; Do"rho"fer and Norris,

p. 88, pl.1, fig. 12.

Remarks: Singh (1971) reports a range of Late Jurassic to early Cenomanian for Klukisporites pseudoreticulatus. Only one specimen of Klukisporites pseudoreticulatus occurs in the study area. It is found below the first volcanic ash in a sample from a bed of Facies B (backswamp) on Padloping Island.

Genus Undulatisporites Pflug, 1953

Type Species: Undulatisporites microcutis Pflug, 1953.

Undulatisporites undulapolus Brenner, 1963

Pl. 3 Fig. 12

Selected Synonymy:

1971 Undulatisporites undulapolus Brenner; Singh, p. 148-149, pl. 20, figs. 11, 12.

1974 Undulatisporites undulapolus Brenner; Hopkins, p. 21, pl. 5, fig. 62.

1980 Undulatisporites undulapolus Brenner; Wingate, p. 31, pl. 11, fig. 15.

1982 Undulatisporites undulapolus Brenner; Burden, p. 260, pl. 17, figs. 21-22.

1983 Undulatisporites undulapolus Brenner; Fensome, p. 444, pl. 16, fig. 2.

Remarks: The range for this species is Oxfordian to Albian (Burden, 1982; Fensome, 1983). This species occurs occasionally (1-2 specimens/sample) in samples from beds of Facies B, D and C (backswamp and overbank) below the first volcanic ash on Padloping Island and below the debris flow on Quqaluit Island. Two corroded specimens were observed in samples from beds of Facies B (backswamp) above the debris flow on Quqaluit Island.

Genus Biretisporites Delcourt and Sprumont emend.

Delcourt, Dettmann and Hughes, 1963

Type Species: Biretisporites potoniaei Delcourt and Sprumont, 1955.

Biretisporites potoniaei Delcourt and Sprumont, 1955

Pl. 3 Fig. 13

Selected Synonymy:

1963 Biretisporites cf. B. potoniaei Delcourt and Sprumont; Dettmann, p. 26, pl. 2, figs. 1, 2.

1971 Biretisporites potoniaei Delcourt and Sprumont; Singh, p. 49, pl. 3, figs. 15, 16.

1980 Biretisporites potoniaei Delcourt and Sprumont; Wingate, p. 14, pl. 3, fig. 5.

1982 Biretisporites potoniaei Delcourt and Sprumont; Burden, p. 263, pl. 17, figs. 33, 34.

Remarks: This species occurs frequently (1-5 specimens/sample) and is present in almost all samples from the study area. One corroded specimen occurs in a sample from a bed of Facies B (backswamp) located above the debris flow on Quqaluit Island. One problem encountered when examining spores which may or may not be Biretisporites is preservation and folding. When this species is folded it is extremely difficult to discern it from Cyathidites minor Couper or Deltoidospora halli Miner. Biretisporites potoniaei is found in the Early Cretaceous of Western Canada, Belgium and France (Singh, 1971; Norris, 1967) and the Early Cretaceous of Southeastern Australia (Dettmann, 1963).

Genus Dictyophyllidites Couper emend. Dettmann, 1963

Type Species: Dityophyllidites harrisii Couper, 1958.

Dictyophyllidites sp.

Pl. 3 Fig. 14

Selected Synonymy:

1971 Dictyophyllidites sp.; Singh, p. 104, pl. 14, fig. 13.

1973 Dictyophyllidites sp.; Hopkins and Balkwill, p. 14, pl. 1, fig. 24.

Remarks: The North American range for Dictyophyllidites sp. is Cretaceous (Singh, 1971). This is a common species and occurs in most samples (1-5 specimens/sample) both above and below the first volcanic ash on Padloping Island and above and below the debris flow on Quqaluit Island.

Genus Stereisporites Pflug, 1953

Type Species: Stereisporites stereoides (Potonie' and Venitz) Pflug, 1953.

Stereisporites antiquasporites (Wilson and Webster) Dettmann, 1963

Pl. 3 Fig. 15

Selected Synonymy:

1963 Stereisporites antiquasporites (Wilson and Webster) Dettmann, p. 25, pl. 1, figs. 20, 21.

1971 Stereisporites antiquasporites (Wilson and Webster) Dettmann; Singh, p. 33-34, pl. 1, figs. 4, 5.

1975 Stereisportes antiquasporites (Wilson and Webster) Dettmann; Brideaux and McIntyre, p. 14, pl. 1, fig. 6.

1982 Stereisporites antiquasporites (Wilson and Webster) Dettmann; Burden, p. 266, pl. 18, figs. 3, 4.

Remarks: Singh (1971) states that Stereisporites antiquasporites occurs from the Jurassic to Tertiary, worldwide. In this study S. antiquasporites occurs occasionally (1-2 specimens/sample) in most samples from below the first volcanic ash (Padloping Island) and below the debris flow (Quqaluit Island).

Genus Deltoidospora Miner 1935

Type species: Deltoidospora hallii Miner, 1935.

Deltoidospora hallii Miner, 1935

Pl. 3 Fig. 16

Selected Synonymy:

1964 Deltoidospora hallii Miner; Singh, p. 80, pl. 9, figs. 13, 14.

1971 Deltoidospora hallii Miner; Singh, p. 118, pl. 16, fig. 8.

1980 Deltoidospora hallii Miner; Wingate, p. 24, pl. 9, fig. 14.

1982 Deltoidospora hallii Miner; Burden, p. 261, pl. 17, fig. 23.

1986 Deltoidospora hallii Miner; Boland, p. 106, pl. 1, fig. 11.

Remarks: Deltoidospora hallii ranges from Jurassic to Cretaceous worldwide (Singh, 1971; Burden, 1982). This is a common species in the study area; it occurs commonly (1-10 specimens/sample) in samples from beds of most facies except for coal samples where as many as 27 specimens were observed in a 200 grain count. Only one specimen (corroded) was observed in a sample from a bed of Facies B (backswamp) located above the debris flow on Quqaluit Island.

Genus Cyathidites Couper, 1953

Type Species: Cyathidites australis Couper, 1953.

Cyathidites minor Couper, 1953

Pl. 4 Fig. 1

Selected Synonymy:

1958 Cyathidites minor Couper; Couper, p. 139, pl. 20, figs. 9, 10.

1963 Cyathidites minor Couper; Dettmann, p. 22, pl. 1, figs. 4, 5.

1964 Cyathidites minor Couper; Singh, p. 71, pl. 8, fig. 13.

1965 Cyathidites minor Couper; McGregor, p. 24, pl. 7, figs. 3, 4.

1966 Cyathidites minor Couper; Burger, p. 237, pl. 4, fig. 1.

1971 Cyathidites minor Couper; Singh, p. 101, pl. 14, fig. 9.

1973 Cyathidites minor Couper; Hopkins and Balkwill, p. 15, pl. 2, fig. 27.

1974 Cyathidites minor Couper; Hopkins, p. 12, pl. 2, fig. 20.

1975 Cyathidites minor Couper; Brideaux and McIntyre, p. 14, pl. 1, fig. 3.

1982 Cyathidites minor Couper; Burden, p. 267, pl. 18, fig. 6.

Remarks: Cyathidites minor is a cosmopolitan taxon with a range of Jurassic to Tertiary (Singh, 1971; Burden, 1982). This is an abundant species and occurs both above and below the first volcanic ash in samples from beds of most facies. As many as 32 specimens of Cyathidites minor are present in samples below the first volcanic ash (Padloping Island) and debris flow (Quqaluit Island), whereas above the ash and debris flow the maximum number of specimens/sample encountered is 8. As pointed out in the remarks of Biretisporites potoniaei Delcourt and Sprumont, preservation plays an important role in identification of this genus.

Genus Concavisporites Pflug, 1953

Type Species: Concavisporites rugulatus Pflug, 1953.

Concavisporites jurienensis Balme, 1957

Pl. 4 Fig. 2

Selected Synonymy:

1966 Concavisporites jurienensis Balme; Burger, p. 237, pl. 4, fig. 6.

1971 Concavisporites jurienensis Balme; Singh, p. 112, pl. 15, figs. 16, 17.

1980 Concavisporites jurienensis Balme; Wingate, p. 25, pl. 9, fig. 12.

1982 Concavisporites jurienensis Balme; Burden, p. 267, pl. 18, figs. 7-10.

Remarks: This taxon ranges from Late Jurassic to Early Cretaceous worldwide (Singh, 1971; Burden, 1982). The two occurrences of this species are from coal samples located below the first volcanic ash on Padloping Island.

Genus Concavissimisporites Delcourt and Sprumont, 1955

Type Species: Concavissimisporites verrucosus Delcourt and Sprumont emend. Delcourt, Dettmann and Hughes, 1963.

Concavissimisporites minor (Pocock) Delcourt, Dettmann and Hughes, 1963

Pl. 4 Fig. 3

Selected Synonymy:

1971 Concavissimisporites minor (Pocock) Delcourt, Dettmann and Hughes; Singh, p. 113, pl. 15, fig. 18.

1982 Concavissimisporites minor (Pocock) Delcourt, Dettmann and Hughes; Burden, p. 277, pl. 19, figs. 21, 22.

Remarks: The stratigraphic range of Concavissimisporites minor, according to Burden (1982), is Late Jurassic to Albian within Western Canada. Only two specimens of Concavissimisporites minor were observed below the first volcanic ash in a coal sample from Padloping Island, and mudstone (Facies B) sample located below the debris flow on Quqaluit Island.

Concavissimisporites penolaensis Dettmann, 1963

Pl. 4 Fig. 4

Selected Synonymy:

1963 Concavissimisporites penolaensis Dettmann, p. 31, pl. 3, figs. 13-16.

1970 Concavissimisporites sp. cf. C. penolaensis Dettmann; Kemp, p. 85, pl. 10, figs. 4-6.

1982 Concavissimisporites sp. cf. C. penolaensis Dettmann; Burden, p. 278, pl. 19, figs. 27, 28.

Remarks: The one specimen, in a sample from a bed of Facies C (overbank) located below the debris flow on Quqaluit Island, has interradial thickenings on the distal surface and is 5 µm smaller than Dettmann's (1963) minimum size, which is 52 µm, for this species. The distribution of this taxon is Valanginian to early Aptian worldwide (Dettmann, 1963).

Genus Neoraistrickia Potonie', 1956

Type Species: Neoraistrickia truncata (Cookson) Potonie', 1956.

Neoraistrickia truncata (Cookson) Potonie', 1956

Pl. 4 Fig. 5

Selected Synonymy:

1963 Neoraistrickia truncatus (Cookson) ; Dettmann, p. 36, pl. 5, figs. 4, 5.

1971 Neoraistrickia truncata (Cookson) Potonie'; Singh, p. 47, pl. 3, fig. 13.

1982 Neoraistrickia truncata (Cookson) Potonie'; Burden, p. 268, pl. 18, figs. 11-13.

Remarks: According to Singh (1971) Neoraistrickia truncata is distributed worldwide in the Jurassic and Cretaceous. This species (one specimen in very poor condition) occurs in a sample of the volcanic ash on Padloping Island, once (poor condition) in a sample from a bed of Facies B (backswamp) located above the debris flow on Quqaluit Island and once in good condition in a sample from a bed of Facies E (meandering channel) located below the first volcanic ash on Padloping Island.

Genus Osmundacidites Couper, 1953

Type species: Osmundacidites wellmanii Couper, 1953.

Osmundacidites wellmanii Couper, 1953

Pl. 4 Fig. 6

Selected Synonymy:

1958 Osmundacidites wellmanii Couper; Couper, p. 134, pl.16, figs. 4, 5.

1963 Osmundacidites wellmanii Couper; Dettmann, p. 32, pl. 3, figs. 19-21.

1964 Osmundacidites wellmanii Couper; Singh, p. 44, pl. 1, fig. 20.

1966 Osmundacidites wellmanii Couper; Burger, p. 251, pl. 20, fig. 3.

1971 Osmundacidites wellmanii Couper; Singh, p. 50, pl. 4, fig. 1.

1973 Osmundacidites wellmanii Couper; Hopkins and Balkwill, p. 12, pl. 1, figs. 15, 16.

1974 Osmundacidites wellmanii Couper; Hopkins, p. 13, pl. 2, fig. 24.

1975 Osmundacidites wellmanii Couper; Brideaux and McIntyre, p. 14, pl. 1, fig. 11.

1975 Osmundacidites wellmanii Couper; Srivastava, p. 54, pl. 25, figs. 13, 14.

1982 Osmundacidites wellmanii Couper; Burden, p. 268, pl. 18, figs. 14, 15.

Remarks: The stratigraphic range for this species is Liassic to Senonian worldwide (Srivastava, 1975). Osmundacidites wellmanii is a common species and occurs occasionally (1-2 specimens/sample) in most samples collected below the first volcanic ash on Padloping Island and below the debris flow on Quqaluit Island.

Genus Baculatisporites Thomson and Pflug, 1953

Type Species: Baculatisporites primarius (Wolff) Thomson and Pflug, 1953.

Baculatisporites comaumensis (Cookson) Potonie', 1956

Pl. 4 Fig. 7

Selected Synonymy:

1963 Baculatisporites comaumensis (Cookson) Potonie'; Dettmann, p. 35, pl. 3, figs. 22, 23.

1971 Baculatisporites comaumen... (Cookson) Potonie'; Singh, p. 48, pl. 3, fig. 14.

1982 Baculatisporites comaumensis (Cookson) Potonie'; Burden,
p. 269, pl. 18, figs. 16-18.

Remarks: This species, according to Singh (1971) is cosmopolitan and ranges from Late Triassic to Tertiary. Only three specimens of this taxon were encountered in samples from beds of Facies C (overbank) located below the debris flow on Quqaluit Island.

Genus Acanthotriletes Naumova, 1939 ex 1949

Type Species: Acanthotriletes ciliatus (Knox) Potonie' and Kremp, 1954.

Acanthotriletes varispinosus Pocock, 1962

Pl. 4 Fig. 8

Selected Synonymy:

1962 Acanthotriletes varispinosus Pocock; p. 36, pl. 1, figs. 18-20.

1964 Acanthotriletes varispinosus Pocock; Singh, p. 43, pl. 1, figs. 17, 18.

1971 Acanthotriletes varispinosus Pocock; Singh, p. 45, pl. 3, fig. 8.

1975 Acanthotriletes varispinosus Pocock; Brideaux and McIntyre,
p. 14, pl. 1, fig. 13.

1977 Acanthotriletes varispinosus Pocock; Do"rho"fer and Norris,
p. 88, pl. 1, fig. 16.

Remarks: According to Singh (1964, 1971) and Norris (1967) A. varispinosus is a common Early Cretaceous spore worldwide. Specimens of Acanthotriletes varispinosus occurred occasionally (1-2 specimens/sample) in samples from beds of Facies B, D and C (backswamp and overbank) both above and below the first volcanic ash on Padloping Island and above and below the debris flow on Quqaluit Island. Specimens found above the first volcanic ash (in a sample from a bed of Facies B) and debris flow are corroded.

Genus Granulatisporites Ibrahim emend. Potonie' and Kremp, 1954

Type Species: Granulatisporites granulatus Ibrahim, 1933.

Granulatisporites sp.

Pl. 4 Fig. 9

Selected Synonymy:

1964 Granulatisporites sp.; Singh, p. 98, pl. 13, fig. 8.

1982 Granulatisporites sp.; Burden, p. 274, pl. 19, figs. 13-16.

Remarks: This spore occurs in the Early Cretaceous of eastern Australia (Hopkins, 1974), and in the Barremian? to middle Albian in the northern hemisphere (Burden, 1982). Granulatisporites sp. occurs occasionally (1-2 specimens/sample) in samples from all sections, both above and below the first volcanic ash and debris flow; however, specimens from samples above the first volcanic ash and debris flow are corroded.

Genus Verrucosisporites Ibrahim emend. Potonie' and Kremp, 1954

Type Species: Verrucosisporites verrucosus Ibrahim emend. Potonie' and Kremp, 1955.

Verrucosisporites rotundus Singh, 1964

Pl. 4 Fig. 10

Selected Synonymy:

1964 Verrucosisporites rotundus Singh, p. 96, pl. 13, fig. 3.

1971 Verrucosisporites rotundus Singh; Singh, p. 149, pl. 20, fig. 14.

Remarks: The North American range for Verrucosisporites rotundus is Aptian and Albian (Singh, 1971; Hopkins, 1974). This species occurs frequently (1-5 specimens/sample) in samples from beds of Facies C, B and D (overbank and backswamp) and occasionally (1-2 specimens/sample) in samples from beds of Facies E (meandering channel) and Facies F (distal alluvial fan). One corroded specimen was observed in the first volcanic ash on Quqaluit Island and in a sample from a bed of Facies B (backswamp) which overlies this ash.

Monolete Spores

Genus Laevigatosporites Ibrahim emend. Schopf, Wilson and Bentall, 1944

Type Species: Laevigatosporites vulgaris (Ibrahim) Ibrahim, 1933.

Laevigatosporites ovatus Wilson and Webster, 1946

Pl. 4 Fig. 11

Selected Synonymy:

1963 Laevigatosporites ovatus Wilson and Webster; Dettmann, p. 86, pl. 19, figs. 9-11.

1964 Laevigatosporites ovatus Wilson and Webster; Singh, p. 99, pl. 13, figs. 9-11.

1971 Laevigatosporites ovatus Wilson and Webster; Singh, p. 105, pl. 14, fig. 14.

1973 Laevigatosporites ovatus Wilson and Webster; Hopkins and Balkwill, p. 15, pl. 1, fig. 25.

1974 Laevigatosporites ovatus Wilson and Webster; Hopkins, p. 14, pl. 3, fig. 28.

1975 Laevigatosporites ovatus Wilson and Webster; Bridéaux and McIntyre, p. 16, pl. 3, fig. 8.

1980 Laevigatosporites ovatus Wilson and Webster; Wingate, p. 23, pl. 9, fig. 6.

Remarks: Singh (1971) and Hopkins (1974) suggest a Jurassic and Cretaceous age for Laevigatosporites ovatus; however, Hopkins (1974) suggests it is much more abundant in the Tertiary. This monolete spore is very common in the study area occurring in almost all samples located both above and below the first volcanic ash (Padloping Island) and debris flow (Quqaluit Island).

Genus Punctatosporites Ibrahim, 1933

Type Species: Punctatosporites minutus Ibrahim, 1933.

Punctatosporites scabratus (Couper) Singh, 1971

Pl. 4 Fig. 12

Selected Synonymy:

1958 Marattisporites scabratus Couper, p. 133, pl. 15, figs. 20-23.

1971 Punctatosporites scabratus (Couper) Singh, p. 106, pl. 14, fig. 15.

1980 Punctatosporites scabratus (Couper) Singh; Wingate, p. 13, pl. 3, fig. 2.

1982 Punctatosporites scabratus (Couper) Singh; Burden, p. 285, pl. 20, figs. 30, 31.

Remarks: According to Singh (1971) and Burden (1982) Punctatosporites scabratus occurs from Late Triassic to Albian and is widespread in the northern hemisphere. This species occurs in most overbank (Facies C) samples (1-4 specimens/sample) and in a sample from a bed of Facies F (distal alluvial fan) on Durban Island (12 specimens). A single occurrence of this taxon above the debris flow on Quqaluit Island (Facies B, backswamp) is corroded and very poorly preserved.

Inaperturate Pollen

Genus Inaperturopollenites

Pflug, 1952 ex Thompson and Pflug emend. Potonie', 1958

Type Species: Inaperturopollenites dubius (Potonie' and Venitz) Thomson and Pflug, 1953.

Inaperturopollenites sp.

Pl. 4 Fig. 13

Selected Synonymy:

1971 Inaperturopollenites sp.; Singh, p. 150, pl. 21, fig. 1.

1973 Inaperturopollenites sp.; Hopkins and Balkwill, p. 20, pl. 2, fig. 45.

1974 Inaperturopollenites sp.; Hopkins, p. 23, pl. 6, fig. 70.

Remarks: Singh (1971) and Norris (1967) report ages of middle and late Albian for this species in the Peace River and Central areas of Alberta. This species is found in most samples below the first volcanic ash (Padloping Island) and debris flow (Quqaluit Island). It occurs in high abundance (up to 35 specimens/sample) in samples from beds of Facies F (distal alluvial fan) and in samples from beds of Facies C and B (overbank and backswamp).

Genus Taxodiaceaepollenites Kremp, 1949 ex Potonie', 1958

Type Species: Taxodiaceaepollenites hiatus Potonie' ex Potonie', 1958.

Taxodiaceaepollenites hiatus (Potonie') Kremp, 1949

Pl. 4 Fig. 14

Selected Synonymy:

1971 Taxodiaceaepollenites hiatus (Potonie') Kremp; Singh, p. 158, pl. 22, fig. 7.

1975 Taxodiaceaepollenites hiatus (Potonie') Kremp; Brideaux and McIntyre, p. 17, pl. 4, fig. 19.

1980 Taxodiaceaepollenites hiatus (Potonie') Kremp; Wingate, p. 37, pl. 13, fig. 15.

Remarks: Singh (1971) states that the distribution of Taxodiaceaepollenites hiatus is widespread throughout the world; it occurs in middle Albian to Miocene strata of Western Canada. It is very common in all samples in this study. Higher concentrations of T. hiatus occur in samples from beds of finer grained facies, particularly Facies D (coal).

Genus Sequoiapollenites Thiergart, 1938

Type Species: Sequoiapollenites polyformosus Thiergart, 1938.

Sequoiapollenites paleocenicus Stanley, 1965

Pl. 4 Fig. 15

Selected Synonymy:

1965 Sequoiapollenites paleocenicus Stanley, p. 283, pl. 38, figs. 8-11.

Remarks: Stanley (1965) reports this species from Paleocene strata of northwestern South Dakota. This taxon occurs only four times; one specimen in a sample from a bed of the the volcanic ash on Padloping Island and 3 specimens in a sample from a bed of Facies E which overlies the ash on Padloping Island.

Genus Araucariacites Cookson, 1947 ex Couper 1953

Type Species: Araucariacites australis Cookson, 1947.

Araucariacites australis Cookson, 1947

Pl. 5 Fig. 1

Selected Synonymy:

1958 Araucariacites australis Couper, p. 151, pl. 27, figs. 3-5.

1963 Araucariacites australis Cookson; Dettmann, p. 105-106, pl. 26, fig. 15.

1971 Araucariacites australis Cookson; Singh, p. 156, pl. 22, fig. 4.

1974 Araucariacites australis Cookson; Hopkins, p. 22, pl. 5, fig. 66.

1975 Araucariacites australis Cookson; Brideaux and McIntyre, p. 17, pl. 4, fig. 15.

1980 Araucariacites australis Cookson; Wingate, p. 37, pl. 13, fig. 14.

Remarks: The minimum size of this taxon, according to Couper (1958) is 52 μm. Specimens in this study are commonly as small as 40 μm. Singh (1971), Couper (1958), Hopkins (1974) report that Araucariacites australis occurs in Jurassic to Tertiary strata and is widespread in many parts of the world. A. australis is common (1-5 specimens/sample) in most samples in the study area.

Bisaccate Pollen

Genus Podocarpidites Cookson, 1947 ex Couper 1953

Type Species: Podocarpidites ellipticus Cookson, 1947.

Podocarpidites canadensis Pocock, 1962

Pl. 5 Fig. 2

Selected Synonymy:

1964 Podocarpidites canadensis Pocock; Singh, p. 163, pl. 16, figs. 1-3.

1965 Podocarpidites canadensis Pocock; McGregor, p. 24, pl. 7, fig. 40.

1971 Podocarpidites canadensis Pocock; Singh, p. 163, pl. 23, figs. 3, 4.

1975 Podocarpidites canadensis Pocock; Brideaux and McIntyre, p. 16, pl. 4, fig. 2.

1982 Podocarpidites canadensis Pocock; Burden, p. 310, pl. 25, figs. 7-9.

Remarks: Burden and Hills (in prep.) report a Canadian range of Valanginian to late Albian for Podocarpidites canadensis. P. canadensis is not a common species in this study. It occurs occasionally (1-2 specimens/sample) in samples from both above and below the first volcanic ash (Padloping Island) and debris flow (Quqaluit Island). Specimens from strata above the first volcanic ash and debris flow are corroded and identification is difficult.

Podocarpidites miniscuIus Singh, 1964

Pl. 5 Fig. 3

Selected Synonymy:

1964 Podocarpidites miniscuIus Singh, p. 117, pl. 15, figs. 15, 16.

1971 Podocarpidites miniscullus Singh; Singh, p. 165, pl. 24, fig. 1.

1982 Podocarpidites miniscullus Singh; Burden, p. 313, pl. 25, fig. 15.

1986 Podocarpidites miniscullus Singh; Boland, p. 162, pl. 4, fig. 7.

Remarks: This species was previously observed by Singh (1964, 1971) and Burden (1982) in Neocomian to Albian strata of western Canada. Podocarpidites miniscullus has been observed only rarely (1-2 specimens/sample) in samples from beds of Facies E, F, C and B (meandering channel, distal alluvial fan, overbank, and backswamp) taken from below the debris flow on Quqaluit Island and from Durban Island.

Podocarpidites multesimus (Bolkovitina) Pocock, 1962

Pl. 5 Fig. 4

Selected Synonymy:

1964 Podocarpidites multesimus (Bolkhovitina) Pocock; Singh, p. 116, pl. 15, figs. 12, 13.

1971 Podocarpidites multesimus (Bolkhovitina) Pocock; Singh, p. 166, pl. 24, fig. 2.

1975 Podocarpidites multesimus (Bolkhovitina) Pocock; Brideaux and McIntyre, p. 16, pl. 4, figs. 3, 4.

1980 Podocarpidites multesimus (Bolkhovitina) Pocock; Wingate, p. 38, pl. 14, figs. 7, 8.

1982 Podocarpidites multiesimus (Bolkhovitina) Pocock; Burden, p. 314, pl. 25, fig. 16.

1986 Podocarpidites multesimus (Bolkhovitina) Pocock; Boland, p. 163, pl. 4, fig. 8.

Remarks: The range in the northern hemisphere and Australia for Podocarpidites multesimus is Jurassic and Cretaceous (Burden, 1982). This species has only been observed occasionally (1-3 specimens/sample) in samples from Facies C, B and D (overbank and backswamp) taken from below the first volcanic ash (Padloping Island) and debris flow (Quqaluit Island).

Genus Pityosporites Seward emend. Manum, 1960

Type Species: Pityosporites antarcticus Seward, 1914.

Pityosporites alatipollenites (Rouse) Singh, 1964

Pl. 5 Fig. 5

Selected Synonymy:

1964 Pityosporites alatipollenites (Rouse) Singh, p. 123, pl. 16, fig. 10.

1971 Pityosporites alatipollenites (Rouse) Singh; Singh, p. 173, pl. 25, fig. 9.

1982 Pityosporites alatipollenites (Rouse) Singh; Burden, p. 315, pl. 26, fig. 1.

Remarks: The range of this species in western Canada, according to Singh (1971), is Late Jurassic to Late Cretaceous. This species is present in many samples in low abundance (1-3 specimens/sample), located below the first volcanic ash (Padloping Island) and debris flow (Quqaluit Island) and once in very poor condition, in a sample from a bed of Facies B located above the debris flow. It is most common in samples from beds of Facies C (overbank).

Genus Abiespollenites Thiergart emend. Potonie', 1958

Type Species: Abiespollenites absolutus Thiergart, 1937.

Abiespollenites sp.

Pl. 5 Fig. 6

Selected Synonymy:

1971 Abiespollenites sp.; Singh, p. 168, pl. 24, fig. 8.

Remarks: Singh's (1971, p. 168) description of Abiespollenites sp. is suitable for specimens in this study. Singh (1971) reported Abiespollenites sp. from the middle Albian in the Peace River area of Alberta. The separation of Abiespollenites and Piceapollenites, in this study, is extremely difficult due to the absence of well preserved specimens. Many broken pieces of large bisaccates are present both above and below the first volcanic ash. These broken bisaccates are most common in coarse and medium-grained sandstones (Facies A, braided channel sands). Broken bisaccates from samples located above the first volcanic ash (Padloping Island) and debris flow (Quqaluit Island) are corroded.

Genus Vitreisporites Leschik emend. Jansonius, 1962

Type Species: Vitreisporites signatus Leschik, 1955.

Vitreisporites pallidus (Reissinger) Nilsson, 1958

Pl. 5 Fig. 7

Selected Synonymy:

1964 Vitreisporites pallidus (Reissinger) Nilsson; Singh, p. 102, pl. 14, fig. 1.

1965 Vitreisporites pallidus (Reissenger) Nilsson; McGregor, p. 24, pl. 7, fig. 38.

1966 Vitreisporites pallidus (Reissinger) Nilsson; Burger, p. 256, pl. 27, fig. 3.

1971 Vitreisporites pallidus (Reissinger) Nilsson; Singh, p. 154, pl. 22, fig. 1.

1973 Vitreisporites pallidus (Reissinger) Nilsson; Hopkins and Balkwill, p. 16, pl. 2, fig. 34.

1974 Vitreisporites pallidus (Reissinger) Nilsson; Hopkins, p. 21, pl. 5, fig. 65.

1975 Vitreisporites pallidus (Reissinger) Nilsson; Brideaux and McIntyre, p. 16, pl. 3, fig. 30.

1980 Vitreisporites pallidus (Reissinger) Nilsson; Wingate, p. 35, pl. 13, fig. 7.

1982 Vitreisporites pallidus (Reissinger) Nilsson; Burden, p. 318, pl. 26, fig. 4.

Remarks: According to Singh (1971), Srivastava (1975) and Burden (1982) the range for Vitreisporites pallidus is Triassic to Cretaceous worldwide. This species occurs occasionally (1-2 specimens/sample) in samples from beds of Facies D, B and C (backswamp and overbank) located below the first volcanic ash (Padloping Island) and debris flow (Quqaluit Island).

Genus Alisporites Daugherty emend. Jansonius, 1971

Type Species: Alisporites opii Daugherty, 1941.

Alisporites bilateralis Rouse, 1959

Pl. 5 Fig. 8

Selected Synonymy:

1964 Alisporites thomasii (Couper) Pocock; Singh, p. 109, pl. 14, figs. 11, 12.

1965 Alisporites thomasii (Couper) Nilsson; McGregor, p. 24, pl. 7, fig. 39.

1966 Alisporites thomasii (Couper) Pocock; Burger, p. 259, pl. 35, fig. 2.

1971 Alisporites bilateralis Rouse; Singh, p. 169, pl. 24, fig. 9.

1975 Alsporites bilateralis Rouse; Brideaux and McIntyre, p. 16, pl. 3, fig. 32.

1982 Alisporites bilateralis Rouse; Burden, p. 318, pl. 26, figs. 5, 6.

1985 Alisporites bilateralis Rouse; Burden and Holloway, p. 34, pl. 1, fig. 3.

Remarks: Singh (1971) reports a range of Late Jurassic to Cenomanian for Alisporites bilateralis. This very common (Singh, 1971) Early Cretaceous bisaccate pollen grain is abundant in most samples both above and below the first volcanic ash and debris flow. Grains in samples from beds located above the ash and debris flow are corroded.

Alisporites grandis (Cookson) Dettmann, 1963

Pl. 5 Fig. 9

Selected Synonymy:

1964 Alisporites rotundus Rouse; Singh, pl. 14, figs. 13, 14; p. 110, pl. 15, figs. 1, 2.

1971 Alsporites grandis (Cookson) Dettmann; Singh, p. 170, pl. 25, figs. 1, 2.

1975 Alisporites grandis (Cookson) Dettmann; Brideaux and McIntyre, p. 16, pl. 3, fig. 29.

1980 Alisporites grandis (Cookson) Dettmann; Wingate, p. 39, pl. 15, fig. 1.

1982 Alisporites grandis (Cookson) Dettmann; Burden, p. 318, pl. 26, fig. 7.

Remarks: Burden (1982) reports a range of Mesozoic in the northern hemisphere and Australia for Alisporites grandis. This species is present in samples from beds of Facies C (overbank) located below the debris flow on Quqaluit Island. Few Alisporites grandis specimens are present in the study area. Specimens of this taxon found in samples from a bed of Facies B (backswamp) located above the debris flow on Quqaluit Island are corroded.

Genus Piceaepollenites Thiergart, 1937, 1938

Type Species: Picea-pollenites alatus (Potonie') Thiergart, 1937.

Piceaepollenites sp.

Pl. 5 Fig. 10

Selected Synonymy:

1964 Piceaepollenites sp.; Singh, p. 121, pl. 16, fig. 7.

Remarks: Singh (1964) reported this species as being very rare in the middle Albian of western Canada. The separation of Abiespollenites and Piceaepollenites is extremely difficult due to the absence of well preserved specimens. This taxon occurs occasionally (1-3 specimens/sample) in most samples of beds located below the first volcanic ash (Padloping Island) and debris flow (Quqaluit Island). Broken, corroded pieces of these bisaccates are present in samples from beds located above the first volcanic ash and debris flow.

Genus Rugubivesiculites Pierce, 1961

Type Species: Rugubivesiculites convolutus Pierce, 1961.

Rugubivesiculites reductus ?Pierce, 1961

Pl. 5 Fig. 11

Selected Synonymy:

1971 Rugubivesiculites reductus Pierce; Singh, p. 167, pl. 24, figs. 4, 5.

Remarks: Specimens in this study are markedly corroded and therefore are only tentatively assigned to this species. According to Burden and Hills (in prep.) this taxon ranges from the early Albian to Paleocene. R. reductus occurs only once in a sample from a bed of Facies C (overbank) located below the debris flow on Quqaluit Island.

Genus Cedripites Wodehouse, 1933

Type Species: Cedripites eocenicus Wodehouse, 1933.

Cedripites canadensis Pocock, 1962

Pl. 5 Fig. 12

Selected Synonymy:

1964 Cedripites canadensis Pocock; Singh, p. 112, pl. 15, fig. 6.

1971 Cedripites canadensis Pocock; Singh, p. 171, pl. 25, figs. 4, 5.

1975 Cedripites canadensis Pocock; Brideaux and McIntyre, p. 16, pl. 3, fig. 37.

1982 Cedripites canadensis Pocock; Burden, p. 325, pl. 27, figs. 1, 2.

Remarks: According to Singh (1971) this species is distributed in Barremian to Albian strata in Alberta. Cedripites canadensis occurs occasionally (up to 8 specimens/sample) in most samples from beds located below the first volcanic ash (Padloping Island) and debris flow (Quqaluit Island).

Cedripites cretaceus Pocock, 1962

Pl. 5 Fig. 13

Selected Synonymy:

1964 Cedripites cretaceus Pocock; Singh, p. 111, pl. 15, figs. 3-5.

1971 Cedripites cretaceus Pocock; Singh, p. 171, pl. 25, fig. 6.

1975 Cedripites cretaceus Pocock; Brideaux and McIntyre, p. 16, pl. 3, figs. 33, 34.

1980 Cedripites cretaceus Pocock; Wingate, p. 40, pl. 15, fig. 4.

1982 Cedripites cretaceus Pocock; Burden, p. 326, pl. 27, figs. 3, 4.

Remarks: Burden (1982) reports a range of Valanginian to Campanian for Cedripites cretaceus. This taxon is very common (up to 31 specimens/sample) in most samples. Corroded specimens of this species are common in a sample from a bed of Facies B (backswamp) located above the debris flow on Quqaluit Island.

Genus Pristinuspollenites B.D. Tschudy, 1973

Type species: Pristinuspollenites microsaccus (Couper) B.D. Tschudy, 1973.

Pristinuspollenites microsaccus (Couper) B.D. Tschudy, 1973

Pl. 5 Fig. 14

Selected Synonymy:

1958 Pteruchipollenites microsaccus Couper, p. 151, pl. 26, figs. 13, 14.

1982 Pristinuspollenites microsaccus (Couper) Tschudy; Burden, p. 319, pl. 26, figs. 10-13.

Remarks: According to Burden (1982) the range for this species is Late Jurassic and

Cretaceous worldwide. Only one specimen of Pristinuspollenites microsaccus is present in the study area. It occurs in a sample from a bed of Facies C (overbank) collected below the debris flow on Quqaluit Island.

Monosulcate Pollen

Genus Cerebropollenites Nilsson, 1958

Type Species: Cerebropollenites mesozoicus (Couper) Nilsson, 1958.

Cerebropollenites mesozoicus (Couper) Nilsson, 1958

Pl. 5 Fig. 15

Selected Synonymy:

1966 Cerebropollenites mesozoicus (Couper) Nilsson; Burger, p. 261, pl. 27, fig. 4; pl. 28, fig. 1.

1971 Cerebropollenites mesozoicus (Couper) Nilsson; Singh, p. 172, pl. 25, fig. 7.

1975 Cerebropollenites mesozoicus (Couper) Nilsson; Brideaux and McIntyre, p. 16, pl. 3, fig. 35, 36.

1977 Cerebropollenites mesozoicus (Couper); Do"rho"fer and Norris; p. 88, pl. 1, fig. 3.

1980 Cerebropollenites mesozoicus (Couper) Nilsson; Wingate, p. 40, pl. 15, fig. 5.

1982 Cerebropollenites mesozoicus (Couper) Nilsson; Burden, p. 307, pl. 24, figs. 14, 15.

Remarks: This monosulcate pollen grain is widespread in both North America and Europe in Jurassic and Cretaceous strata (Burden, 1982). Cerebropollenites mesozoicus is a common species in most samples from all three islands in the study area. It occurs in samples from beds located both above and below the first volcanic ash on Padloping Island and debris flow on Quqaluit Island.

Genus Cycadopites Wodehouse, 1933

Type Species: Cycadopites follicularis Wilson and Webster, 1946.

Cycadopites follicularis Wilson and Webster, 1946

Pl. 6 Fig. 1

Selected Synonymy:

1964 Cycadopites fragilis Singh, p. 103, pl. 14, fig. 2.

1965 Cycadopites follicularis Wilson and Webster; McGregor, p. 26, pl. 8, fig. 24.

1983 Cycadopites follicularis Wilson and Webster; Fensome, p. 553, pl. 21, figs. 4, 6.

Remarks: The worldwide range for this species, as given by Fensome (1983), is late Paleozoic to Cenozoic. This species occurs occasionally (1-2 specimens/sample) in most samples from beds located below the first volcanic ash (Padloping Island) and debris flow (Quqaluit Island).

Tricolpate Pollen

Tricolpites sp. 1

Pl. 6 Fig. 2

Description: Tricolpate grain. The equatorial diameter of Tricolpites sp. 1 is 37 μm. The exine of the specimen is granulate.

Remarks: This specimen resembles, Tricolporopollenites krushchii (Potonie') Thomson and Pflug sensu Elsik, 1968 In Gaponoff (1984) however, due to the orientation of the single specimen encountered definite identification was not possible. Only one specimen of Tricolpites sp. 1 is present; in a sample of Facies B (backswamp) located above the debris flow on Quqaluit Island.

Tricolpites sp. 2

Pl. 6 Fig. 3

Description: This tricolpate spherical grain is 18 x 16 μm with a tectate wall (1.5 μm thick) and exine which exhibits uniformly distributed fine reticulate sculpture. One colp is visible and is a simple short (7 μm) slit, 2 μm wide.

Remarks:. A single specimen of Tricolpites sp. 2 was observed in the sample of volcanic ash from Padloping Island.

Tricolpites sp. 3

Pl. 6 Fig. 4

Description: This prolate tricolpate grain is 22 μm in polar length and 18 μm in equatorial width. The wall of the grain is thick (1.0 μm), however, the surface of the grain is psilate except within the colpi. The colpi extend the entire length of the grain and flair slightly at the poles to 4-6 μm in width. The surface sculpture of the colpi is granulate.

Remarks: A single specimen of Tricolpites sp. 3 was observed in the sample from a bed of volcanic ash from Padloping Island.

Tricolpites sp. 4

Pl. 6 Fig. 5

Description: This tricolpate subtriangular grian is 17.5 μm in largest equatorial width and 15.5 μm in smallest equatorial width; the wall is 1.2 μm thick. The exine exhibits evenly distributed granulate sculpture. The one visible colp flairs slightly (to a maximum width of 8 μm) at the poles.

Remarks: Tricolpites sp. 4 was observed only once in a sample of volcanic ash from Padloping Island.

Tricolpites sp. 5

Pl. 6 Fig. 6

Description: These tricolpate grains range in polar length from 19 to 31 $\mu$m and in equatorial width from 10 to 19 $\mu$m. Surface sculpture consists of a reticulate pattern which becomes slightly smaller nearer the poles (from muri width of approximately 1 $\mu$m near the equator). The colpus is a simple slit which extends to both poles.

Remarks: Two specimens of Tricolpites sp. 5 were observed in a sample from a bed of the volcanic ash from Padloping Island.

Tricolporate Pollen

Genus Cupuliferoipollenites Potonie', 1951 ex Potonie', 1960

Type Species: Cupuliferoipollenites pusillus (Potonie') Potonie', 1960.

Cupuliferoipollenites sp.

Pl. 6 Fig. 7

Description: This prolate tricolporate grain measures 22 $\mu$m in polar length by 18 $\mu$m in equatorial width. The wall is psilate. Colpi almost reach the poles.

Remarks: One specimen of Cupuliferoipollenites sp. (in a sample of the volcanic ash from Padloping Island) was observed. Frederiksen (1983) reported this genus from the Middle Eocene of California.

Genus Rugutricolporites (Gonza'lez) Guzma'n, 1967

Type Species: Rugutricolporites felix (Gonza'lez) Guzma'n, 1967.

Rugutricolporites sp.

Pl. 6 Fig. 8

Selected Synonymy:

1983 Rugutricolporites sp. 1; Frederiksen, p. 85, pl. 23, figs. 17, 18.

Remarks: Frederiksen (1983) describes Rugutricolporites as prolate to subprolate, tricolporate; usually possessing long colpi. The single specimen observed in this study (in a sample from the volcanic ash on Quqaluit Island) is 23 µm in polar lengh by 16 µm in equatorial width. This size falls well within Frederiksen's (1983) size range for this taxon. The exine of this grain is 1.5 µm thick and is striate to rugulate. This ornament runs oblique to the polar axis. Colpi extend nearly the full length of the grain. Frederiksen (1983) reports this genus from the Middle Eocene of California.

Triporate Pollen

Genus Carpinipites Srivastava, 1966

Type Species: Carpinipites ancipites (Wodehouse) Srivastava, 1966.

Carpinipites sp. cf. C. spackmaniana (Traverse) Zhou, 1975

Pl. 6 Fig. 9

Selected Synonymy:

1986 Carpinipites sp. cf. Carpinipites spackmaniana (Traverse) Zhou; Norris, p. 39, pl. 10, figs. 31-33.

Remarks: According to Norris (1986) this taxon ranges from Eocene to Miocene. Specimens of this species are present in a sample of the volcanic ash and in a sample from a bed of Facies E (meandering channel) located above the ash on Padloping Island.

Genus Myricipites Wodehouse, 1933

Type Species: Myricipites dubius Wodehouse, 1933.

Myricipites annulites (Martin and Rouse) Norris, 1986

Pl. 6 Fig. 10

Selected Synonymy:

1966 Myrica annulites Martin and Rouse, p. 195, pl. 9, figs. 91, 92.

1969 Myrica annulites Martin and Rouse, Hopkins, p. 1124, pl. 10, figs. 153, 154.

1986 Myricipites annulites (Martin and Rouse) Norris, p. 39, pl. 10, figs. 30, 34.

Remarks: This species has been observed in the Upper Oligocene and Miocene strata of the MacKenzie Delta area, Northwest Territories (Norris, 1986) and in the Eocene and Oligocene of British Columbia (Martin and Rouse, 1966 and Hopkins, 1969). This taxon occurs (3-5 specimens/sample) in a sample from the volcanic ash and in a sample from a bed of Facies E (meandering channel) which overlies this ash on Padloping Island.

Genus Trivestibulopollenites Pflug, 1953

Type Species: Trivestibulopollenites betuloides Pflug, 1953.

Trivestibulopollenites betuloides Pflug, 1953

Pl. 6 Fig. 11

Selected Synonymy:

1986 Trivestibulopollenites betuloides Pflug, In Thomson and Pflug; Norris, p. 40, pl. 10, figs. 38-42.

Remarks: Norris (1986) reported this taxon from the Late Oligocene and Pliocene of the MacKenzie Delta region of the Northwest Territories. Thomson and Pflug (1953) as cited in Norris (1986) state that this species is present in the European Tertiary and is abundant in the Pliocene. Norris (1986) summarizies the range as Paleogene and Neogene. Trivestibulopollenites betuloides is a dominant (19 and 27 specimens/sample) species, found in two samples from beds located above and in beds of the first volcanic ash on Padloping Island.

Periporate Pollen

Genus Polyatriopollenites Pflug, 1953

Type Species: Polyatriopollenites stellatus (Potonie') Pflug, 1953.

Polyatriopollenites stellatus (Potonie') Pflug, 1953

Pl. 6 Fig. 12

Selected Synonymy:

1966 Pterocarya stellatus (Potonie'); Martin and Rouse, p. 196, pl. 8, figs. 79, 80.

1969 Pterocarya stellatus Martin and Rouse; Hopkins, p. 1121, pl. 9, figs. 122-124.

1971 Pterocarya stellatus (Potonie') Martin and Rouse; Piel, p. 1910, pl. 13, figs. 113, 114.

1986 Polyatriopollenites stellatus (Potonie') Pflug; Norris, p. 42, pl. 11, figs. 5-7.

Remarks: According to Martin and Rouse (1966), Hopkins (1969), Piel (1971) and Norris (1986) this species is common in Eocene and Oligocene strata of British Columbia and the Northwest Territories. It also occurs in Tertiary strata of Europe (Norris, 1986). This taxon occurs only once from a sample from a bed of Facies B (backswamp) located above the debris flow on Quqaluit Island.

Polyatriopollenites vermontensis (Traverse) Frederiksen, 1980

Pl. 6 Fig. 13

Selected Synonymy:

1983 Polyatriopollenites vermontensis (Traverse) Frederiksen; Frederiksen, p. 43, pl. 13, figs. 4, 5.

Remarks: Martin and Rouse (1966) consider Polyatriopollenites stellatus (Potonie') Pflug and Polyatriopollenites vermontensis Traverse synonomous. Frederiksen (1980) suggests that P. vermontensis (Traverse) Frederidsen be used for North American specimens and P. stellatus (Potonie') Pflug be used for European specimens on the basis that P. stellatus has higher labra than P. vermontensis. Based on the criteria stated by Frederiksen (1980), the two species have been divided in this study. Frederiksen (1983) reports this species from the Middle Eocene of San Diego, California. P. vermontensis was observed in samples from beds located in and above the first volcanic ash (10 specimens in the volcanic ash sample and 1 specimen in a sample from a bed of Facies E (meandering channel)) on Padloping Island.

FUNGAL REMAINS

Genus Pesavis Elsik and Jansonius, 1974

Type Species: Pesavis tagluensis Elsik and Jansonius, 1974.

Pesavis tagluensis Elsik and Jansonius, 1974

Pl. 7 Fig. 1

Selected Synonymy:

1974 Pesavis tagluensis Elsik and Jansonius, p. 956, pl. 1, figs. 5-11.

1976 Pesavis tagluensis Elsik and Jansonius; Jansonius, p. 131, pl. 1, fig. 1.

1986 Pesavis tagluensis Elsik and Jansonius; Norris, p. 26, pl. 3, figs. 24, 25.

Remarks: Fungal spores increase in abundance upward (stratigraphically) from the Maastrichtian-Paleocene boundary (Elsik and Jansonius, 1974). They report a Paleocene-Eocene age for these fungal forms in Northwestern Canada, British Columbia, and Alaska. This fungal body is present in samples from beds located in and above the volcanic ash on Padloping Island and in a sample from a bed of Facies B (backswamp) (located above the debris flow on Quqaluit Island and above the volcanic ash on Padloping Island).

Genus Callimothallus Dilcher, 1965

Type Species: Callimothallus pertusus Dilcher, 1965.

Callimothallus pertusus Dilcher, 1965

Pl. 7 Fig. 2

Selected Synonymy:

1965 Callimothallus pertusus Dilcher, p. 13, pl. 6, fig. 45.

1986 Callimothallus pertusus Dilcher; Norris, p. 30, pl. 6, figs. 4, 6-9.

Remarks: The range for Callimothallus pertusus is Eocene (Dilcher, 1965; Norris, 1986). This fungal body is common in the samples taken from beds of Facies B and E located above the first volcanic ash on Padloping Island and in samples from beds of Facies B (located above the debris flow on Quqaluit Island).

MARINE MICROPLANKTON

Chorate Dinoflagellates

Genus Oligosphaeridium Davey and Williams emend. Davey, 1982

Type Species: Oligosphaeridium complex (White) Davey and Williams, 1966.

Oligosphaeridium complex? (White) Davey and Williams, 1966

Pl. 7 Fig. 3

Selected Synonymy:

1971 Oligosphaeridium complex (White) Davey and Williams; Singh, p. 333, pl. 53, figs. 4-6.

1975 Oligosphaeridium complex (White) Davey and Williams; Brideaux and McIntyre, p. 19 and 28, pl. 8, fig. 2.

1975 Oligosphaeridium complex (White) Davey and Williams; Williams and Brideaux, p. 110, pl. 21, fig. 2.

1985 Oligosphaeridium complex (White) Davey and Williams; Williams and Bujak, p. 935, fig. 34.14.

Remarks: According to Brideaux and McIntyre (1975) and Singh (1971) this species is widely distributed in Cretaceous and Tertiary strata. Only one poorly preserved specimen, in a sample from beds of the first volcanic ash located on Quqaluit Island, was observed in this study. This single poorly preserved broken specimen is only tentatively assigned to this species (only one undamaged orthogonal process remains on the cyst).

Genus Spiniferites Mantell emend. Sarjeant, 1970

Type species: Spiniferites ramosus (Ehrenberg) Loeblich and Loeblich, 1966.

Spiniferites sp. 1

Pl. 7 Fig. 4

Description: Spiniferites sp. 1 is a subspherical chorate cyst measuring 46 um x 36 um not including processes. Processes measure 10 um long and 2 um wide, the tip of which bifurcate. Preservation of the single specimen is poor.

Remarks: Only one specimen of Spiniferites sp. 1, in a sample from beds of the volcanic ash located on Quqaluit Island, was observed.

Spiniferites sp. 2

Pl. 7 Fig. 5

Description: Spiniferites sp. 2 is a spherical chorate cyst measuring 62 μm in diameter not including processes. Processes measure 14 μm long and are < 2 μm wide. The tip of the processes appear to be capitate, however preservation is poor. The specimen possesses a radial split which has been interpreted as a mechanical break and not an archeopyle. The number and position of the processes could not be determined.

Remarks: A single specimen of Spiniferites sp. 2 occurs in a sample from a bed of the volcanic ash located on Quqaluit Island. This genus is long ranging (Lentin and Williams, 1985) and therefore of little assistance in age determination.

Spiniferites sp. 3

Pl. 7 Fig. 6

Description: Spiniferites sp. 3 is a chorate spherical cyst which measures 30 μm in diameter. Processes are 10 μm long and 2 μm wide at the base. The processes taper in width towards the tip to < 1.5 μm wide. Due to poor preservation the exact number and position of processes, therefore tabulation pattern, could not be determined.

Remarks: Only one specimen is present in a sample from a bed of the volcanic ash on Quqaluit Island.

Dinoflagellate Type 1

Pl. 7 Fig. 7

Description: This chorate cyst is subspherical and measures 58 x 42 μm. Processes are approximately 24 μm long and taper to a point (processes measure 6 μm wide at the base and < 3 μm wide at the tip), however, many processes are broken. The cingulum and tabulation pattern were not discernable.

Remarks: A single specimen of "Dinoflagellate Type 1" was found in the study area (in a sample from a bed of the volcanic ash on Quqaluit Island).

Proximate Dinoflagellates

Genus Spinidinium Cookson and Eisenack emend. Lentin and Williams, 1976

Type Species: Spinidinium styloniferum Cookson and Eisenack, 1962.

Spinidinium sp.?

Pl. 7 Fig. 8

Remarks: Only one specimen of Spinidinium sp. is present in the study area in a sample from beds of the volcanic ash located on Quqaluit Island. This broken proximate cyst measures 75 x 42 μm. This cyst is broken in both the apical and antapical areas therefore assignment to this genus is only tentative. According to Lentin and Williams (1985) this genus occurs throughout the world in Cretaceous and Tertiary strata.

Cavate Dinoflagellates

Dinoflagellate Type 2

Pl. 7 Fig. 9

Description: A cavate cyst which is two layered; both an endocoel and pericoel are evident. The length of the main body ranges from 37-71 μm; the width of the main body ranges from 38-48 μm; the total cyst length ranges from 60 μm to 104 μm. The main body of the cyst is folded and possesses a granular sculpture. The antapical and apical cavities (pericoels) are psilate and triangular in shape. A cingulum is evident on one specimen and is approximately 4 $\mu$m wide. Tabulation pattern could not be discerned.

Remarks: Two specimens of "Dinoflagellate Type 2" were discovered in a sample from a bed of the volcanic ash located on Quqaluit Island. "Dinoflagellate Type 2" may be related to Geiselodinium tyonekensis sp. nov. described by Engelhardt (1976).

### 3.4 Other Organic Matter

Organic matter present in coal samples from Padlóping Island and mudstone samples from Durban Island has been assessed for source rock quality. This was performed using both plane polarized light and ultraviolet light microscopy on polished blocks. Macerals were identified following the work of Gutjahr (1983) (Table 3.2) and percentages of each were estimated (Table 3.3).

Organic matter types were also studied and classified following the work of Bujak et al.(1977a, 1977b) (Table 3.4). This classification scheme has been used for the Scotian Shelf and Grand Banks and catagorizies organic components using transmitted light. Organic matter has been described and classified using four morphological terms: amorphogen, phyrogen, hylogen and melanogen, corresponding to amorphous (organic matter in fluffy masses), herbaceous (all nonopaque recognizable plant matter; includes cuticle, spores, pollen and dinoflagellates), woody (nonopaque fibrous plant material) and coaly organic matter (opaque organic material), respectively.

Maturity estimates have been determined (Table 3.5) using vitrinite reflectance and thermal alteration index (TAI). Percent vitrinite reflectance has been measured using plane polarized light microscopy with reflectance measurement capabilities. Thermal alteration index (TAI) measurements on palynomorphs (a bisaccate pollen grain population and a spore population) were taken (Table 3.5) following the work of Staplin (1969, 1982). His scale ranges from 1 to 5; higher numbers correspond to a greater thermal maturity. The color chart used for this study was that of Pearson (1984). Pantone color chips were employed to measure the subtle color differences in the palynomorphs. Upon obtaining the measurements, the average TAI for each sample was calculated.

TABLE 3.2

ORGANIC MACERALS (modified from Gutjahr (1983))

| | |
|---|---|
| **INERTINITE (Carbon-rich)** | |
| | – Constituents of coal which are more or less non-reactive; fusibility of these macerals is very weak or nil. |
| Fusinite | – The richest of carbon content of all the constituents of coal. |
| Semi-fusinite | – The intermediate stage between Fusinite and Vitrinite. |
| Macrinite | – Non-granular groundmass of high reflectance, exhibits no structure. |
| Sclerotinite | – Fungal remains. |
| Micrinite | – Pale grey to white grains; reflectance higher than Vitrinite, is related to Liptinites and may be formed from them (particularly from Resinite). |
| **VITRINITE (Oxygen-rich)** | |
| | – The most common maceral occurring in coals; forms the humic fraction. |
| **LIPTINITE (Hydrogen-rich)** | |
| | – Precursors of oil and gas. |
| Sporinite | – From exines of spores and pollen. |
| Resinite | – From resinous secretions; excretions of plant cells. |
| Cutinite | – From cuticles of leaves and stems. |
| Alginite | – From algae. |
| Suberinite | – Consists of corkified cell walls (bark) formed on the surface of the roots, stems, and fruit. |
| Liptodetrinite | – Fragments of the above. |
| **BITUMEN (Solid hydrocarbon)** | |
| | – End product of Liptinite. |

TABLE 3.3

ORGANIC MATTER TYPING USING REFLECTED LIGHT

| PERCENTAGE | SAMPLE NUMBER PD-01C -19A | PD-01A -00 | PD-01C -11 | PD-10C -15 | DN-01A -08 | DN-01A -06 |
|---|---|---|---|---|---|---|
| Mineral | 5 | 6 | 9 | 9 | 73 | 84 |
| Total Vitrinite | 33 | 30 | 34 | 39 | 2 | 0 |
| Semifusinite | 3 | 2 | 3 | 2 | 6 | 0 |
| Fusinite | 9 | 6 | 6 | 6 | 4 | 2 |
| Micrinite | 30 | 25 | 26 | 30 | 0 | 0 |
| Total Inertinite | 42 | 33 | 35 | 38 | 10 | 2 |
| Resinite | 2 | 10 | 7 | 1 | 0 | 0 |
| Sporinite | 2 | 1 | 2 | 2 | 0 | 0 |
| Cutinite | 9 | 0 | 1 | 6 | 0 | 0 |
| Alginite | 6 | 19 | 10 | 4 | 0 | 0 |
| Liptodetrinite | 1 | 1 | 2 | 1 | 1 | 1 |
| Total Liptinite | 20 | 31 | 22 | 14 | 1 | 1 |
| Solid Hydrocarbons | 0 | 0 | 0 | 0 | 6 | 6 |
| Other (200 Points Counted) | 0 | 0 | 0 | 0 | 8 | 7 |

TABLE 3.4

ORGANIC MATTER TYPING USING TRANSMITTED LIGHT

| PERCENTAGE | SAMPLE NUMBER PD-01C-11 | PD-01C-19A |
|---|---|---|
| AMORPHOGEN | 3.6 | 0.0 |
| PHYROGEN | 13.8 | 5.0 |
| HYLOGEN | 60.0 | 40.2 |
| MELANOGEN | 22.8 | 54.8 |

## TABLE 3.5

### MATURITY MEASUREMENTS

| | SAMPLE NUMBER PD-01C -19A | PD-01A -00 | PD-01C -11 | PD-01C -15 | DN-01A -08 |
|---|---|---|---|---|---|
| Vitrinite (Collinite) Reflectance (%Ro) (50 Points) | .517 | .548 | .500 | .481 | .589 |
| Mean Vitrinite Reflectance = .527<br>Standard Deviation = .0425<br>Max. = .589 Min. = .481 | | | | | |
| Thermal Alteration Index (TAI) Spores | 1.06 | NA | 1.46 | NA | NA |
| Mean = 1.26<br>Standard Deviation = .2828<br>Max. = 1.46 Min. = 1.06 | | | | | |
| Bisaccates | 1.76 | NA | 1.94 | NA | 2.14 |
| Mean = 1.95<br>Standard Deviation = .2055<br>Max. = 2.14 Min. = 1.76 | | | | | |
| Coal Rank | HVB | HVB | HVB | HVB | — |

HVB = High Volatile bituminous.

### MATURITY MEASUREMENTS (SUMARY)

| MEAN | | CORRELATIVE %Ro |
|---|---|---|
| Vitrinite Reflectance (%Ro): | .527 | — |
| Thermal Alteration Index (TAI): Spores: | 1.26 | < 0.3 Waples, 1982. |
| : Bisaccates: | 1.95 | < 0.3 Waples, 1982. |
| Coal Rank: High Volatile Bituminous | | (< 0.4 - 1.0) Bustin, et al., 1983. |

# CHAPTER 4 DISCUSSION

## 4.1 Biostratigraphy

Palynological analyses of sedimentary strata from Padloping, Quqaluit and Durban islands fall into two distinct palynological assemblages, herein called Assemblage 1 and Assemblage 2; figure 4.1 indicates the known ranges of the significant taxa in these assembages.

### 4.1.1 Assemblage 1

Taxa

Assemblage 1 is characterized by the occurrence of: Polycingulatisporites sp. cf. P. radiatus Singh, Distaltriangulisporites perplexus (Singh) Singh, Distaltriangulisporites irregularis Singh, Densoisporites microrugulatus Brenner, Appendicisporites bifurcatus Singh, Appendicisporites problematicus (Burger) Singh, Trilobosporites hannonicus (Delcourt and Sprumont) Potonie', Foveogleicheniidites confossus (Hedlund) Burger, Lycopodiacidites canaliculatus Singh, Cicatricosisporites imbricatus (Markova) Singh, Retitriletes singhii Srivastava, Tappanispora reticulata (Singh) Srivastava, Foveosporites labiosus Singh, Concavissimisporites penolaensis Dettmann, Verrucosisporites rotundus Singh, Podocarpidites canadensis Pocock, Rugubivesiculites reductus? Pierce, and Cedripites canadensis Pocock.

Other very common taxa in Assemblage 1 include: Alisporites bilateralis Rouse, Cedripites cretaceus Pocock, Cerebropollenites mesozoicus (Couper) Nilsson, Cyathidites minor Couper, Gleicheniidites senonicus Ross, Inaperturopollenites sp., and Taxodiaceaepollenites hiatus (Potonie') Kremp. Rare taxa found in this assemblage are indicated in palynomorph counts in appendix D.

Distribution

Assemblage 1 is found in strata located below the first volcanic ash on Padloping

Island and below the debris flow on Quqaluit Island. It is also found in all sedimentary strata examined on Durban Island.

Age

The basis for the age of Assemblage 1 has been determined from the western Canadian palynological studies of Singh (1964, 1971, 1983), Burden (1982), Burden and Hills (in prep.); northern Canadian studies by Hopkins (1974) and Hopkins and Balkwill (1973); an Australian study by Dettmann (1963) and a European study by Burger (1966).

The restricted ranges (Figure 4.1) of Foveogleicheniidites confossus (Hedlund) Burger, Lycopodiacidites canaliculatus Singh, and Verrucosisporites rotundus Singh suggest an Albian age for Assemblage 1, however Albian strata located further north (Hassel and Christopher Formations) contain simple angiosperm grains (Hopkins, 1974; Hopkins and Balkwill, 1973). Other stratigraphically significant palynomorphs (Figure 4.1) in Assemblage 1 are found in the Lower Cretaceous (Aptian-Albian) rocks in Alberta (Singh 1964, 1971; Burden, 1982; Burden and Hills, in prep.). Based on the occurrence of the same taxa (Assemblage 1 and Aptian-Albian strata of Alberta) and the presence of angiosperms in western and northern Canadian Albian strata, an Aptian to latest Albian age is suggested for Assemblage 1. Early Cretaceous plant megafossils are restricted to strata which contain Assemblage 1.

Remarks

1. Assemblage 1 contains few or no species of Trilobosporites Pant ex. Potonie', Pilosisporites Delcourt and Sprumont, and Concavissimisporites Delcourt and Sprumont. These genera are present in the Christopher Formation (Albian) (Hopkins, 1974) and in western Canadian studies (Burden, 1982; Burden and Hills, in prep.; Singh, 1964, 1971), however, are rare to absent in the Hassell Formation (Hopkins and Balkwill, 1973).

2. In Assemblage 1, specimens of Cicatricosisporites Pflug and Thomson and

Appendicisporites Weyland and Krieger are very rare. Both these genera have been reported in western Canadian studies (Singh, 1964; 1971; Burden, 1982) and occur in the Christopher Formation (Albian) of Arctic Canada (Hopkins and Balkwill, 1973); however, they are very rare in the Hassel Formation (Hopkins and Balkwill, 1973).

3. Assemblage 1 contains high percentages of bisaccates, particularly Cedripites Wodehouse. High counts (Appendix D), suggests only that the radiation of this taxon may be linked to favorable climatic conditions subsequently followed by favorable preservational conditions. Very abundant bisaccate pollen is also found in the Hassel Formation; however, it is less abundant in later Cretaceous rocks of the central Sverdrup Basin (Hopkins and Balkwill, 1973).

### 4.1.2 Assemblage 2

Taxa

Assemblage 2 is characterized by the occurrence of Cupuliferoipollenites sp., Rugutricolporites sp., Carpinipites sp. cf. C. spackmaniana (Traverse) Zhou, Myricipites annulites (Martin and Rouse) Norris, Trivestibulopollenites betuloides Pflug, Polyatriopollenites vermontensis (Traverse) Frederiksen, Polyatriopollenites stellatus (Potonie') Pflug, Pesavis tagluensis Elsik and Jansonius, and Callimothallus pertusus Dilcher.

Common, reworked and corroded, Early Cretaceous taxa found in Assemblage 2 include: Alisporites bilateralis Rouse, Alisporites grandis (Cookson) Dettmann, Taxodiaceaepollenites hiatus (Potonie') Kremp, Gleicheniidites senonicus Ross, Cyathidites minor Couper, Cedripites cretaceus Pocock, Biretisporites potoniaei Delcourt and Sprumont, and Verrucosisporites rotundus Singh. Also present in this assemblage are six specimens of dinoflagelates and five unknown tricolpate species; indicated in appendix D.

Distribution

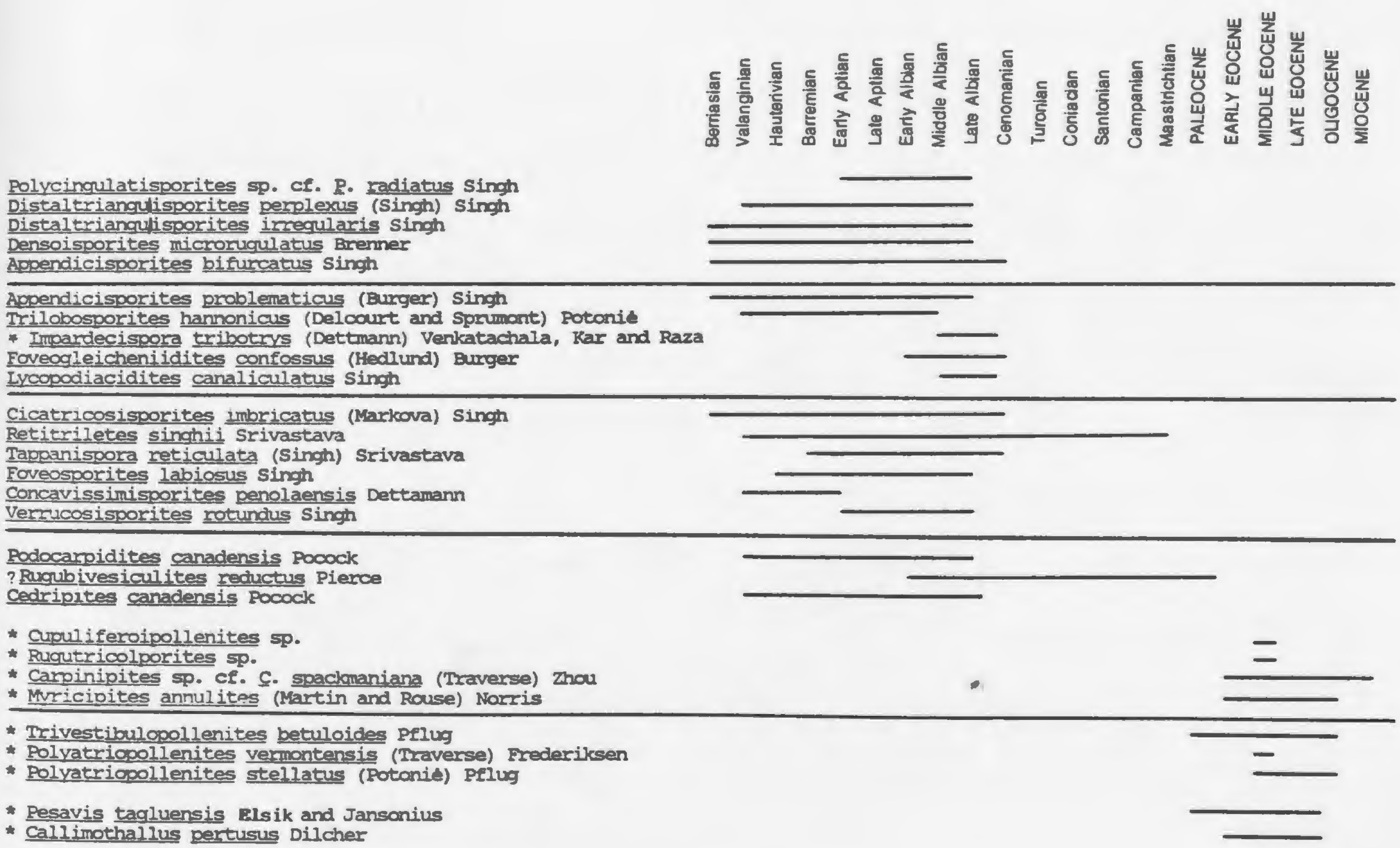



Figure 4.1 Range chart of significant taxa identified in this study (* indicates species which occur in or above the first volcanic ash on Padloping Island and/or above the gravel conglomerate on Quqaluit Island).

Assemblage 2 exists in sections located above the lower contact of the first volcanic ash on Padloping Island and above the upper contact of the debris flow on Quqaluit Island.

Age

The basis for the age of Assemblage 2 has been determined from the western Canadian palynological studies of Martin and Rouse (1966), Piel (1971), and Hopkins (1969); northern Canadian studies Elsik and Jansonius (1974) and Norris (1986) and American studies by Frederiksen (1983) and Dilcher (1965). The ranges of the taxa in Assemblage 2 (Figure 4.1) suggest a Late Paleocene-Eocene age. In particular, the presence of: Trivestibulopollenites betuloides Pflug (Paleogene-Neogene), Callimothallus pertusus Dilcher (Eocene), Cupuliferoipollenites sp. (Middle Eocene), Rugutricolporites sp. (Middle Eocene) and Pesavis tagluensis Elsik and Jansonius (Paleocene-Eocene) are good evidence for a Late Paleocene-Eocene age. Paleocene-Eocene plant megafossils are restricted to strata which contain Assemblage 2.

Remarks

The high percentage of reworked Cretaceous taxa in this assemblage is not uncommon for an Arctic Tertiary basin deposit. Norris and Miall (1984, p. 174) state that "Arctic Tertiary basins in Ellesmere and Axel Heiberg islands are characterized by rejuvenation and uplift of marginal areas leading to recycling of older palynomorphs, including Cretaceous, into Tertiary."

## 4.2 Palynology and Lithology

Hughes and Moody-Stuart (1967) used the phrase "palynological facies" to include all organic elements in a kerogen preparation (the entire acid resistant organic content of the rock). Its application has been directed towards paleoenvironmental, biostratigraphic, and source rock studies (Batten, 1981). Other authors (Habib and

Groth, 1967; Hughes and Moody-Stuart, 1967) have used palynological assemblages (characteristic of specific lithological units) for defining sedimentary paleoenvironments on the basis of their palynological content.

Some factors which affect the abundance of spores and pollen in a rock include: production rates (some taxa produce large numbers of palynomorphs relative to real abundances; size, shape and density effect where palynomorphs occur in terms of hydrodynamics; the more common and closer a parent plant is to the depositional site, the more palynomorphs it will deposit and; post-depositional effects such as secondary corrosion and biodegradation (Williams and Sarjeant, 1967; Batten, 1982).

Some generalities concerning the organic content in the various sedimentary rocks from the study area have been identified (Table 4.1):

1. Concentration Factor (no. of Lycopodium grains/total no. of grains counted) is extremely useful in identification of environments of deposition in terms of "energy of depositional medium". The lowest palynomorph concentrations (high Concentration Factors) occur in high energy depositional environments (i.e. Facies A, braided stream), whereas the highest palynomorph concentrations (low Concentration Factors) occur in lower energy (relative) depositional environments (i.e. Facies D, peat swamp).

2. High percentages of bisaccates (conifer pollen) occur in meandering stream environments (relative to other environments). High percentages may relate to either the transport of conifer pollen from hinterland areas or that the flood plain was covered with coniferous vegetation. Conversely, high percentages of bisaccates may not directly reflect vegetation type; abundance may be related entirely to hydrodynamic conditions (e.g. Catto, 1985).

3. The presence of dinoflagellate cysts in one sample of air-fall ash suggests that the ash "rained" into a marine or marginal-marine environment.

TABLE 4.1

SUMMARY OF PALYNOLOGICAL DATA

| Corresponding Environment | | braided stream complex | meandering stream complex | backswamp ponds | backswamp peat swamps | air-fall ash | distal alluvial fan |
|---|---|---|---|---|---|---|---|
| Corresponding Facies | | A and C | E and C | B | D | H | F |
| *Concentration Factor | | 0.25 | 0.05** | 0.03*** | 0.01 | 1.56 | 0.54 |
| Diversity | | 1.5-2.5 | 1.5-2.5 | 1.0-2.6 | 2.0-2.3 | 1.4-2.2 | 1.6-2.0 |
| Evenness | | 6-9 | 4.5-9 | 4.5-8.5 | 7-8 | 6.2-8 | 7-7.3 |
| Bisaccates | Total | 20-50% | 10-95% | 30-55% | 15-40% | 15-42% | 40-60% |
| | Broken | 20-65% | 10-90% | 10-75% | 20-45% | 50-70% | 30-60% |
| Gleicheniidites | | 1->14% | 0-12% | 0->14% | 2->14% | 0-8% | 0-5% |
| Taxodiaceaepollenites | | 0-20% | 0->30% | 0-30% | 5->30% | 5->30% | 0-6% |
| Inaperturopollenites | | 2-21% | 0->30% | 0-30% | 5->30% | | 4-24% |
| Angiosperm Pollen | | | | | | >0-28% | |
| Dinoflagellates | | | | | | 0-<1% | |
| Other Spores | | 10-21% | 4-28% | 5-25% | 10-35% | 5-12% | 15-25% |
| Other Pollen | | 0-12% | 2-10% | 0-5% | 0-8% | 0-<1% | 0-<3% |
| Woody Debris | | Abundant | Abundant | Present | Abundant | None | Present |
| Comments | | Corroded Palynomorphs | Corroded Palynomorphs | Amorphous O. M. Present | | Corroded Palynomorphs | Corroded Palynomorphs |

*(no. of Lycopodium grains/total no. of grains counted in sample, i.e. the lower the value the higher the palynomorph concentration)

**(three samples in this complex have very low abundance ratios, approximately 2.15)

***(two samples in this complex have low abundance ratios, approximately 0.28)

O.M. = Organic Matter

4. Corroded palynomorphs are common wherever exposure and secondary meteroric water circulation are likely to occur. Woody debris is abundant in high energy and coally depositional environments; this is almost certainly related to the energy required to carry these particles and to the source of these particles. Amorphous organic matter in pond deposits relates to the presence of algae and bacteria.

## 4.3 Geologic Model

### 4.3.1 Local Basin Development

Detailed observation of the sedimentary strata for lithology, facies and palynology provides the basis for reconstructing the geologic history of these deposits. Phase 1 (Early Cretaceous) depicts initial basin faulting producing a half-graben, and rapid sediment infilling in a braided stream depositional environment (Figure 4.2A). Faulting was normal, striking approximately N-S, with a small rotational component, thereby producing an elevated (relative) region to the south. The Precambrian gneiss and local (Durban Island) granite are considered the source rocks for these sediments. The half-graben formed during basin filling. If the half-graben was pre-sediment infill, the braided stream complex would probably have eroded the extensive Precambrian regolith. Phase 2 (Early Cretaceous) illustrates continued infilling under conditions of uniform subsidence (Figure 4.2A). The depositional environment during phase 2 is that of a meandering stream. Phase 3 indicates renewed motion (Late Paleocene-Eocene) of the major fault controlling the development of this sedimentary deposit and the onset of volcanism in the area (Figure 4.2B). A gravel supported conglomerate (debris flow), unconformably overlies Lower Cretaceous fluviatile strata which contain Cretaceous sediments shed from this uplift. Air-fall volcanic ash, which overlies the conglomerate or, where the conglomerate is not present, directly overlies Lower Cretaceous fluviatile strata, was deposited during volcanic eruptions. This hiatus (50 Ma between Phases 2 and 3)is recognized solely on paly-

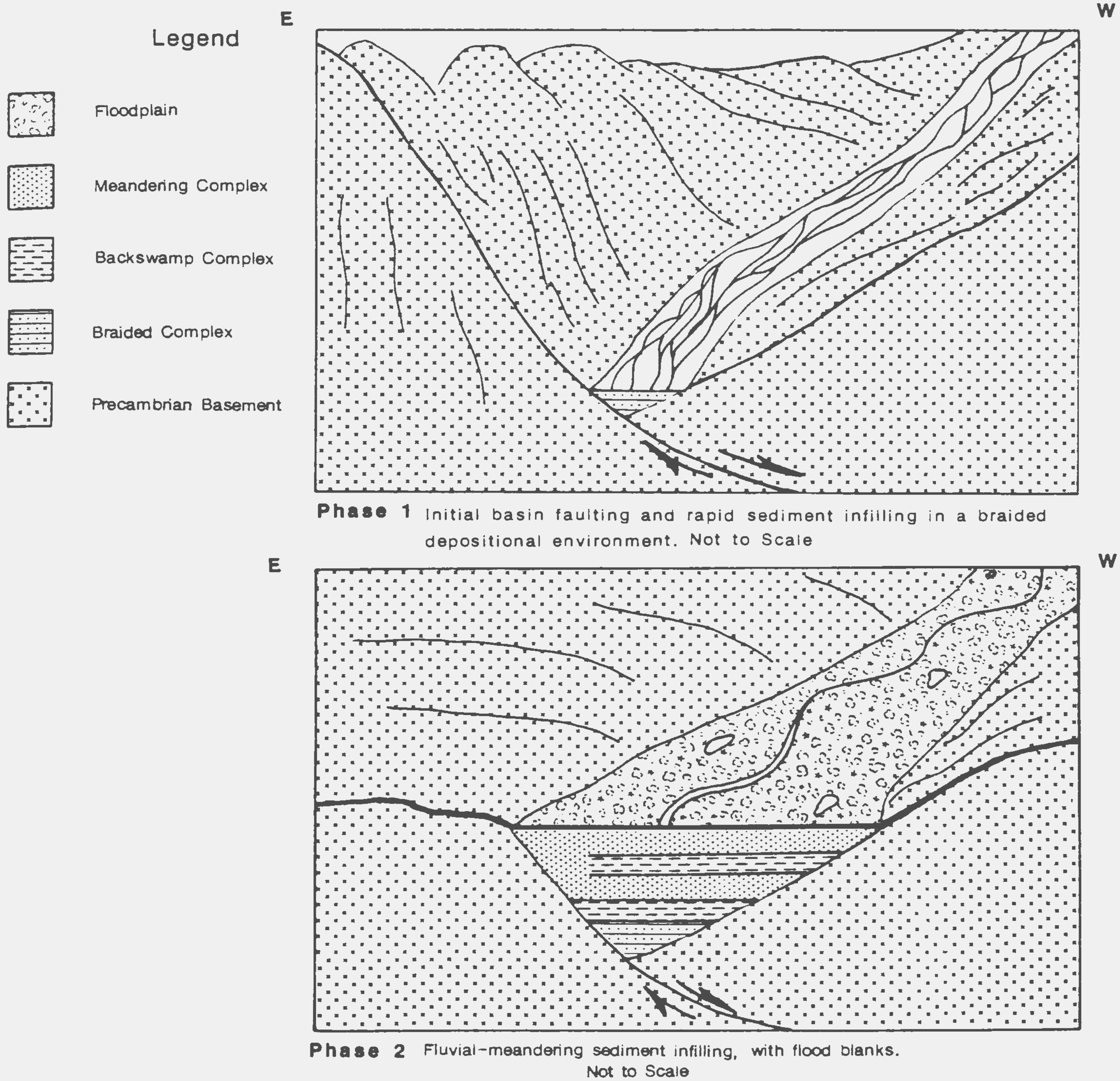
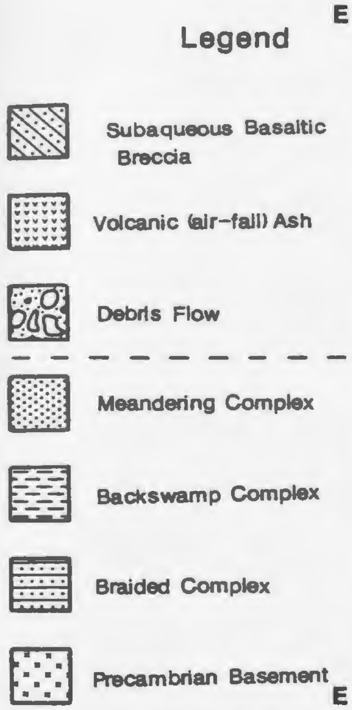
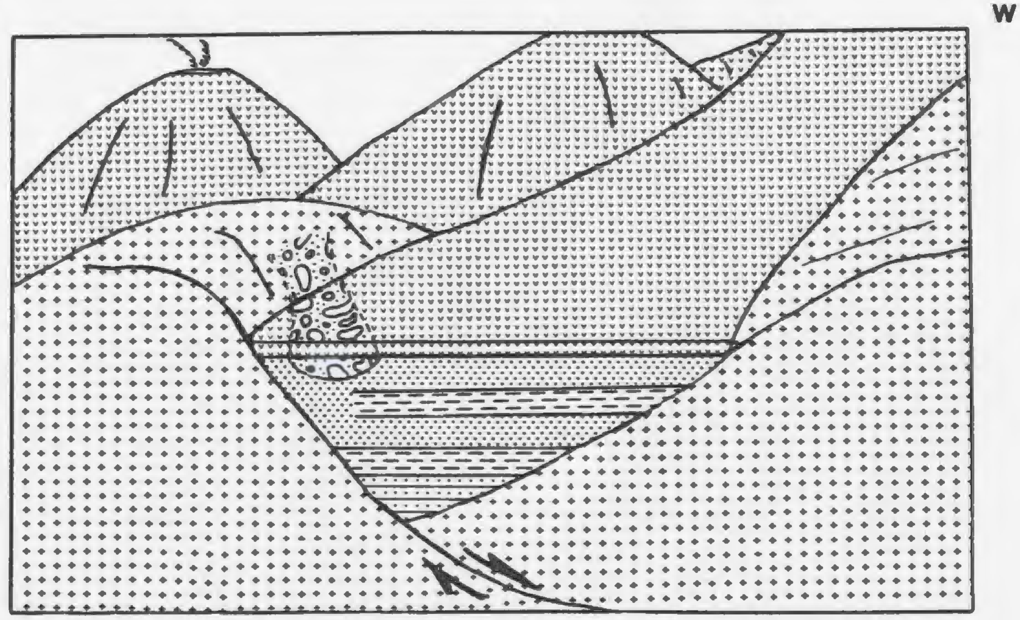
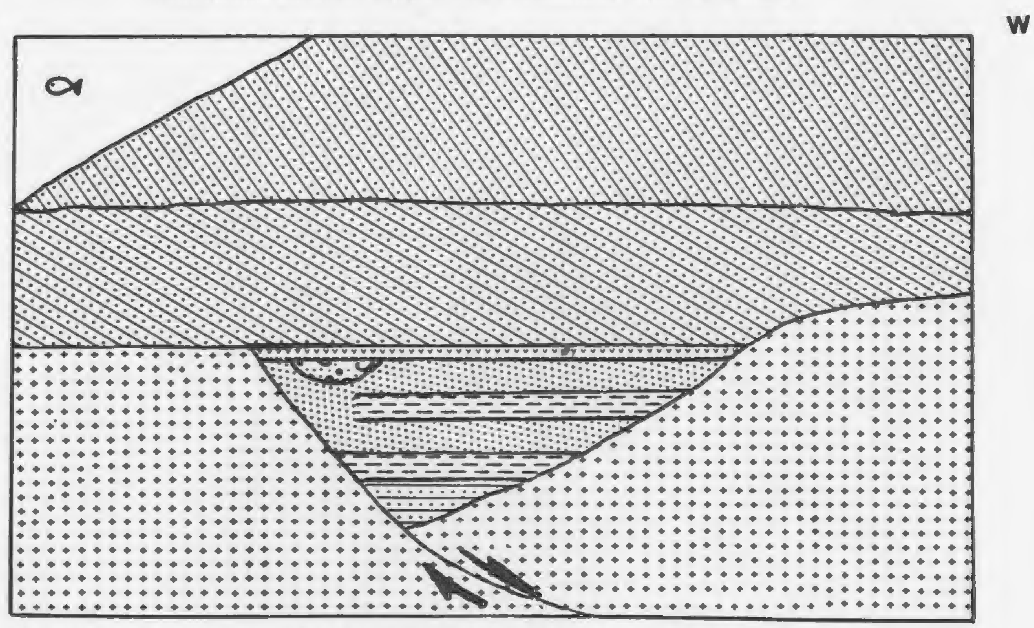



Figure 4.2A Geologic history (Phases 1 and 2, Early Cretaceous).




**Phase 3** Debris flow and volcanic ash unconformably overlying the fluviatile strata. Onset of volcanism. Not to Scale




**Phase 4** Basin subsidence, deposition of thin terrestrial deposits, renewed subsidence and deposition of subaqueous basaltic breccia.
Not to Scale

Figure 4.2B Geologic history (Phases 3 and 4, Late Paleocene-Eocene).

nological evidence and is addressed in section 4.3.2. Phase 4 is characterized by continued fluvial deposition (Late Paleocene-Eocene) and deposition of cross bedded subaqueous basaltic breccia (Figure 4.2B). Following Late Paleocene-Eocene sediment deposition, yet prior to the deposition of volcanic breccia, the basin subsided. The overlying basaltic breccia was deposited in at least 60 metres of water (Clarke and Upton, 1971). Following emplacement of the overlying basalts the entire area was uplifted such that it was a coastal nunatak during the last glaciation (Andrews, 1980).

**4.3.2 Regional Scope**

The Mesozoic and Cenozoic sedimentary strata located on the southeast coast of Baffin Island constitute one of several sedimentary deposits in the north-east Arctic Archipelago, Greenland and and north-west Atlantic ocean (Figure 4.3). Many of these deposits exhibit similarities in structural style and stratigraphy (Miall et al., 1980). Points of note include:

1. Sediment transport was along the basin axis; this is the case for fluviodeltaic strata in the Eclipse Trough (Miall et al., 1980) and for Cretaceous deltaic strata in the Nugssuag Embayment of western Greenland (Henderson et al., 1980). According to Miall et al. (1980) basin-parallel deposition patterns indicate active subsidence during deposition.

2. A regional late Maastrichtian-Early Paleocene unconformity in both Eclipse Trough and Labrador Shelf may also occur in strata of southeastern Baffin Island (between the Lower Cretaceous and Upper Paleocene-Eocene strata on Padloping and Quqaluit islands). According to Miall et al. (1980) the timing of this unconformity may correspond with the tectonic movements separating Greenland and North America, the generation of Baffin Bay volcanic rocks, and the occurrence of global changes in sea level.

3. Menzies (1982) states that marine conditions existed in Baffin Bay at the end of the Cretaceous. Also, MacLean and Williams (1980) report a rich Campanian dinoflagellate assemblage from a core taken in Buchan Trough. This supports the existence of a seaway connecting the Buchan Trough area with Davis Strait, and the North Atlantic in the Campanian (MacLean and Williams, 1980). Although the mudstones and sandstones which compose the sedimentary strata above beds of the debris flow and volcanic ash on Quqaluit and Padloping islands contain only terrestrial palynomorphs; a sample of the volcanic ash from Quqaluit Island contains dinoflagellates, an indication of marine to marginal-marine conditions.

4. The assignment of these strata (volcaniclastic complex and thin overlying terrestrial sediments) to the Late Paleocene-Eocene supports Clarke and Upton's (1971) $58 \pm 2$ ma (Paleocene) age for the overlying volcanics.

5. Nonmarine Albian sedimentary strata, sampled in core, at "station 16" located 13 km northeast of Padloping Island in Davis Strait (MacLean and Williams, 1983), may be depositionally equivalent to strata in this study and may suggest widespread Early Cretaceous terrestrial deposition.

According to Srivastava (1978), initiation of rifting between Greenland and North America occurred in the Campanian (75 Ma). However, this study illustrates from paleobotany and palynology that sedimentary strata were deposited in rift-related or crustal attenuation-related half grabens active in the Early Cretaceous (Aptian to latest Albian) and Late Paleocene-Eocene.

## 4.4 Petroleum Geology

### 4.4.1 Present State of the Offshore

To date, no exploratory wells have been drilled in the offshore area adjacent to the study region. This is primarily because of high exploration costs and lack of well-defined prospects. However, five wells have been drilled off the coast of western

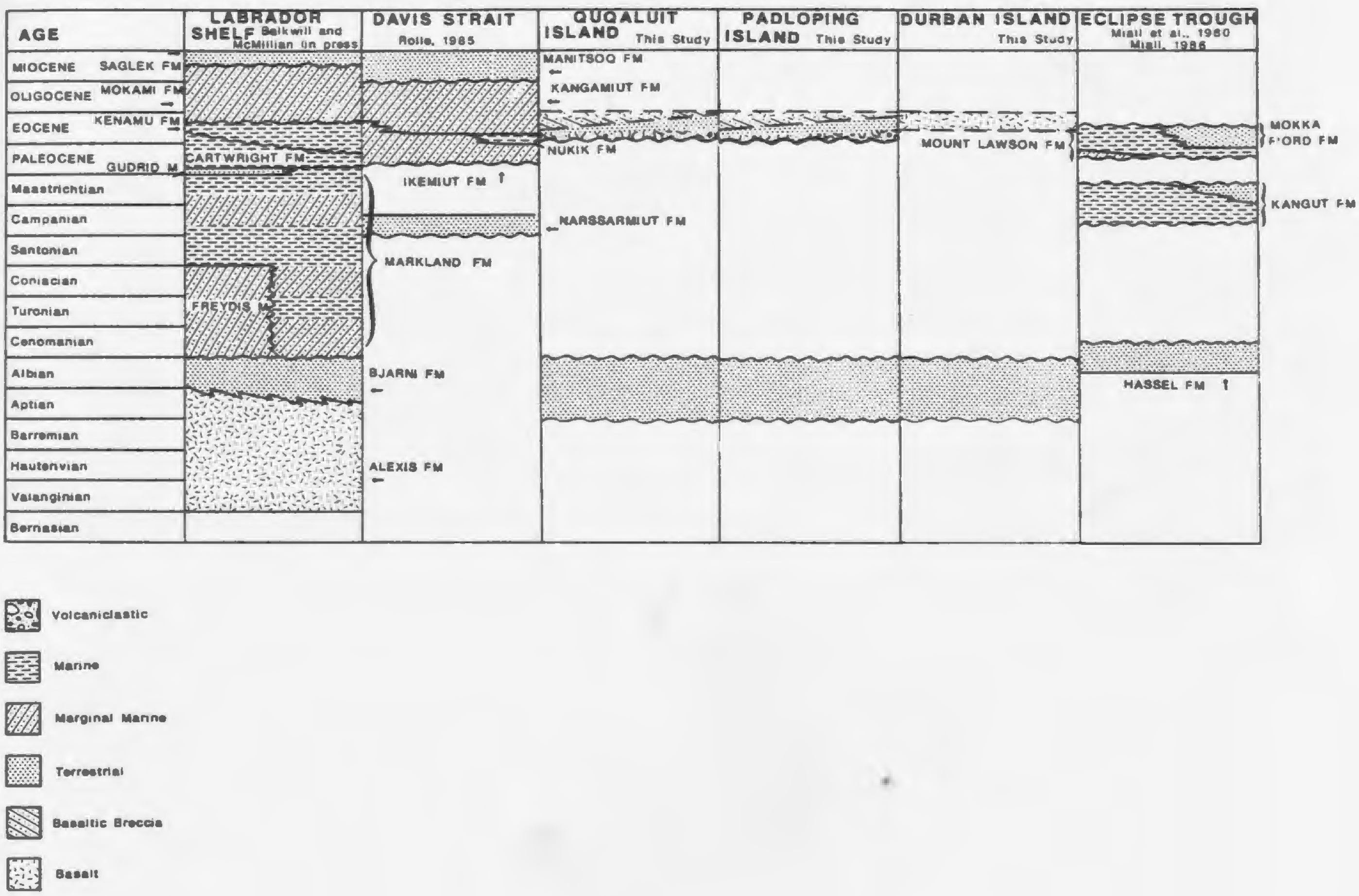



Figure 4.3 Regional stratigraphic correlation.

Greenland and two wells have been drilled off the southern coast of Baffin Island in the northern Labrador Sea (Figure 4.4).

The five wells drilled, through Neogene to Campanian strata, in the offshore region of western Greenland did not discover hydrocarbons (Rolle, 1985). The two wildcat wells (Gjoa G-37 and Hekja O-71) drilled off the south coast of Baffin Island penetrated Paleocene to Eocene strata; Hekja O-71 intersected a gas/condensate-filled sandstone (Klose et al., 1982). This hydrocarbon-bearing sandstone was deposited in deltaic to nearshore conditions during the Paleocene (Klose et al., 1982).

#### 4.4.2 Petroleum Prospects (Cape Dyer Region)

As expected the organic matter contained in the fluvial sedimentary rocks exposed on Padloping, Quqaluit, and Durban islands is immature. Both TAI and %Ro values (approximately 1.6 and .53 respectively) are lower than the values for the main generation stages for oil and gas. In addition, according to Gutjahr's (1983) classification of potential source rocks, the Padloping Island coals and the shales from Durban Island are landplant-containing source rocks. It is therefore suspected that these potential source rocks may produce gas and minor oil, given a sufficient thermal maturation history.

Sandstones from all three islands exhibit variable porosity and lateral extent. For these reasons one would explore with caution, a potential reservoir (possibly offshore) of this nature.

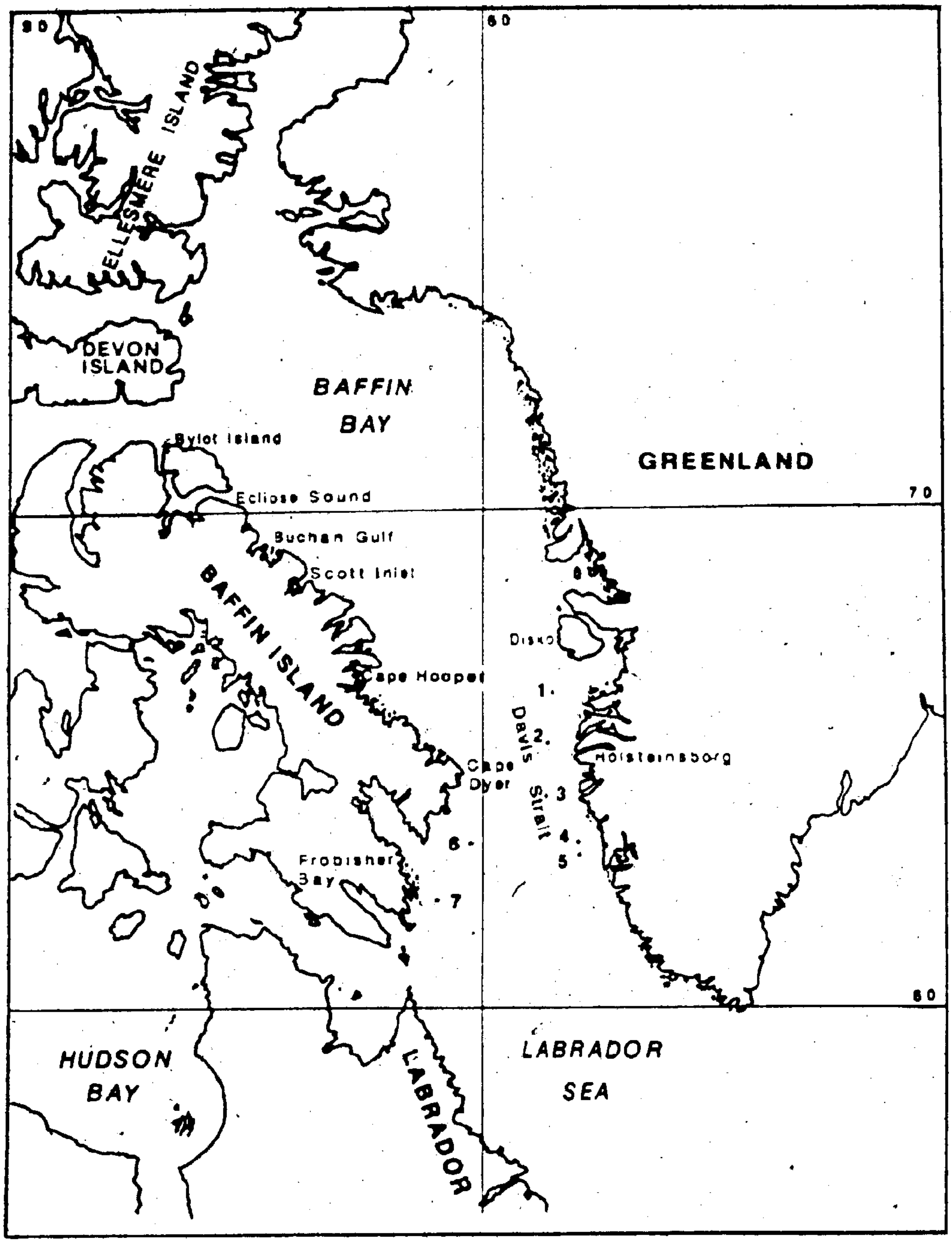



Figure 4.4 Location of the seven exploratory wells drilled to date in the Davis Strait-Northern Labrador Sea area (1=Hellefisk 1, 2=Ikerm 1, 3=Kangamiut 1, 4=Nukik 2, 5=Nukik 1, 6=Gjoa, 7=Hekja).

# CHAPTER 5 CONCLUSIONS

Integrated sedimentological/palynological study has established a geologic model using depositional environments and palynomorph biostratigraphy of Mesozoic and Cenozoic fluvial strata from islands located off the southeast coast of Baffin Island. The results improve our understanding of the timing of initial rifting events or crustal attenuation between Greenland and North America and the likelihood that hydrocarbons may be present offshore.

Strata on a thick regolith of Precambrian gneiss consist of braided, backswamp and meandering fluvial deposits; deposits of distal alluvial fans(?) and volcaniclastics (at upper contact with volcanic breccias and basaltic flows) are present locally.

Strata are of two ages: Aptian to latest Albian (Assemblage 1), located on Durban Island and below the first volcanic ash on Padloping Island and debris flow on Quqaluit Island, and Late Paleocene-Eocene (Assemblage 2), located in and above the first volcanic ash on Padloping and Quqaluit islands and above the debris flow on Quqaluit Island. These ages, Early Cretaceous and Early Tertiary, defined by palynology, are supported by paleobotany.

Since these strata are related to the timing of either initial rifting events or crustal attenuation between Greenland and North America an earlier age for the timing of either tectonic event is proposed. Initial rifting or crustal attenuation probably started in the Early Cretaceous, at least 30 ma earlier than previously stated.

Organic matter in the sedimentary strata is immature and largely humic in nature. If sediments, similar to those onshore, are buried offshore, gas and minor liquid hydrocarbons might be expected.

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# PLATES

All specimens, except those in plate 1 (paleobotany), are illustrated in interference contrast at 1000 X magnification, unless otherwise stated. Specimens are followed by a sample and slide identification number, microscope coordinates and view.

## Plate 1

The scale for all specimens is in centimetres. The sample identification number follows each figure number and caption.

Figure 1. Fossilized Log, ?Metasequoia ocelon or ?Glyptostrobus; PD-LOG.

Figure 2. Coniferous needle, ?Elatides; PD-01B-03.

Figure 3. Leaflets, ?Podozamites; PD-2a.

Figure 4. Root; QU-2.

Figure 5. Fern frond, ?Gleichenites; PD-2d.

Figure 6. Fern frond, ?Cladophlebis; QU-6.

Figure 7. Fern frond, ?Gleichenites; QU-5.

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Plate 2

Figure 1. Polycingulatisporites sp. cf. P. radiatus Singh; QU-01B-19, 86154(3/5), 122.5 18.3, Distal.

Figure 2. Distaltriangulisporites perplexus (Singh) Singh; QU-01B-19, 86154(3/5), 117.19.1, Distal.

Figure 3. Distaltriangulisporites irregularis Singh; QU-01B-23, 86155(5/5), 124.6 24.2, Distal.

Figure 4. Densoisporites microrugulatus Brenner; PD-02A-47, 86166(3/5), 126.8 26.9, Proximal.

Figure 5. Appendicisporites bifurcatus Singh; PD-01C-19, 86114(5/5), 120.1 29.9, 630 X, Mid-focus.

Figure 6. Appendicisporites problematicus (Burger) Singh; DN-01A-18, 86160(5/5), 124.1 12.1, Distal.

Figure 7. Murospora mesozoica Pocock; PD-01C-15, 86113(4/5), 125 28.5, Proximal.

Figure 8. Trilobosporites hannonicus (Delcourt and Sprumont) Potonie'; PD-02A-10, 86008(3/5), 121.1 34.3, 400 X, Proximal.

Figure 9. Impardecispora tribotrys (Dettmann) Venkatachala, Kar and Raza; QU-01A-02, 87027(5/5), 120.3 17.7, Mid-focus.

Figure 10. Sestrosporites pseudoalveolatus (Couper) Dettmann; QU-01B-19, 86154(3/5), 120.3 18, 630 X, Proximal.

Figure 11. Gleicheniidites senonicus Ross; PD-02A-10, 86008(3/5), 127.8 25.8, 630 X, Mid-focus.

Figure 12. Foveogleicheniidites confossus (Hedlund) Burger; PD-02A-47, 86166(3/5), 125.9 41.8, Proximal.

Figure 13. Lycopodiacidites canaliculatus Singh; QU-01B-19, 86166(3/5), 123.4 37.3, Proximal.

Figure 14. ?_Hamulatisporis_ sp.; QU-01A-01, 87025(4/5), 122 20.9.

Figure 15. _Cicatricosisporites annulatus_ Archangelsky and Gamerro; PD-01C-08, 86110(5/5), 120 16.3, Proximal.

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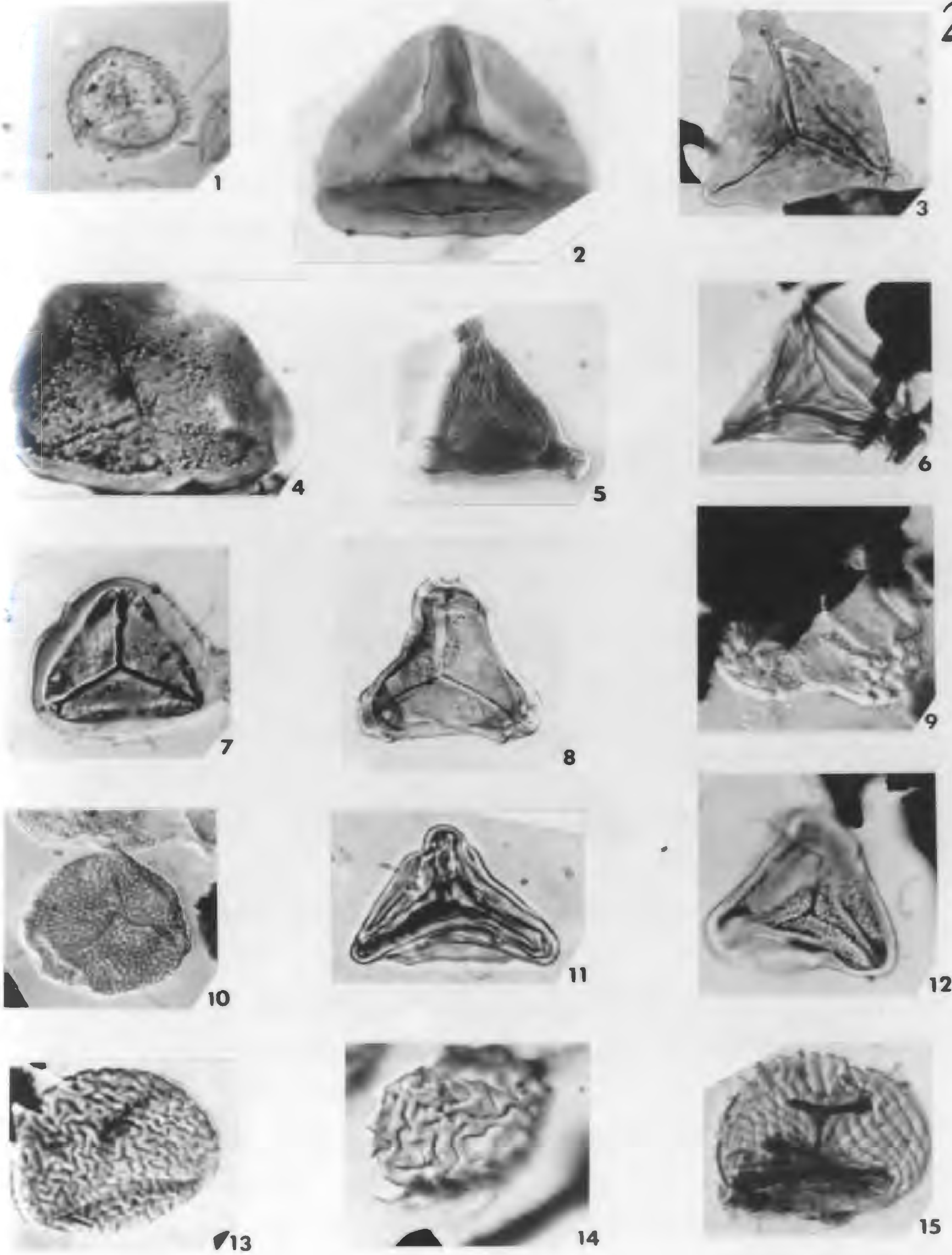

Plate 3

Figure 1. Cicatricosisporites australiensis (Cookson) Potonie'; QU-01B-23, 86155(5/5), 121.4 43.4, Proximal.

Figure 2. Cicatricosisporites hallei Delcourt and Sprumont; PD-01B-11, 86007(3/5), 122.7 17.5, 630 X, Mid-focus.

Figure 3. Cicatricosisporites hughesi Dettmann; PD-02A-10, 86008(3/5), 122.2 43.8, 630 X, Distal.

Figure 4. Cicatricosisporites imbricatus (Markova) Singh; QU-01B-23, 86155(5/5), 121.8 35.6, 630 X, Distal.

Figure 5. Chomotriletes minor (Kedves) Pocock; QU-01B-14, 86153(3/5), 123.7 43.2, Mid-focus.

Figure 6. Retitriletes singhii Srivastava; QU-01B-19, 86154(3/5), 117.2 19.6, Proximal.

Figure 7. Reticulisporites elongatus Singh; QU-01B-19, 86154(3/5), 120.5 31.9, Distal.

Figure 8. Tappanispora reticulata (Singh) Srivastava; QU-01B-19, 86154(3/5), 124.8 20.5, Distal.

Figure 9. Foveosporites labiosus Singh; PD-02A-70, 86010(3/5), 125 32.7, 630 X, Mid-focus.

Figure 10. Klukisporites pseudoreticulatus Couper; PD-01C-01, 86109(4/5), 124.6 25.9, Proximal.

Figure 11. Unknown; QU-01B-27, 86156(3/5), 126.7 44.3.

Figure 12. Undulatisporites undulapolus Brenner; PD-01C-01, 86109(4/5), 124.7 22.5, Mid-focus.

Figure 13. Biretisporites potoniaei Delcourt and Sprumont; QU-01B-19, 86154(3/5), 126 42.3, Mid-focus.

Figure 14. Dictyophyllidites sp.; QU-01B-19, 86154(3/5), 125 43.5, Mid-focus.

Figure 15. _Stereisporites antiquasporites_ (Wilson and Webster) Dettmann; PD-01C-08, 86110(5/5), 120 37.1, Mid-focus.

Figure 16. _Deltoidospora hallii_ Miner; DN01A-07, 86013(3/5), 124.2 36.7, Mid-focus.

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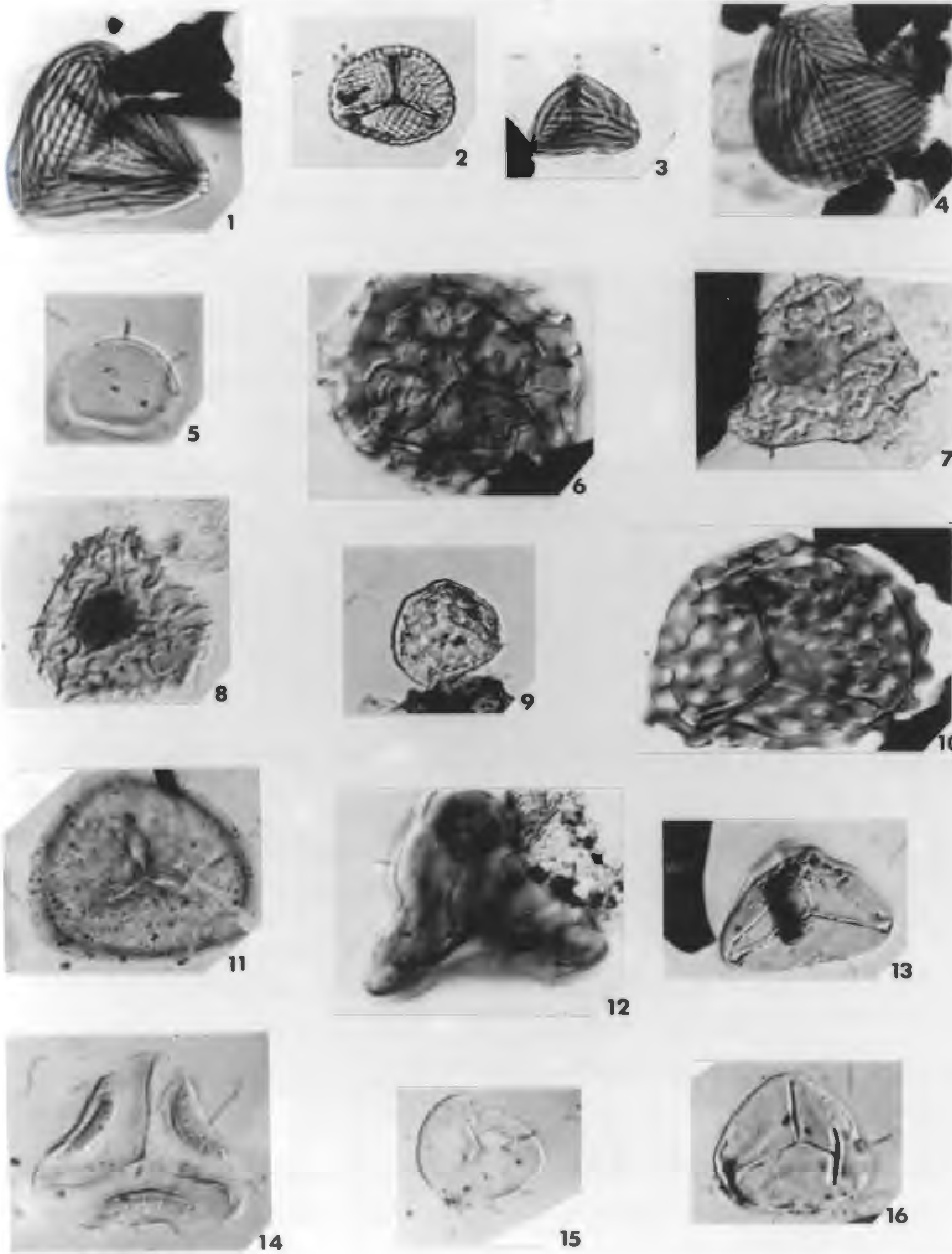

Plate 4

Figure 1. Cyathidites minor Couper; PD-02A-10, 86008(3/5), 126 12.6, Mid-focus.

Figure 2. Concavisporites jurienensis Balm; PD-01C-09, 86111(3/5), 124 34.2, Distal.

Figure 3. Concavissimisporites minor (Pocock) Delcourt, Dettmann and Hughes; PD-01C-08, 86110(5/5), 120 30.7, 630 X, Mid-focus.

Figure 4. Concavissimisporites penolaensis Dettmann; QU-01B-19, 86154(3/5), 120.4 12.2, Mid-focus.

Figure 5. Neoraistrickia truncata (Cookson) Potonie'; PD-02A-68, 86172(5/5), 128.2 49.8, Mid-focus.

Figure 6. Osmundacidites wellmanii Couper; PD-01C-08, 86110(5/5), 124.2 49.5, Mid-focus.

Figure 7. Baculatisporites comaumensis (Cookson) Potonie'; QU-01B-19, 86154(3/5), 120.7 19.2, Mid-focus.

Figure 8. Acanthotriletes varispinosus Pocock; PD-01C-19, 86114(5/5), 120.2 14.7, Mid-focus.

Figure 9. Granulatisporites sp.; QU-01B-23, 86155(5/5), 121.7 9.6, 630 X, Proximal.

Figure 10. Verrucosisporites rotundus Singh; QU-01B-19, 86154(3/5), 126 43.3, Mid-focus.

Figure 11. Laevigatosporites ovatus Wilson and Webster; PD-02B-05, 86115(3/5), 126 30.2, Equatorial.

Figure 12. Punctatosporites scabratus (Couper) Singh; PD-01C-09, 86111(3/5), 124 34.6, Equatorial.

Figure 13. Inaperturopollenites sp.; QU-01B-19, 86154(3/5), 124.1 36.9, Equatorial.

Figure 14. Taxodiaceaepollenites hiatus (Potonie') Kremp; QU-01B-19, 86154(3/5), 124.5 13, Mid-focus.

Figure 15. Sequoiapollenites paleocenicus Stanley; B-5, 87049(4/5), 120 45.9, Mid-focus.

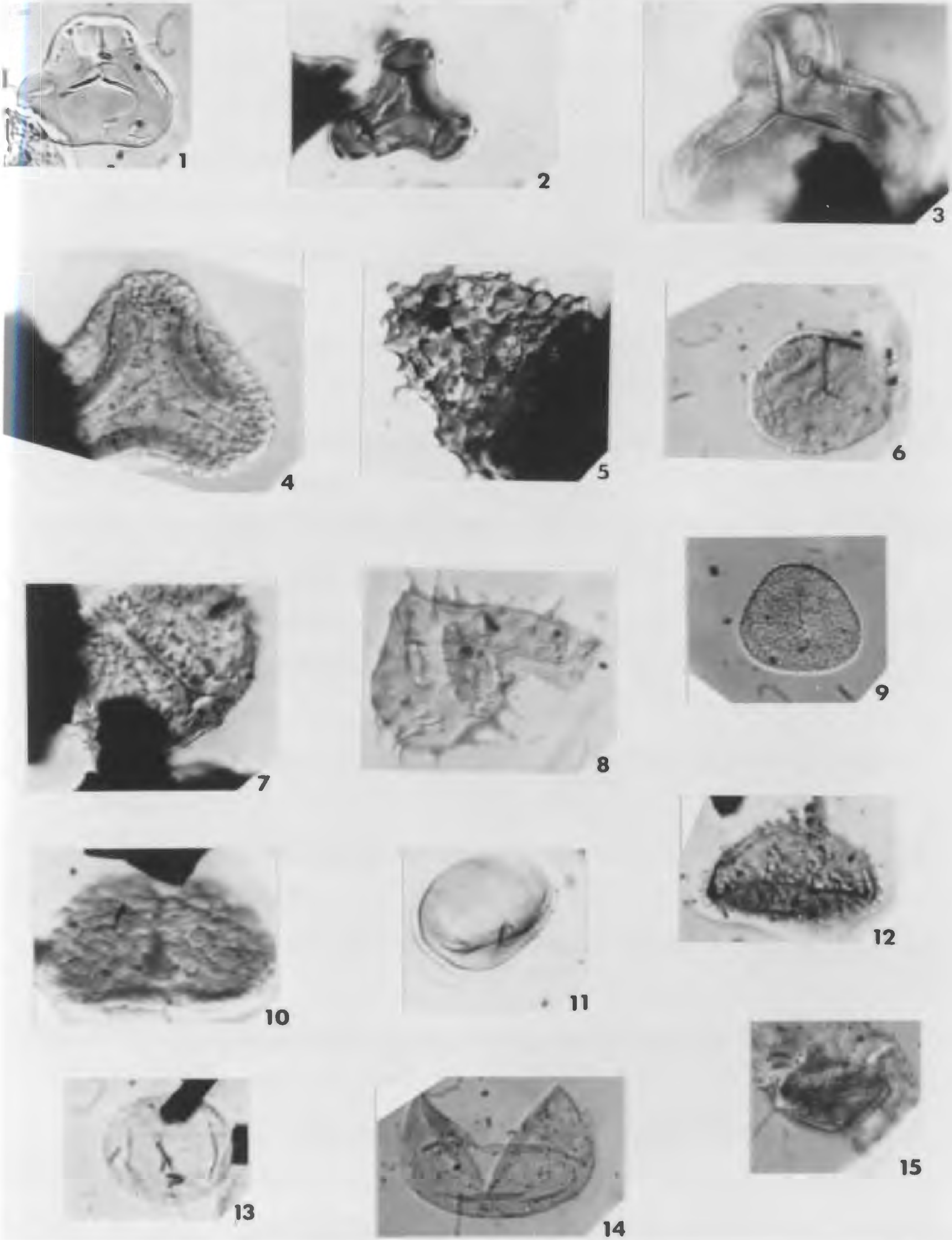
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Plate 5

Figure 1. Araucariacites australis Cookson; QU-01B-19, 86154(3/5), 123.7 19, 630 X, Mid-focus.

Figure 2. Podocarpidites canadensis Pocock; QU-01B-19, 86154(3/5), 124.6 34.6, 630 X, Proximal.

Figure 3. Podocarpidites minisculus Singh; DN-01A-14, 86158(3/5), 122.2 16.1, Equatorial oblique.

Figure 4. Podocarpidites multesimus (Bolkovitina) Pocock; PD-01B-04, 86006(3/5), 124 32.8, 630 X, Distal.

Figure 5. Pityosporites alatipollenites (Rouse) Singh; PD-02A-65, 86170(3/5), 120 17.2, 630 X, Equatorial.

Figure 6. Abiespollenites sp.; PD-02A-45, 86165(4/5), 124.7 44.1, 250 X, Oblique.

Figure 7. Vitreisporites pallidus (Reissinger) Nilsson; PD-01C-09, 86111(3/5), 130 .38.2, Distal.

Figure 8. Alisporites bilateralis Rouse; PD-02B-05, 86115(3/5), 125 45.1, 630 X, Distal.

Figure 9. Alisporites grandis (Cookson) Dettmann; PD-01C-01, 86109(4/5), 131.5 24.6, 400 X, Distal.

Figure 10. Piceaepollenites sp.; PD-01C-01, 86109(4/5), 122.4 25.2, 400 X, Equa torial oblique.

Figure 11. ?Rugubivesiculites reductus Pierce; QU-01B-19, 86154(3/5), 120.5 17, 630 X, Equatorial.

Figure 12. Cedripites canadensis Pocock; QU-01B-19, 86154(3/5), 124.7 33.9, 630 X, Equatorial.

Figure 13. Cedripites cretaceus Pocock; PD-01C-01, 86109(4/5), 119.9 25.9, 630 X, Equatorial.

Figure 14. Pristinuspollenites microsaccus (Couper) B.D. Tschudy; QU-01B-19, 86154(3/5), 120.5 26.5, 630 X, Equatorial end view.

Figure 15. Cerebropollenites mesozoicus (Couper) Nilsson; PD-02A-70, 86010(3/5), 129.5 30, Equatorial.

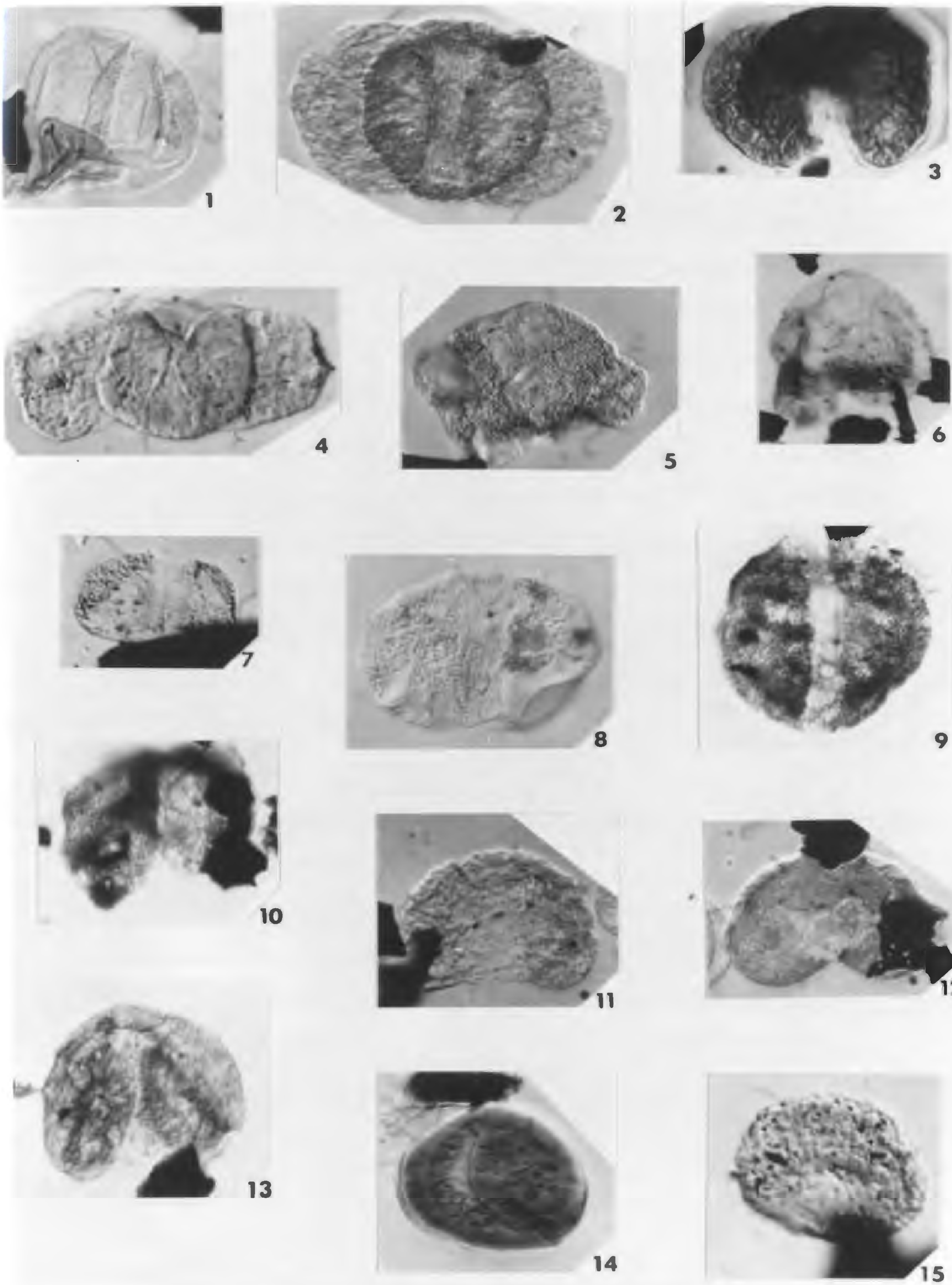
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Plate 6

Figure 1. Cycadopites follicularis Wilson and Webster; PD-02A-36, 86164(4/5), 126.2 22.1, Proximal.

Figure 2. Tricolpites sp. 1; QU-01A-02, 87027(5/5), 127.3 32.3, Polar.

Figure 3. Tricolpites sp. 2; B-5, 87049(4/5), 127 45.2, Equatorial.

Figure 4. Tricolpites sp. 3; B-5, 87049(4/5), 123.9 32.4, Equatorial.

Figure 5. Tricolpites sp. 4; B-5, 87049(4/5), 124.1 23.3, Equatorial.

Figure 6. Tricolpites sp. 5; B-5, 87049(4/5), 126.4 39.3, Equatorial.

Figure 7. Cupuliferoipollenites sp.; B-5, 87049(4/5), 120.1 41.2, Equatorial.

Figure 8. Rugutricolporites sp.; QU-01A-03, 87028(4/5), 125 29.4, Equatorial.

Figure 9. Carpinipites sp. cf. C. spackmaniana (Traverse) Zhou; QU-01A-02, 87027(5/5), 119.5 41.4, Equatorial.

Figure 10. Myricipites annulites (Martin and Rouse) Norris; B-5, 87049(4/5), 125.2 22.8, Equatorial.

Figure 11. Trivestibulopollenites betuloides Pflug; B-5, 87049(4/5), 125 38.1, Equa torial.

Figure 12. Polyatriopollenites stellatus (Potonie') Pflug; QU-01A-02, 87027(5/5), 125.8 41.8, Equatorial.

Figure 13. Polyatriopollenites vermontensis (Traverse) Frederiksen; B-5, 87049(4/ 5), 126.8 34.3, Equatorial.

Figure 14. Corroded Appendicisporites Weyland and Kreiger; QU-01A-02, 87027(5/ 5), 123.8 37.1, 630 X.

Figure 15. Corroded Bisaccate; QU-01A-01, 87025(4/5), 121.5 40.1, 400 X, Proximal.

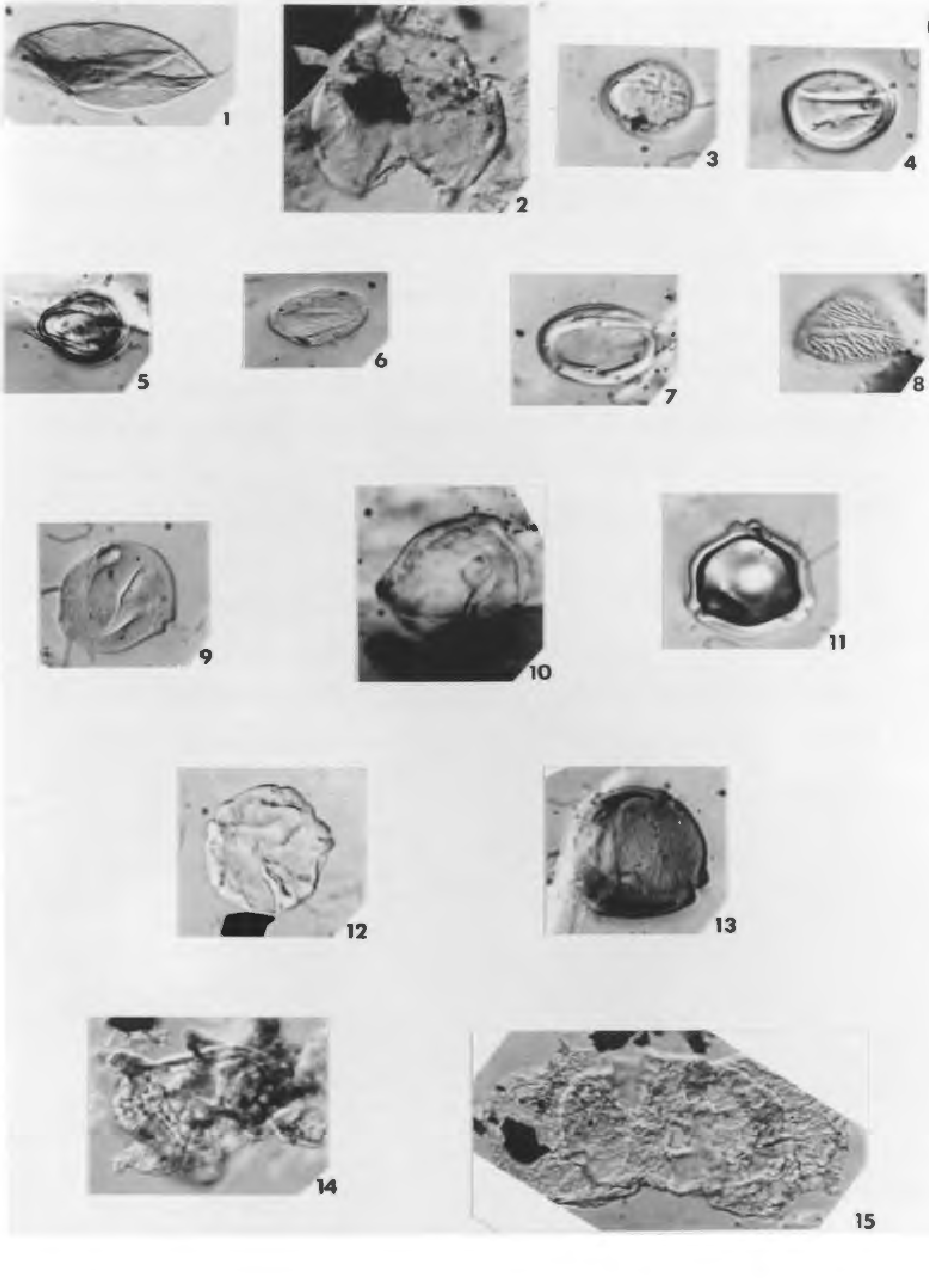
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Plate 7

Figure 1. Pesavis tagluensis Elsik and Jansonius; B-5, 87049(4/5), 125.9 37.6, Mid-focus.

Figure 2. Callimothallus pertusus Dilcher; QU-01A-01, 87025(4/5), 121.8 40.1, 630 X, Mid-focus.

Figure 3. ?Oligosphaeridium complex (White) Davey and Williams; QU-01A-03, 87028(4/5), 125 38.7, 630 X, Phase contrast, Mid-focus.

Figure 4. Spiniferites sp. 1; QU-01A-03, 87028(4/5), 125.1 35, 630 X, Mid-focus.

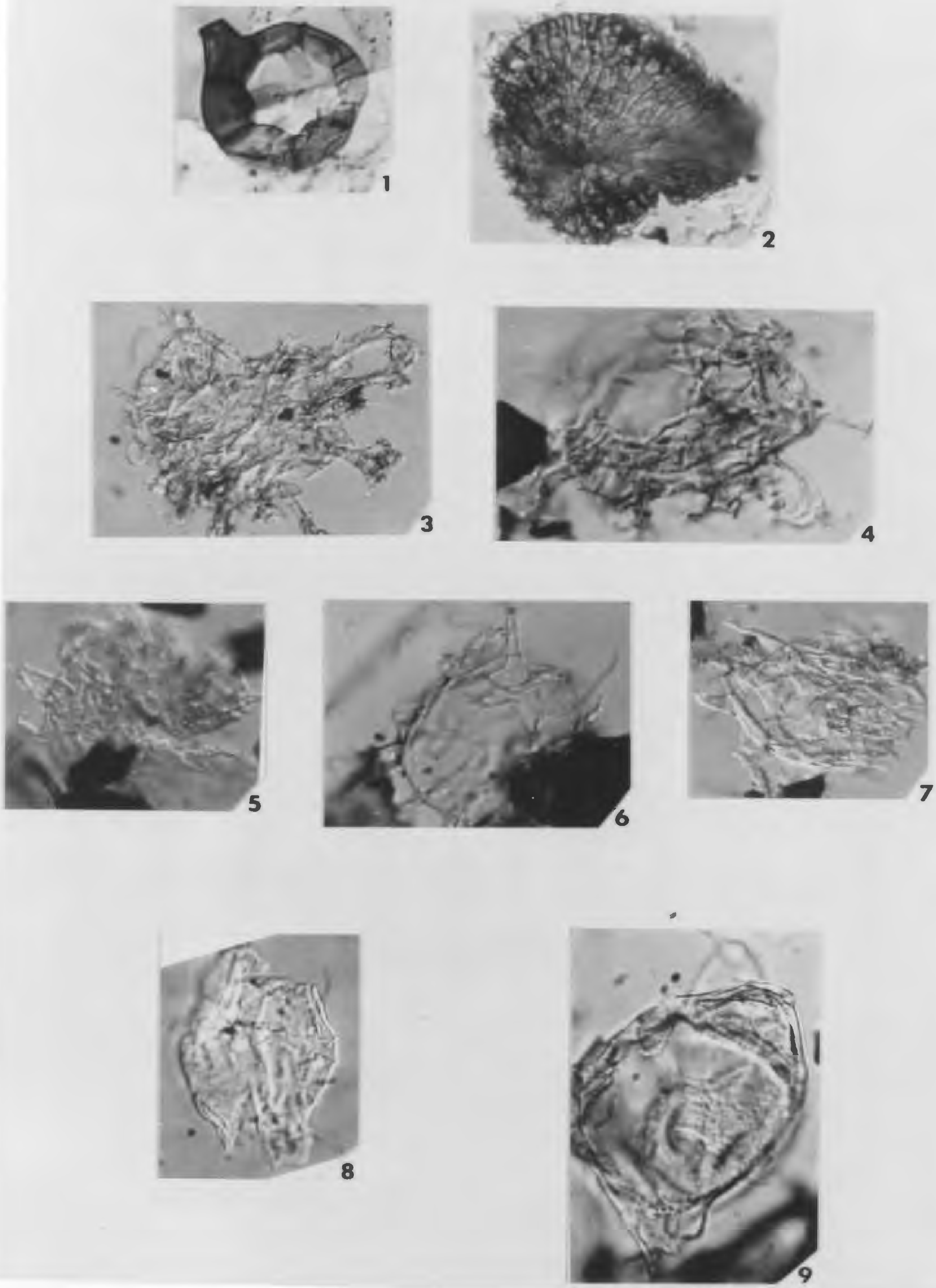
Figure 5. Spiniferites sp. 2; QU-01A-03, 87028(4/5), 125 34.2, 630, Mid-focus.

Figure 6. Spiniferites sp. 3; QU-01A-03, 87028(4/5), 127.5 23.2, Mid-focus.

Figure 7. Dinoflagellate Type 1; QU-01A-03, 87028(4/5), 127 41.4, 630 X, Mid-focus.

Figure 8. ?Spinidinium sp.; QU-01A-03, 87028(4/5), 125 36.4, 630 X, Phase contrast, Mid-focus.

Figure 9. Dinoflagellate Type 2; QU-01A-03, 87028(4/5), 124.7 32.7, Phase contrast, Mid-focus.



# APPENDIX $B_1$

## Petrology – Pointcount Percentages (Rounded)

| Sample | Q | F | L | M | T | G | Mg | O | C | Cc | H | Ps |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DN- | | | | | | | | | | | | |
| 01A-03 | 71 | 4 | 0 | 5 | 5 | 0 | 1 | 1 | 12 | 0 | 0 | 1 |
| 01A-04 | 79 | 7 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 11 |
| 01A-05 | 81 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 15 |
| 01A-09 | 69 | 10 | 2 | 2 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 10 |
| 01A-13 | 49 | 19 | 0 | 4 | 0 | 0 | 0 | 4 | 2 | 0 | 13 | 9 |
| 01A-19 | 66 | 6 | 2 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 23 |
| 01A-20 | 75 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 5 | 7 |
| AL-1 (F) | 57 | 3 | 6 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 15 | 17 |
| D-3A (F) | 90 | 3 | 0 | 1 | 1 | 0 | 2 | 0 | 2 | 0 | 0 | 2 |
| D-3B (F) | 66 | 4 | 0 | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 15 | 1 |
| QU- | | | | | | | | | | | | |
| 01B-04 | 60 | 5 | 4 | 1 | 0 | 0 | 0 | 0 | 11 | 0 | 14 | 5 |
| 01B-21 | 51 | 2 | 0 | 2 | 0 | 0 | 0 | 21 | 14 | 0 | 0 | 10 |
| TOP (F) | 59 | 15 | 15 | 1 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 2 |
| PD- | | | | | | | | | | | | |
| 01-01 (F) | 39 | 7 | 6 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 44 | 0 |
| 01ABase* | 60 | 4 | 0 | 0 | 2 | 0 | 0 | 0 | 16 | 17 | 0 | 1 |
| 01B-09* | 45 | 4 | 0 | 0 | 0 | 0 | 0 | 2 | 30 | 17 | 0 | 2 |
| 01B-14 | 37 | 1 | 0 | 4 | 1 | 0 | 0 | 31 | 25 | 0 | 0 | 1 |
| 01C-06 | 65 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 10 | 12 | 0 | 6 |
| 01C-13 | 63 | 5 | 6 | 5 | 0 | 0 | 0 | 0 | 15 | 0 | 0 | 6 |
| 01C-17 | 49 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 20 | 13 | 0 | 17 |
| 02A-14 | 45 | 7 | 1 | 4 | 1 | 0 | 0 | 5 | 37 | 0 | 0 | 2 |
| 02A-16 | 47 | 1 | 0 | 11 | 0 | 0 | 0 | 30 | 10 | 0 | 0 | 1 |
| 02A-31 | 50 | 5 | 1 | 1 | 0 | 0 | 0 | 24 | 19 | 0 | 0 | 0 |
| 02A-34 | 51 | 7 | 3 | 1 | 0 | 0 | 0 | 10 | 13 | 0 | 0 | 15 |
| 02A-53 | 46 | 9 | 1 | 0 | 0 | 0 | 0 | 8 | 26 | 1 | 0 | 9 |
| 02A-58* | 46 | 7 | 0 | 1 | 0 | 0 | 0 | 12 | 26 | 0 | 0 | 8 |
| 02A-69 | 38 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 19 | 0 | 0 | 25 |
| 02B-09 | 41 | 3 | 1 | 4 | 1 | 0 | 0 | 19 | 30 | 0 | 0 | 1 |

Q = quartz, F = feldspar, M = mica, T = tourmaline, G = garnet, Mg = magnetite, O = organics, C = clay matrix, Cc = calcite cement, H = hematite cement, L = granite and gneiss fragments, Ps = pore space, * = only 250 points, (F) = glacial float.

APPENDIX $B_2$ Petrology – Detrital Modes

| Sample | Facies | Q% | F% | RF% | Grain Size | Sorting |
|---|---|---|---|---|---|---|
| DN- | | | | | | |
| 01A-03 | A | 94.1 | 5.9 | | M | W |
| 01A-04 | A | 89.7 | 8.5 | 1.8 | M/C | M |
| 01A-05 | A | 98.0 | 2.0 | | VC | P/M |
| 01A-09 | F | 84.9 | 12.1 | 3.0 | C | P |
| 01A-13 | F | 71.9 | 27.8 | 0.3 | M | M |
| 01A-19 | F | 89.2 | 8.4 | 2.4 | VC | VP |
| 01A-20 | F | 89.5 | 10.5 | | C | P/M |
| AL-1 (F) | F | 86.5 | 5.0 | 8.5 | C | P |
| D-3A (F) | F | 96.9 | 3.1 | | M | M |
| D-3B (F) | F | 94.3 | 5.1 | 0.6 | M | M |
| MEAN | | 89.5 | 8.8 | 1.6 | | |
| S.D. | | 7.5 | 7.3 | 2.6 | | |
| | | | | | | |
| QU- | | | | | | |
| 01B-04 | A | 87.0 | 6.6 | 6.4 | VC | P/M |
| 01B-21 | E | 96.9 | 3.1 | | F | M |
| TOP (F) | F | 66.1 | 17.1 | 16.8 | VC | VP |
| MEAN | | 83.3 | 8.9 | 7.7 | | |
| S.D. | | 15.7 | 7.2 | 8.4 | | |
| | | | | | | |
| PD- | | | | | | |
| 01-01 (F) | F | 74.6 | 12.7 | 12.7 | VC | VP |
| 01C-06 | E | 90.0 | 8.0 | 2.0 | M | M |
| 01C-13 | E | 835 | 7.7 | 8.8 | M | M/W |
| 02A-16 | C | 98.7 | 1.3 | | F | M |
| 02A-34 | C | 82.1 | 11.7 | 6.2 | M | P |
| MEAN | | 85.7 | 8.3 | 5.9 | | |
| S.D. | | 9.0 | 4.5 | 5.1 | | |
| | | | | | | |
| PD- | | | | | | |
| 01ABase* | A | 93.1 | 6.3 | 0.6** | VC | VP |
| 01B-09* | E | 91.8 | 8.2 | ** | VC | VP |
| 01B-14 | E | 97.9 | 2.1 | ** | F/M | P |
| 01C-17 | E | 100.0 | | ** | VF | M/W |
| 02A-14 | C | 85.1 | 12.9 | 2.0** | F | M |
| 02A-31 | C | 89.2 | 9.4 | 1.4** | F | P/M |
| 02A-53 | C | 83.1 | 15.5 | 1.4** | F | P |
| 02A-58* | C | 85.7 | 13.2 | 1.1** | F | P |
| 02A-69 | C | 98.9 | 1.1 | ** | VF | P/M |
| 02B-09 | A | 92.1 | 5.7 | 2.2** | M | M |
| MEAN | | 91.7 | 7.4 | 0.9 | | |
| S.D. | | 5.9 | 5.2 | 0.8 | | |

Q = quartz, F = feldspar, RF = rock fragments, W = well sorted, M = moderately sorted, P = poorly sorted; VF = very fine grained, F = fine grained, M = medium grained, C = coarse grained, VC = very coarse grained; S.D. = standard deviation; (F) = glacial float, * = only 250 points, ** = > 15% clay matrix.

APPENDIX $C_1$

| Field ID | M.U.N. ID | Facies and Environment |
|---|---|---|
| PD-01B-04 | 86006 | D (backswamp coal) |
| PD-01B-05 | 86105 | D (backswamp coal) |
| PD-01B-06 | 86106 | $C_2$ (overbank) |
| PD-01B-10 | 86107 | $C_2$ (overbank) |
| PD-01B-11 | 86007 | B (backswamp mudstone) |
| PD-01B-12 | 86108 | $C_2$ (overbank) |
| B-5 | 87049 | H (air-fall volcanic ash) |
| PD-01B-14 | 87029 | E (meandering channel sand) |
| | 87048 | E (meandering channel sand) |
| | | |
| PD-01C-01 | 86109 | E (meandering channel sand) |
| PD-01C-08 | 86110 | D (backswamp coal) |
| PD-01C-09 | 86111 | B (backswamp mudstone) |
| PD-01C-11 | 86112 | D (backswamp coal) |
| PD-01C-15 | 86113 | D (backswamp coal) |
| PD-01C-19 | 86114 | D (backswamp coal) |
| | | |
| PD-02A-10 | 86008 | $C_2$ (overbank) |
| PD-02A-17 | 86163 | $C_2$ (overbank) |
| PD-02A-36 | 86164 | $C_2$ (overbank) |
| PD-02A-43 | 86009 | B (backswamp mudstone) |
| PD-02A-45 | 86165 | $C_1$ (overbank) |
| PD-02A-47 | 86166 | $C_2$ (overbank) |
| PD-02A-49 | 86167 | $C_3$ (overbank) |
| PD-02A-52 | 86168 | $C_2$ (overbank) |
| PD-02A-57 | 86169 | B (backswamp mudstone) |
| PD-02A-65 | 86170 | E (meandering channel sand) |
| PD-02A-67 | 86171 | $C_1$ (overbank) |
| PD-02A-68 | 86172 | $C_1$ (overbank) |
| PD-02A-70 | 86010 | $C_1$ (overbank) |
| | | |
| PD-02B-02 | 86011 | $C_2$ (overbank) |
| PD-02B-05 | 86115 | $C_2$ (overbank) |
| PD-02B-08 | 86116 | A (braided channel sand) |
| PD-02B-15 | 86012 | $C_2$ (overbank) |
| | | |
| QU-01A-01 | 87025 | B (backswamp mudstone) |
| QU-01A-02 | 87027 | B (backswamp mudstone) |
| QU-01A-03 | 87028 | H (air-fall volcanic ash) |
| | | |
| QU-01B-03 | 86149 | A (braided channel sand) |
| QU-01B-05 | 86150 | $C_1$ (overbank) |

| | | | |
|---|---|---|---|
| QU-01B-07 | 86151 | $C_1$ | (overbank) |
| QU-01B-09 | 86152 | $C_2$ | (overbank) |
| QU-01B-12 | 86162 | $C_1$ | (overbank) |
| QU-01B-14 | 86153 | $C_2$ | (overbank) |
| QU-01B-19 | 86154 | $C_1$ | (overbank) |
| QU-01B-23 | 86155 | $C_1$ | (overbank) |
| QU-01B-27 | 86156 | B | (backswamp mudstone) |
| QU-01B-77 | 87026 | E | (meandering channel sand) |
| DN-01A-07 | 86013 | B | (backswamp mudstone) |
| DN-01A-10 | 86157 | $C_1$ | (overbank) |
| DN-01A-14 | 86158 | F | (distal alluvial fan) |
| DN-01A-16 | 86159 | F | (distal alluvial fan) |
| DN-01A-18 | 86160 | F | (distal alluvial fan) |
| DN-01A-21 | 86161 | $C_1$ | (overbank) |

## APPENDIX $C_2$

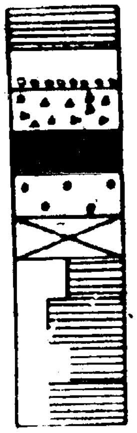
Palynology Statistics Data

| Field ID | Diversity (X 10) | Diversity Variance | No. of species | Evenness (X 1000) | Evenness Variance |
|---|---|---|---|---|---|
| PD-01B-04 | 2.38 | 0.0059 | 18 | 8.23 | 0.0007 |
| PD-01B-05 | BARREN | | | | |
| PD-01B-06 | 1.39 | 0.0445 | 6 | 7.88 | 0.0139 |
| PD-01B-10 | 1.55 | 0.0128 | 16 | 5.61 | 0.0017 |
| PD-01B-11 | 2.16 | 0.0229 | 14 | 8.18 | 0.0033 |
| PD-01B-12 | 0.92 | 0.0538 | 7 | 4.47 | 0.0124 |
| B-5 | 2.21 | 0.0005 | 13 | 8.65 | 0.0001 |
| PD-01B-14 | 1.38 | 0.0103 | 12 | 5.57 | 0.0017 |
| PD-01C-01 | 1.90 | 0.0114 | 23 | 5.97 | 0.0011 |
| PD-01C-08 | 2.29 | 0.0062 | 21 | 7.52 | 0.0007 |
| PD-01C-09 | 2.25 | 0.0083 | 22 | 7.27 | 0.0009 |
| PD-01C-11 | 2.08 | 0.0044 | 17 | 7.35 | 0.0005 |
| PD-01C-15 | 2.18 | 0.0064 | 20 | 7.27 | 0.0007 |
| PD-01C-19 | 2.05 | 0.0064 | 20 | 6.84 | 0.0007 |
| PD-02A-10 | 1.96 | 0.0057 | 17 | 6.91 | 0.0007 |
| PD-02A-17 | 2.05 | 0.0096 | 20 | 6.87 | 0.0011 |
| PD-02A-36 | 2.00 | 0.0224 | 9 | 8.69 | 0.0042 |
| PD-02A-43 | 1.68 | 0.0265 | 11 | 7.01 | 0.0046 |
| PD-02A-45 | 2.13 | 0.0078 | 20 | 7.11 | 0.0009 |
| PD-02A-47 | 1.26 | 0.0107 | 16 | 4.54 | 0.0014 |
| PD-02A-49 | 1.74 | 0.0227 | 7 | 8.99 | 0.0060 |
| PD-02A-52 | 1.87 | 0.0102 | 16 | 6.77 | 0.0013 |
| PD-02A-57 | 1.63 | 0.0384 | 6 | 8.40 | 0.0101 |

| | | | | | |
|---|---|---|---|---|---|
| PD-02A-65 | 1.51 | 0.0102 | 18 | 5.22 | 0.0012 |
| PD-02A-67 | 2.01 | 0.0083 | 15 | 7.25 | 0.0011 |
| PD-02A-68 | 2.26 | 0.0086 | 23 | 7.11 | 0.0009 |
| PD-02A-70 | 1.56 | 0.0149 | 12 | 6.27 | 0.0024 |
| PD-02B-02 | BARREN | | | | |
| PD-02B-05 | 2.12 | 0.0084 | 24 | 6.69 | 0.0008 |
| PD-02B-08 | 1.58 | 0.0116 | 12 | 6.37 | 0.0019 |
| PD-02B-15 | BARREN | | | | |
| PD-01A-01 | 1.52 | 0.0114 | 16 | 5.48 | 0.0015 |
| PD-01A-02 | 0.51 | 0.0070 | 8 | 2.32 | 0.0014 |
| PD-01A-03 | 1.44 | 0.0149 | 10 | 6.25 | 0.0028 |
| QU-01B-03 | BARREN | | | | |
| QU-01B-05 | 2.48 | 0.0077 | 26 | 7.61 | 0.0007 |
| QU-01B-07 | 1.85 | 0.0106 | 21 | 6.09 | 0.0011 |
| QU-01B-09 | 1.97 | 0.0071 | 17 | 6.81 | 0.0008 |
| QU-01B-12 | 1.62 | 0.0240 | 6 | 9.05 | 0.0075 |
| QU-01B-14 | 1.85 | 0.0109 | 20 | 6.17 | 0.0012 |
| QU-01B-19 | 2.03 | 0.0086 | 21 | 6.66 | 0.0009 |
| QU-01B-23 | 2.10 | 0.0058 | 17 | 7.41 | 0.0007 |
| QU-01B-27 | 2.30 | 0.0084 | 21 | 7.55 | 0.0009 |
| QU-01B-77 | BARREN | | | | |
| DN-01A-07 | 1.19 | 0.0104 | 13 | 4.63 | 0.0016 |
| DN-01A-10 | 1.81 | 0.0066 | 14 | 6.86 | 0.0009 |
| DN-01A-14 | 2.11 | 0.0067 | 18 | 7.32 | 0.0008 |
| DN-01A-16 | 1.67 | 0.0082 | 12 | 6.73 | 0.0013 |
| DN-01A-18 | 1.78 | 0.0075 | 14 | 6.75 | 0.0011 |
| DN-01A-21 | BARREN | | | | |

## LEGEND FOR STRATIGRAPHIC SECTION

### LITHOLOGY



Silt and Clay

Sand

Sand with Granules

Volcanic Ash

Coal

Conglomerate

Covered Section

Interbedded Sand/Silt-Clay

50/50 cm Beds

20/80 cm Beds

50/50 Variable Bed Thickness

20/80 Variable Bed Thickness

### FOSSILS,ORGANIC STRUCTURES

Plant impressions

Plant Debris

Laminated Plant Debris

Fossil Logs

### ACCESSORIES

Dewatering Structure

Mud Clasts (Rip Ups)

Siderite Concretions

Calcite Cemented Sandstone

### CONTACTS

— Sharp

Scour

### STRUCTURES

#### CROSS-STRATIFICATION

Trough

Ripple

Epsilon

#### LAMINAE

= Horizontal

H Homogeneous

Convolute Bedding

### SAMPLES

PD 01A-# Sample Number

— Thermal Alteration Index

• Vitrinite Reflectance

/ Palynology

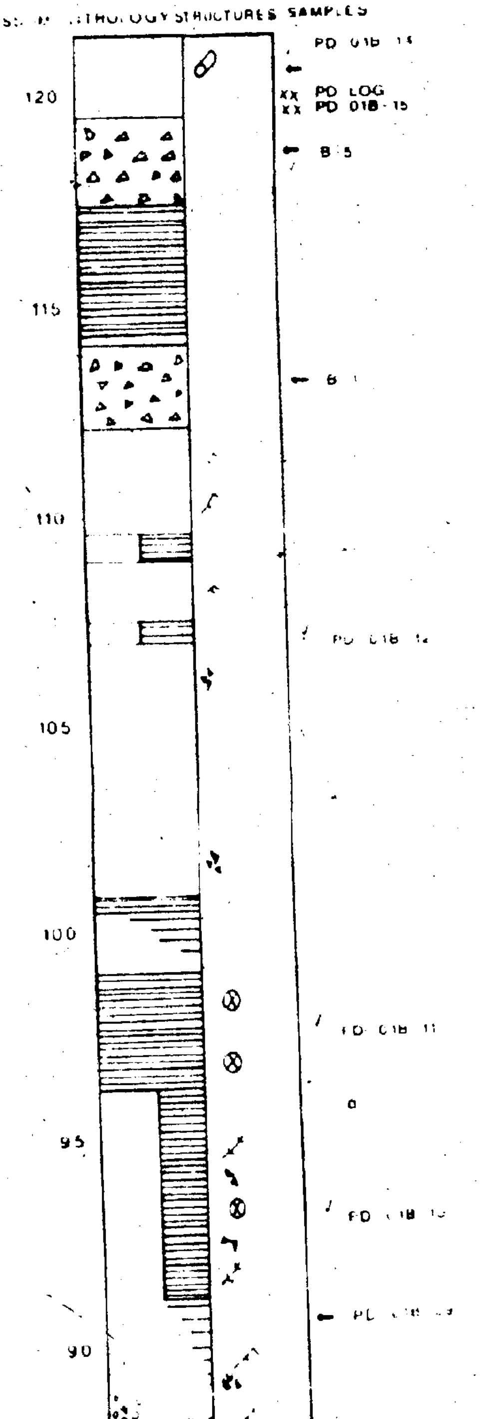
▬ Thin Section

V Coal Analysis

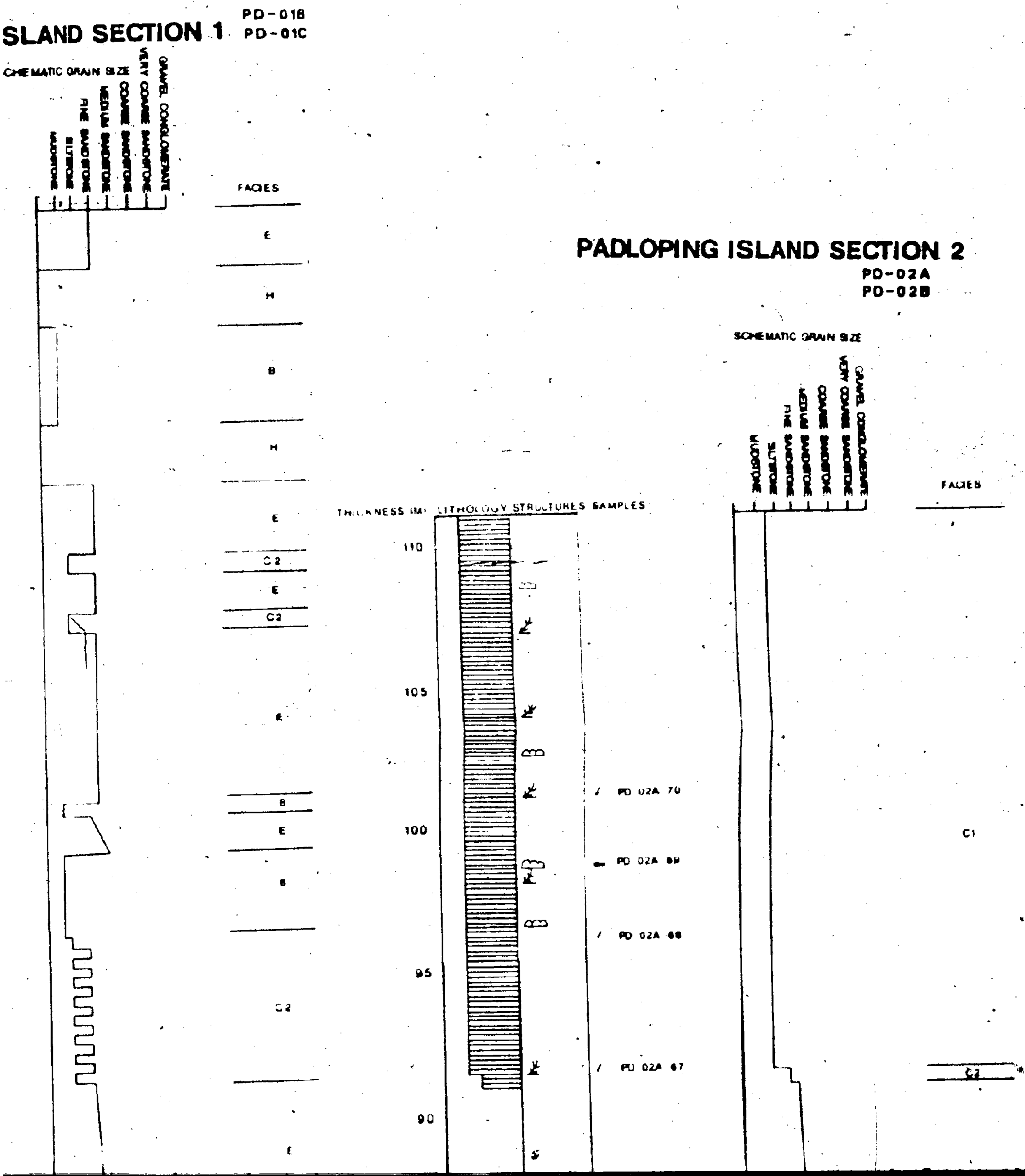
XX Paleobotany

# PADLOPING IS

SC

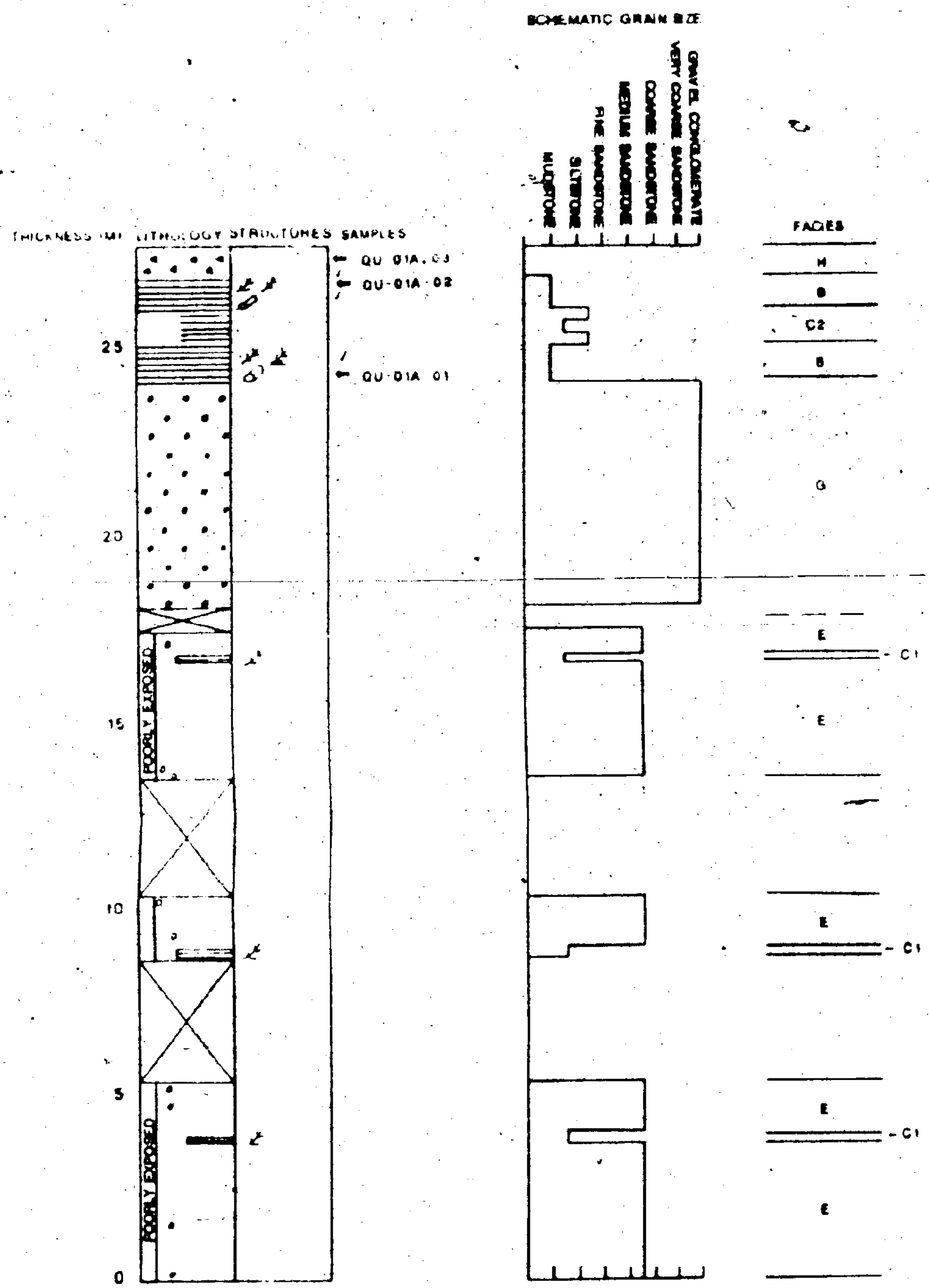


# APPENDIX A


SLAND SECTION 1
PD-01B
PD-01C
CHEMATIC GRAIN SIZE
MUDSTONE
SILTSTONE
FINE SANDSTONE
MEDIUM SANDSTONE
COARSE SANDSTONE
VERY COARSE SANDSTONE
GRAVEL CONGLOMERATE
FACIES
E
H
B
H
E
C2
E
C2
E
B
E
B
C2
E
PADLOPING ISLAND SECTION 2
PD-02A
PD-02B
THICKNESS (M)
LITHOLOGY
STRUCTURES
SAMPLES
110
105
100
95
90
PD 02A 70
PD 02A 69
PD 02A 68
PD 02A 67
SCHEMATIC GRAIN SIZE
MUDSTONE
SILTSTONE
FINE SANDSTONE
MEDIUM SANDSTONE
COARSE SANDSTONE
VERY COARSE SANDSTONE
GRAVEL CONGLOMERATE
FACIES
C1
C2

# QUQALUIT ISLAND SECTION 1

QU-01A

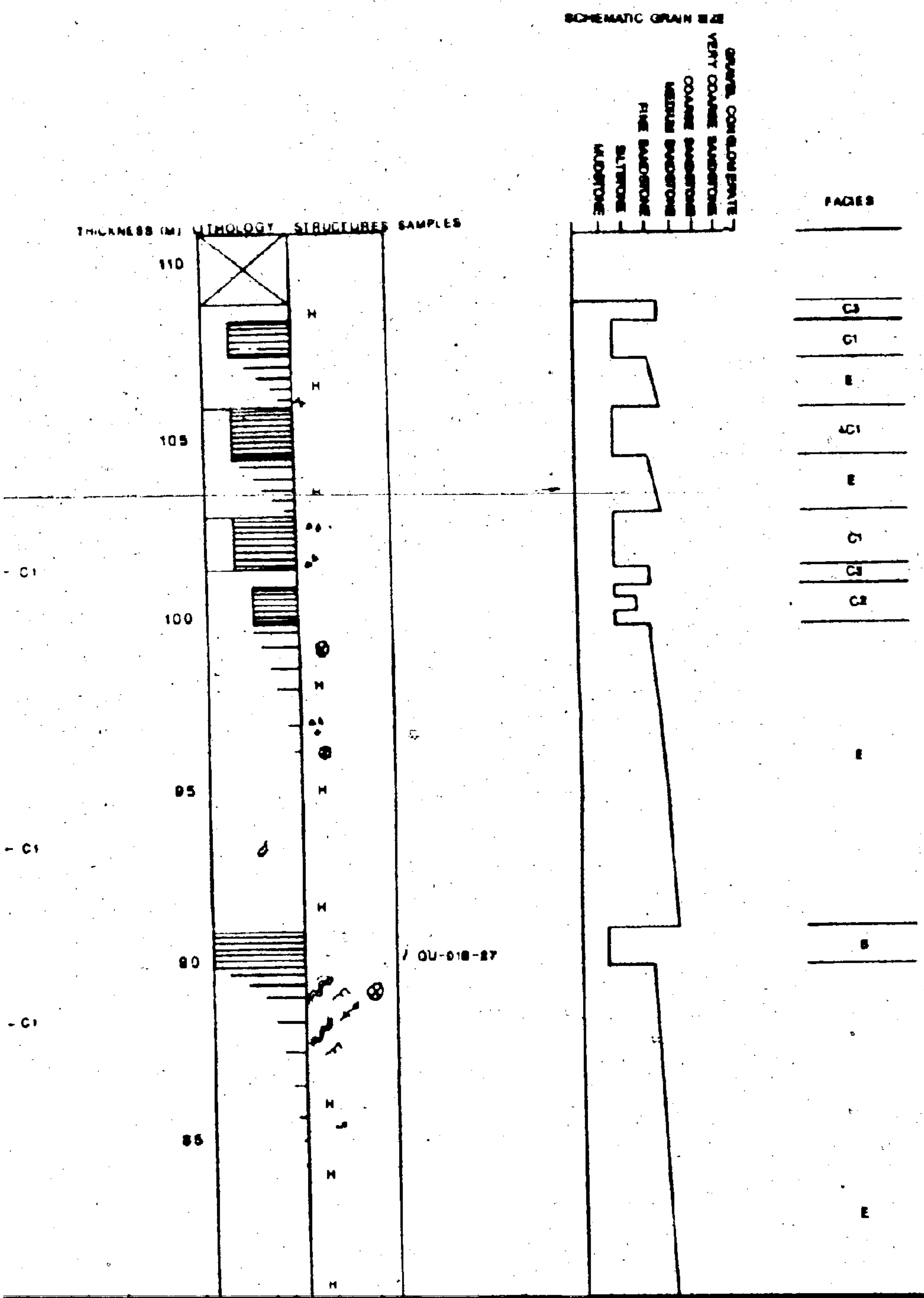



LEGEND FOR STRATIGRAPHIC SECTION

APPENDIX A 2

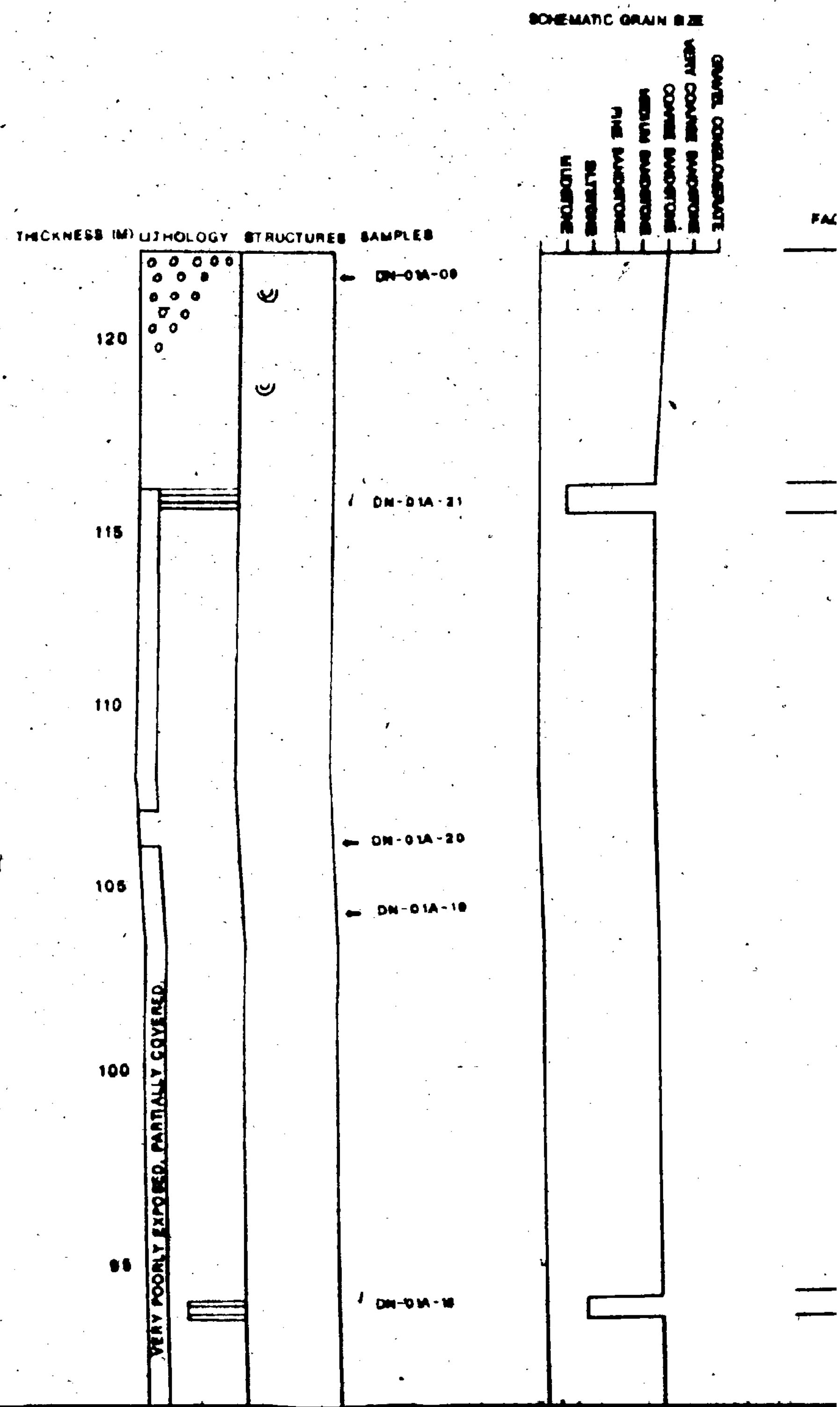
# QUQALUIT ISLAND SECTION 2

QU-01B



# DURBAN ISLAND SECTION 1

DN-01A



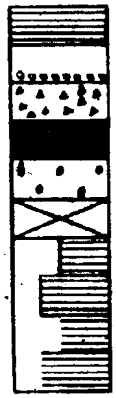
3

FACIES

C1

# LEGEND FOR STRATIGRAPHIC SECTION

## LITHOLOGY




## FOSSILS/ORGANIC STRUCTURES

- Plant Impressions
- Plant Debris
- Laminated Plant Debris
- Fossil Logs

## ACCESSORIES

- Dewatering Structure
- Mud Clasts (Rip Ups)
- Siderite Concretions
- Calcite Cemented Sandstone

## CONTACTS

- Sharp
- Scour

## STRUCTURES

### CROSS-STRATIFICATION

- Trough
- Ripple
- Epsilon

### LAMINAE

- Horizontal
- H Homogeneous
- Convolute Bedding

## SAMPLES

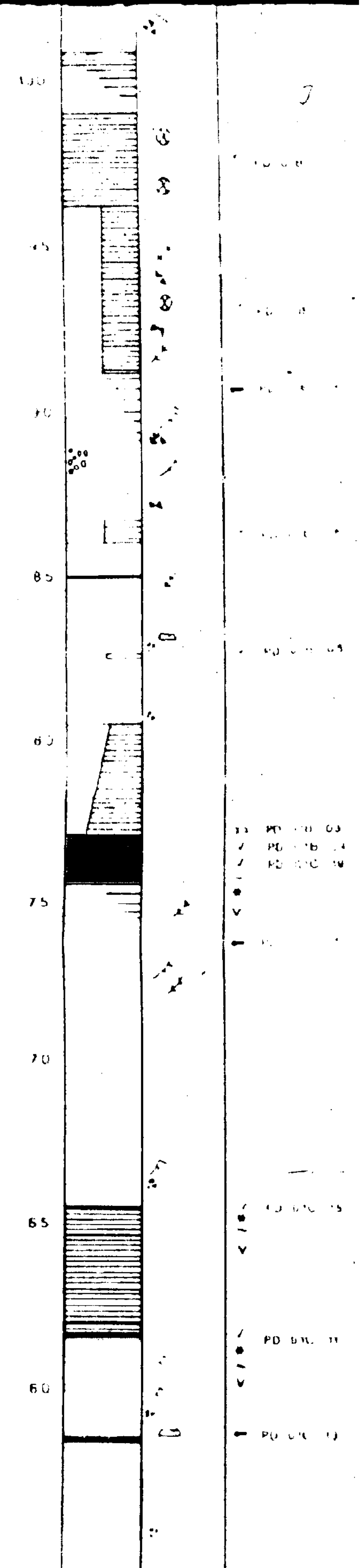
- PD-01A-# Sample Number
- Thermal Alteration Index
- Vitrinite Reflectance
- Palynology
- Thin Section
- V Coal Analysis
- XX Paleobotany

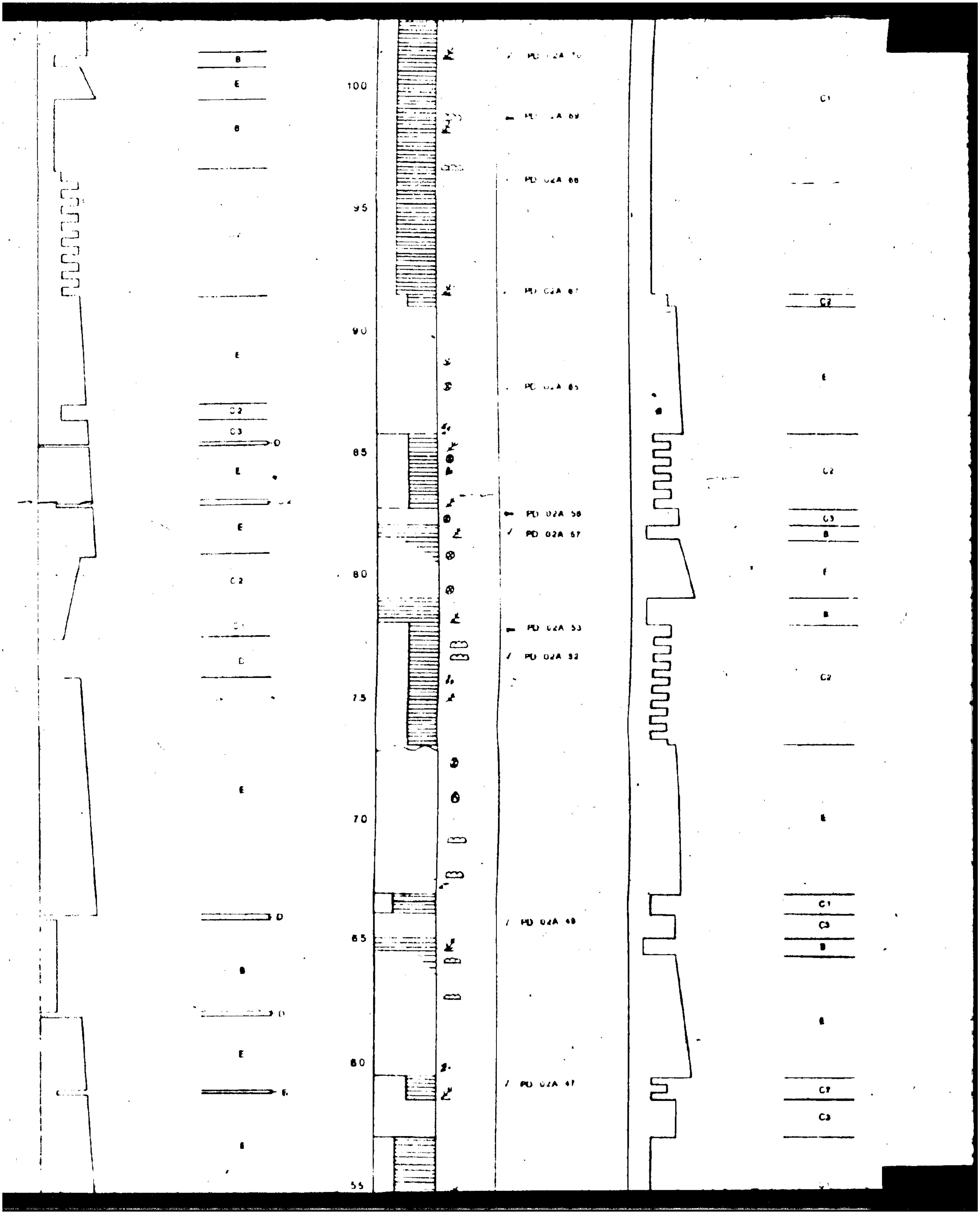
Scour

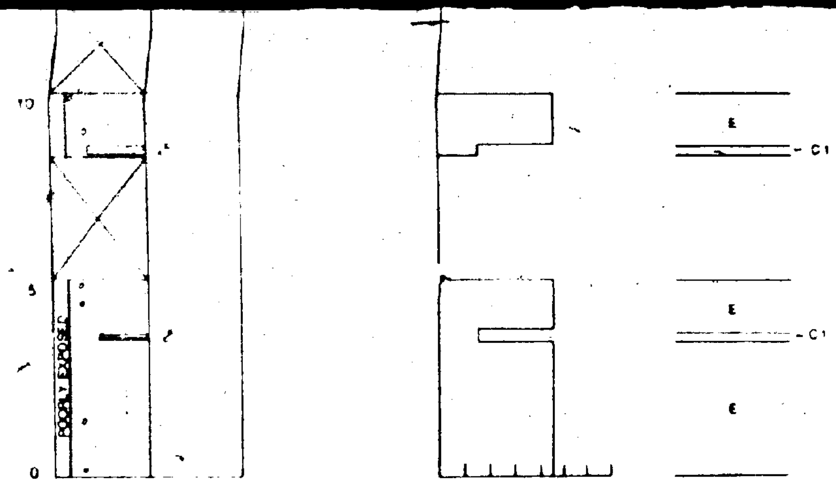
Thin Section

V Coal Analysis

XX Paleobotany

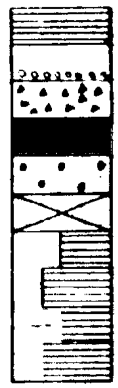



100
95
90
85
80
75
70
65
60
55
PD 02A 68
PD 02A 65
PD 02A 58
PD 02A 57
PD 02A 53
PD 02A 52
PD 02A 49
PD 02A 47




LEGEND FOR STRATIGRAPHIC SECTION

LITHOLOGY



Silt and Clay
Sand
Sand with Granules
Volcanic Ash
Coal
Conglomerate
Covered Section
Interbedded Sand/Silt-Clay
50/50 cm Beds
20/80 cm Beds
50/50 Variable Bed Thickness
20/80 Variable Bed Thickness

FOSSILS & ORGANIC STRUCTURES

- Plant Impressions
- Plant Debris
- Laminated Plant Debris
- Fossil Logs

ACCESSORIES

- Dewatering Structure
- Mud Clasts Rip Ups
- Siderite Concretions
- CCC Calcite Cemented Sandstone

CONTACTS

- Sharp
- Scour

STRUCTURES

CROSS-STRATIFICATION

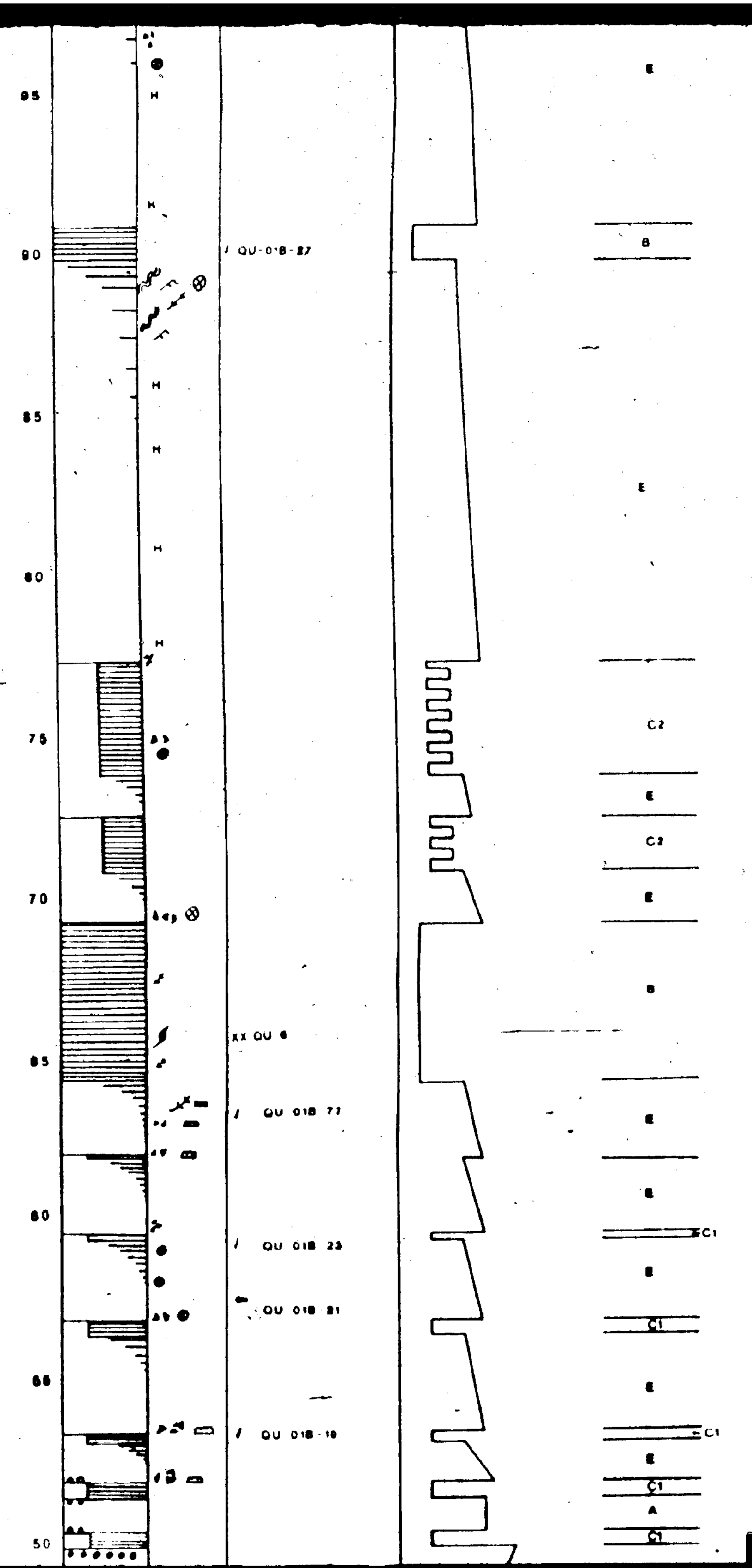
- Trough
- Ripple
- Epsilon

LAMINAE

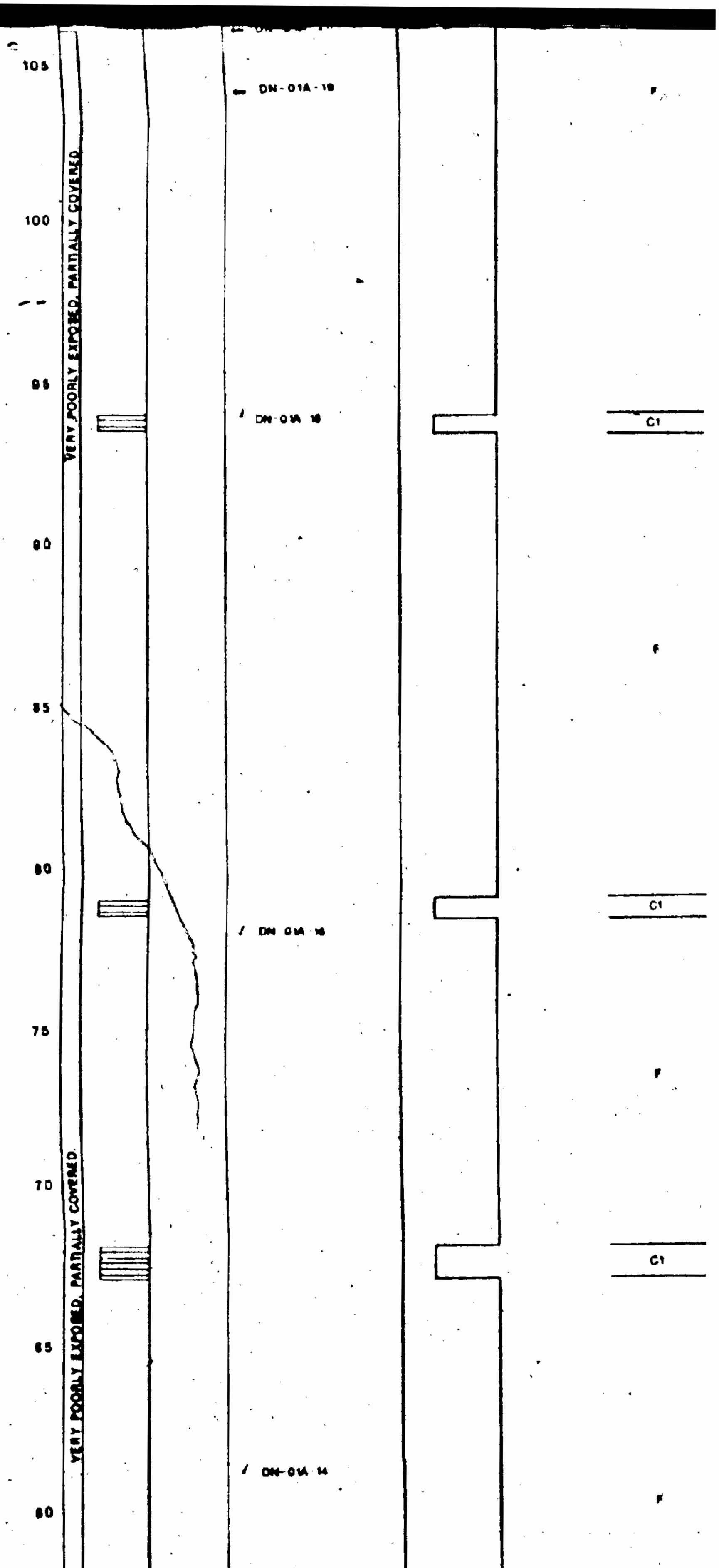
- Horizontal
- H Homogeneous
- Convolute Bedding

SAMPLES

- PD 01A-# Sample Number
- Thermal Alteration Index
- Vitrinite Reflectance
- Palynology
- Thin Section
- V Coal Analysis
- XX Paleobotany



95
90
85
80
75
70
65
60
55
50
QU-018-27
XX QU 6
QU 018 77
QU 018 23
QU 018 21
QU 018 19
E
B
E
C2
E
C2
E
B
E
E
C1
E
C1
E
C1
E
C1
A
C1


105
DN-01A-19
100
VERY POORLY EXPOSED, PARTIALLY COVERED
95
DN-01A 18
C1
90
F
85
80
DN 01A 16
C1
75
F
70
VERY POORLY EXPOSED, PARTIALLY COVERED
C1
65
DN-01A 14
60
F

CONTACTS

— Sharp

ᴧᴧ Smear

● Vitrinite Reflectance

✓ Palynology

⊷ Thin Section

V Coal Analysis

XX Paleobotany

C1

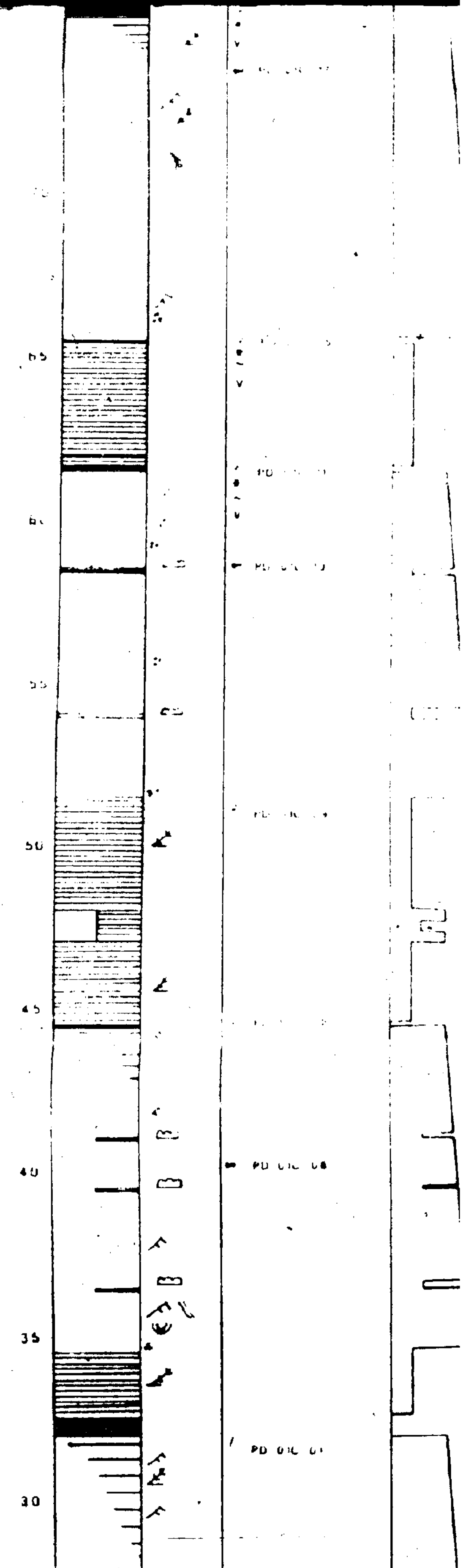
F

C1

F

C1

F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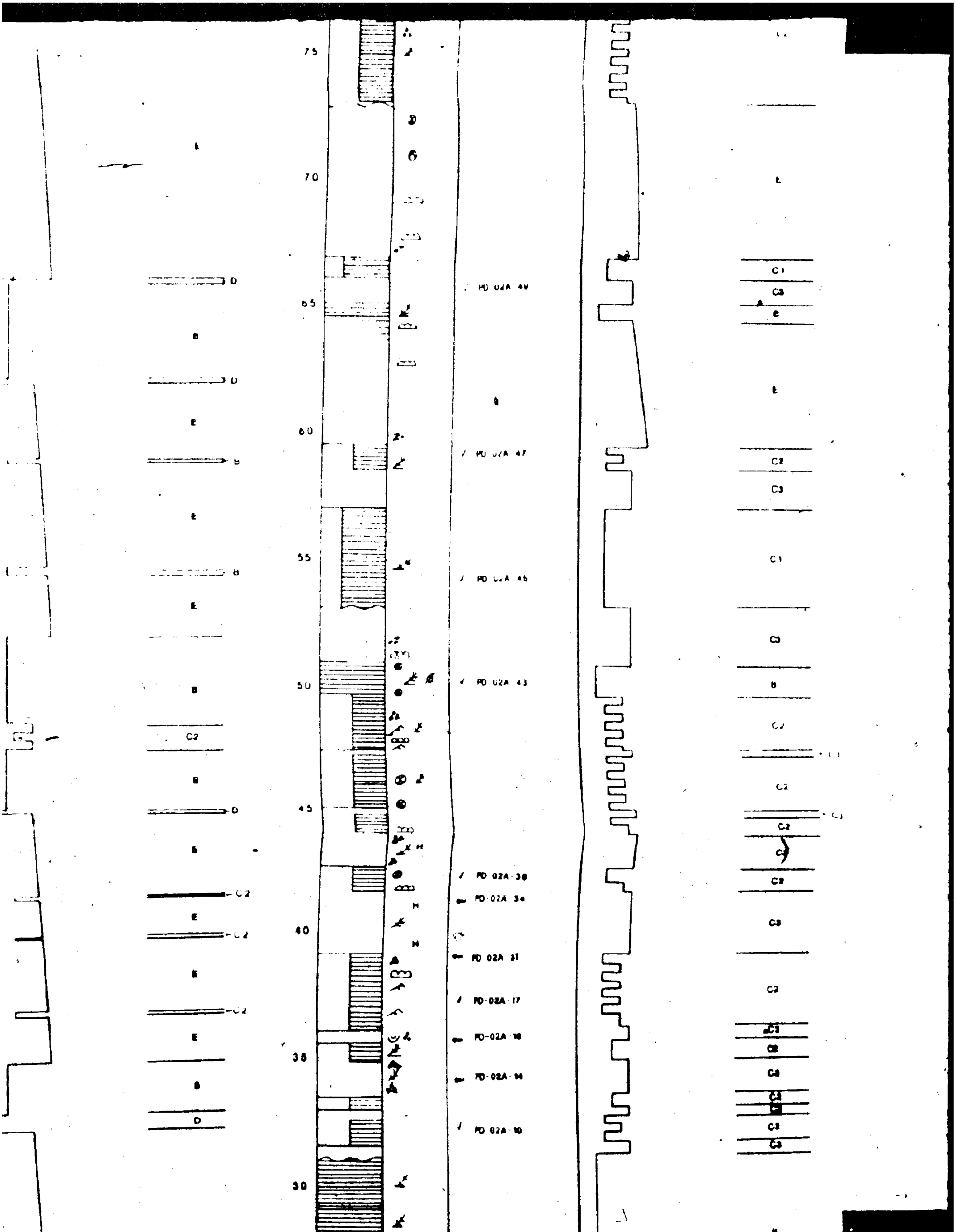
50
45
40
35
30


75
70
65
60
55
50
45
40
35
30
PD 02A 49
PD 02A 47
PD 02A 45
PD 02A 43
PD 02A 38
PD-02A 34
PD 02A 31
PD-02A 17
PD-02A 14
PD 02A 10

[illegible]

Fossil Logs

ACCESSORIES

Dewatering Structure

Mud Clasts (Rip Ups)

Siderite Concretions

Calcite Cemented Sandstone

CONTACTS

Sharp

Scour

[illegible]

LAMINAE

Horizontal

H Homogeneous

Convolute Bedding

SAMPLES

PD 01A-# Sample Number

Thermal Alteration Index

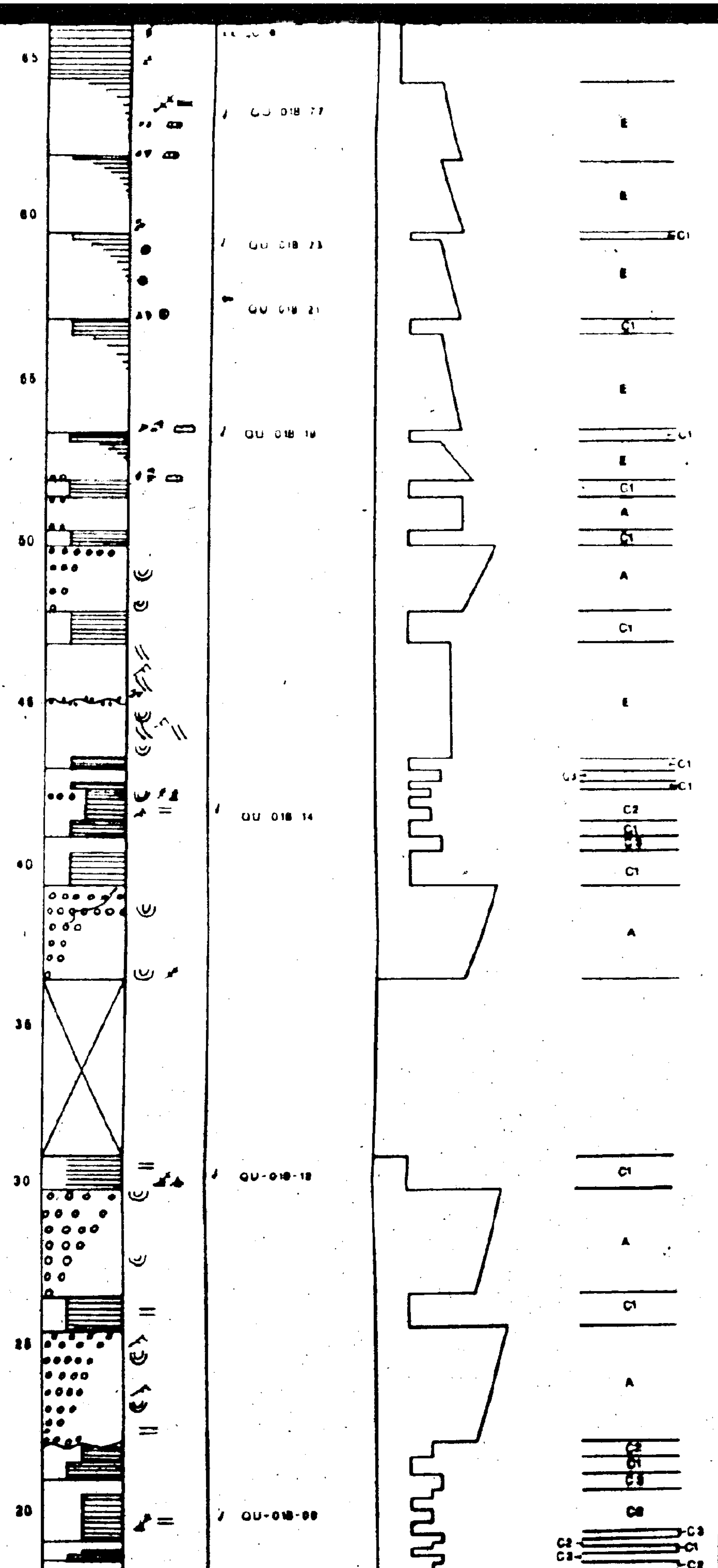
Vitrinite Reflectance

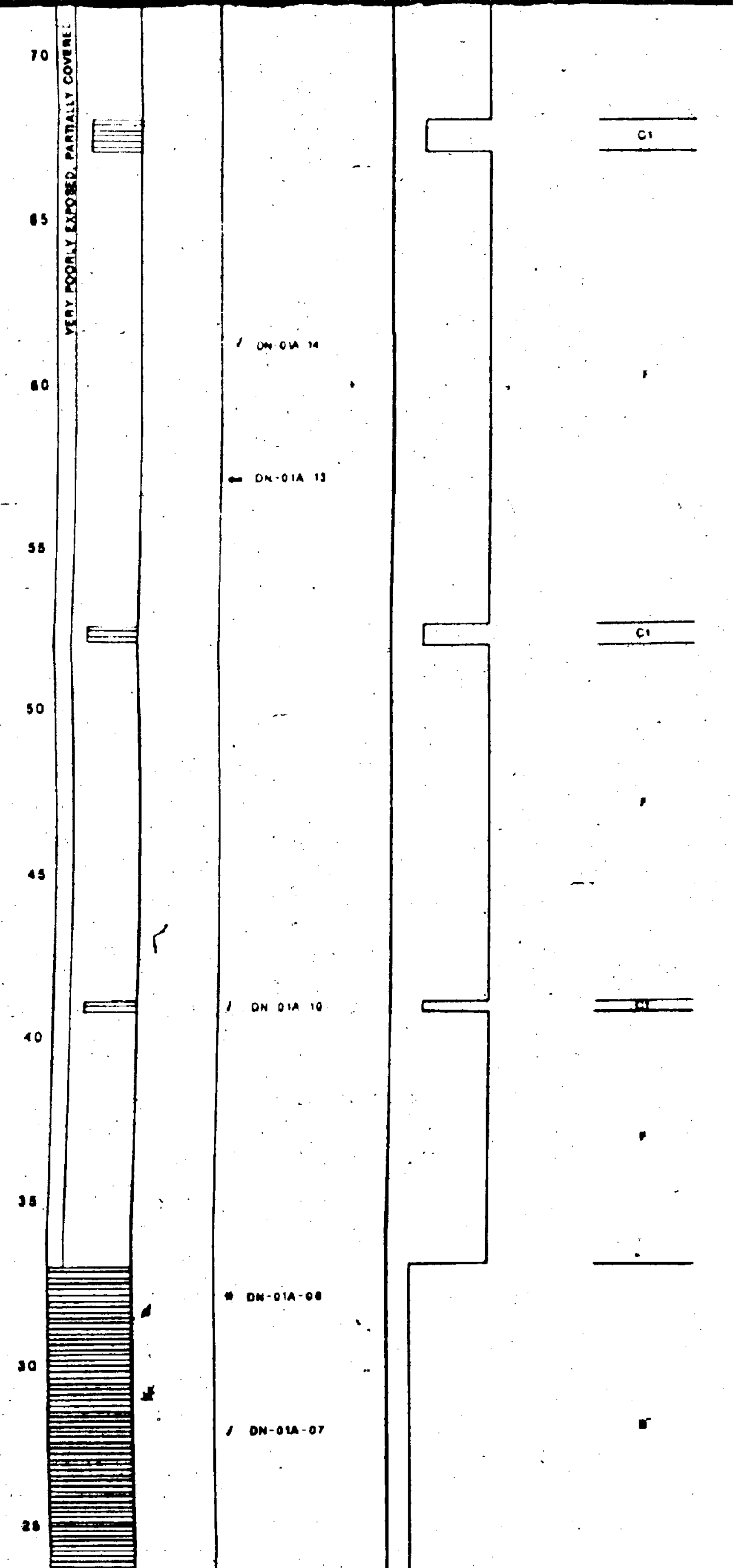
Palynology

Thin Section

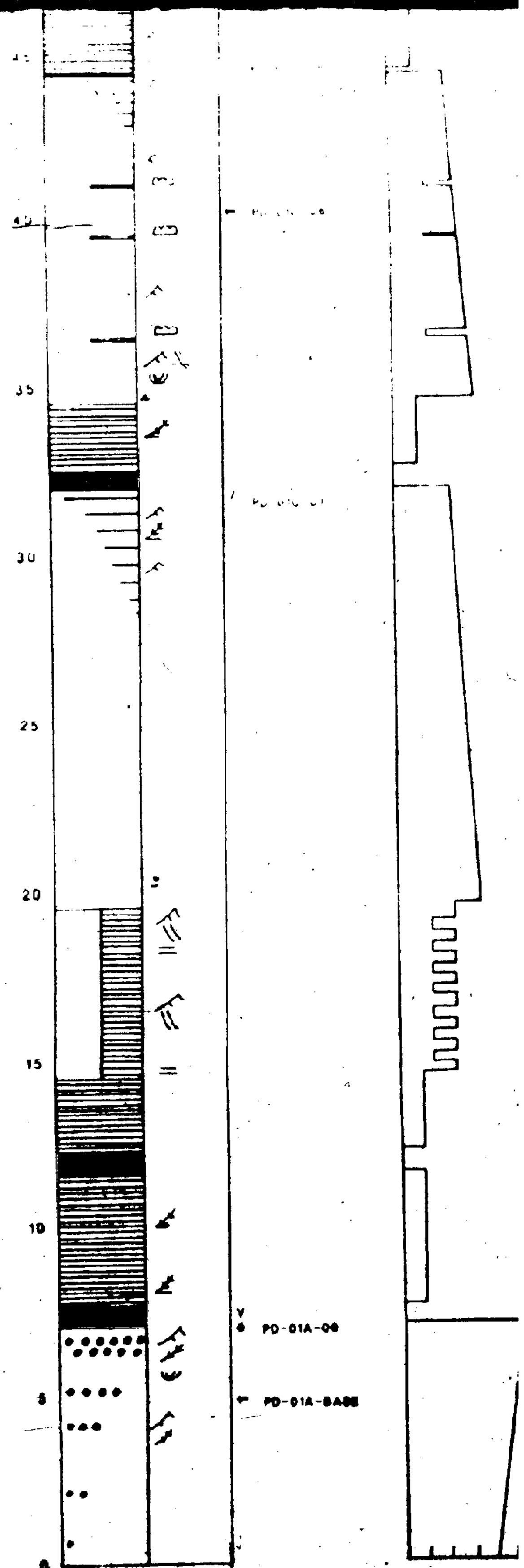
V Coal Analysis

Paleobotany

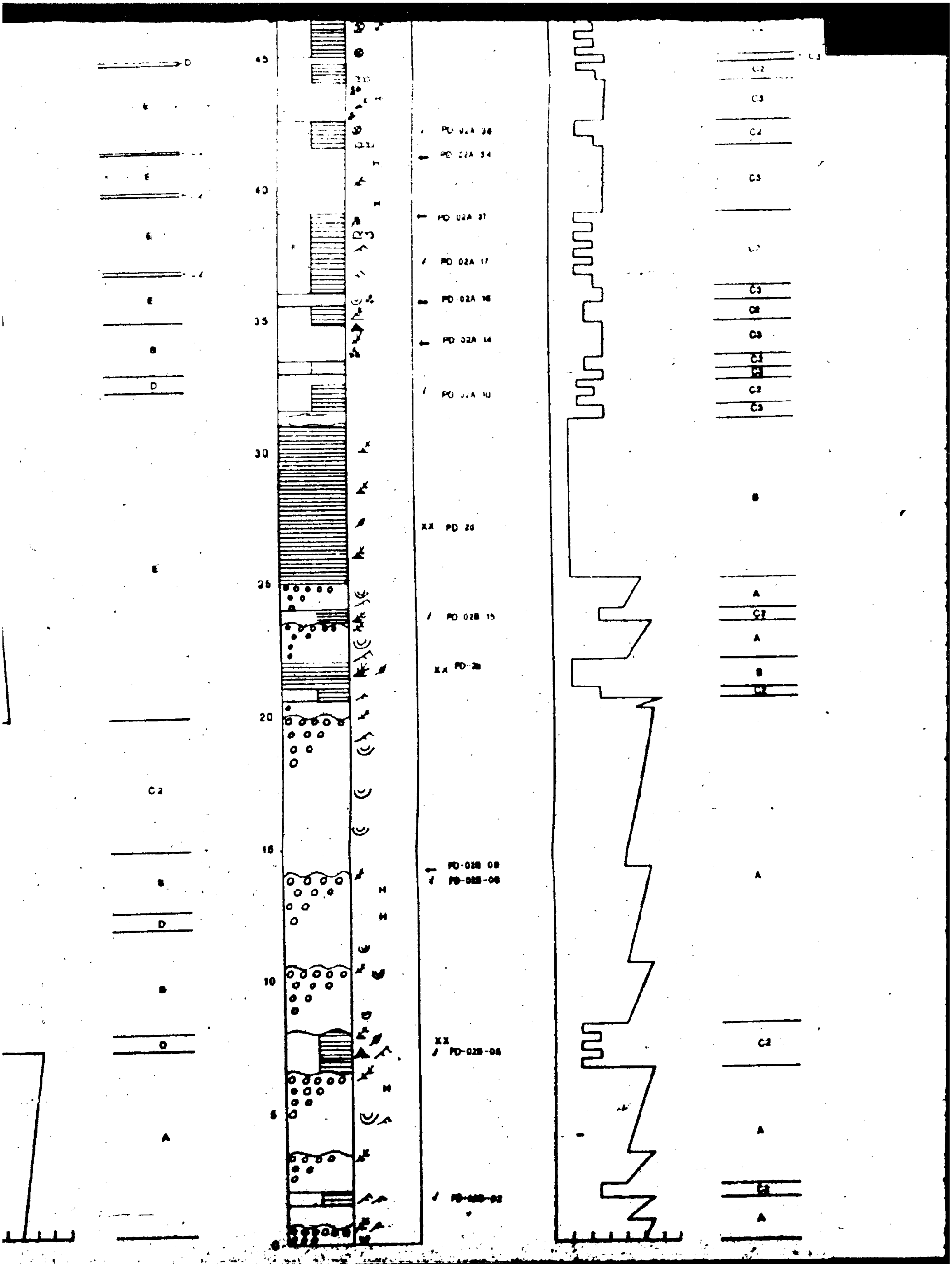

65
60
55
50
45
40
35
30
25
20
QU 018 27
QU 018 23
QU 018 21
QU 018 19
QU 018 14
QU-018-12
QU-018-09
E
C1
A
C2
C3

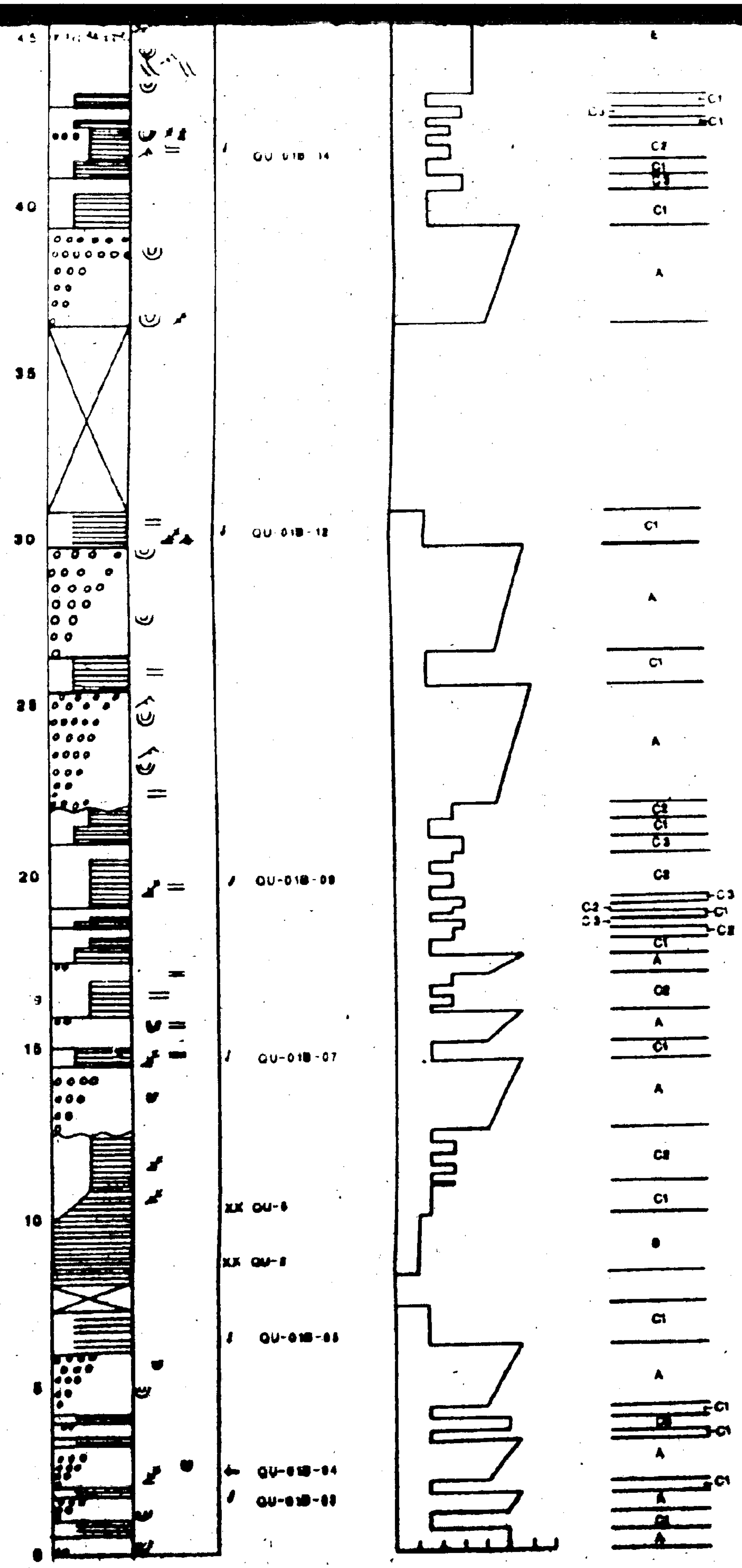


VERY POORLY EXPOSED, PARTIALLY COVERED
70
65
60
55
50
45
40
35
30
25
DN-01A 14
DN-01A 13
DN 01A 10
DN-01A-08
DN-01A-07
C1
F
C1
F
C1
F

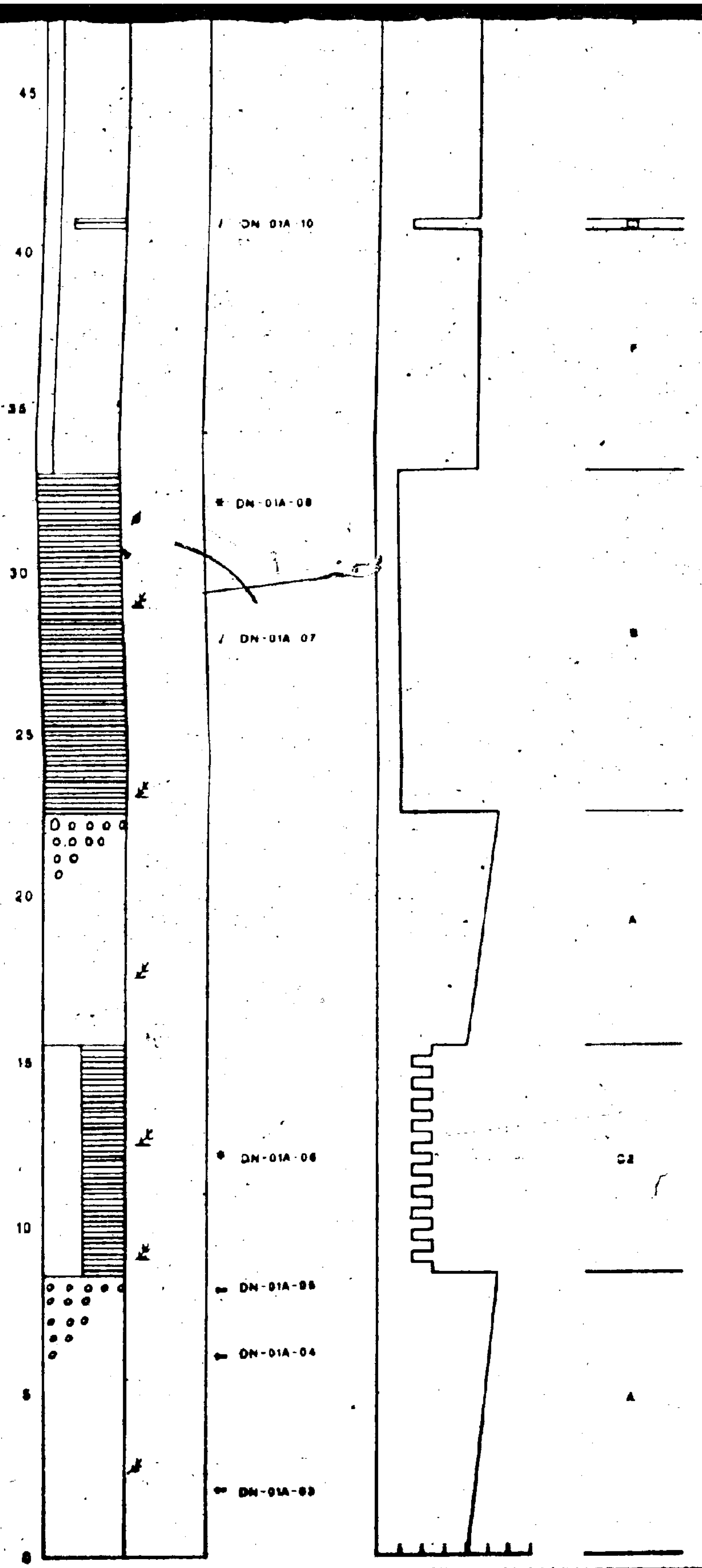


35
30
25
20
15
10
5
0
PD-01A-BASE

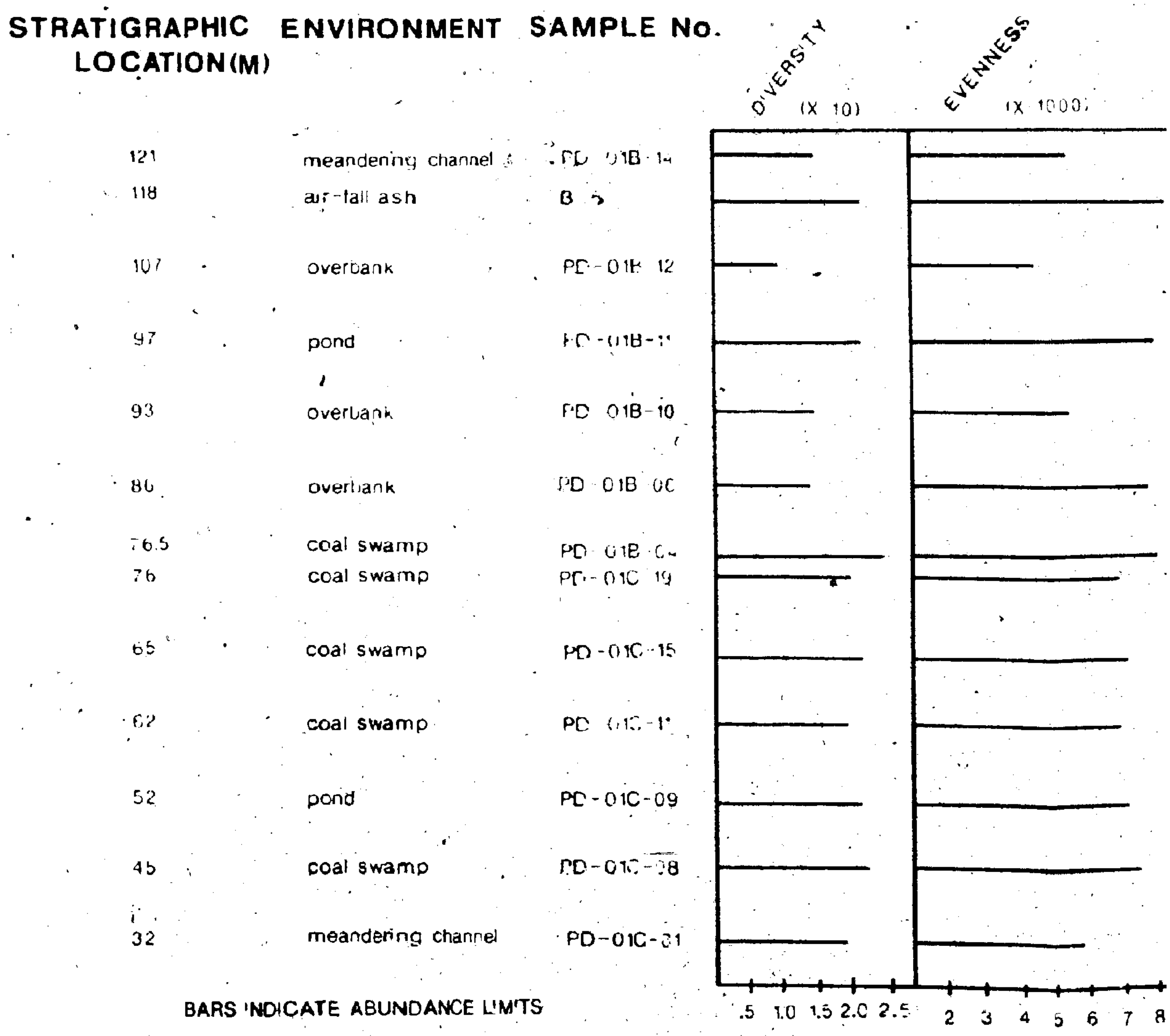




40
35
30
20
15
10
5
0
QU-01B-14
QU-01B-12
QU-01B-07


45
40
35
30
25
20
15
10
5
0
DN-01A-10
DN-01A-08
DN-01A-07
DN-01A-06
DN-01A-05
DN-01A-04
DN-01A-03
F
B
A
C2
A

POLL




BARS INDICATE ABUNDANCE LIMITS

## FIGURE 3.1
## POLLEN DIAGRAM - PADLOPING ISLAND SECTION 1

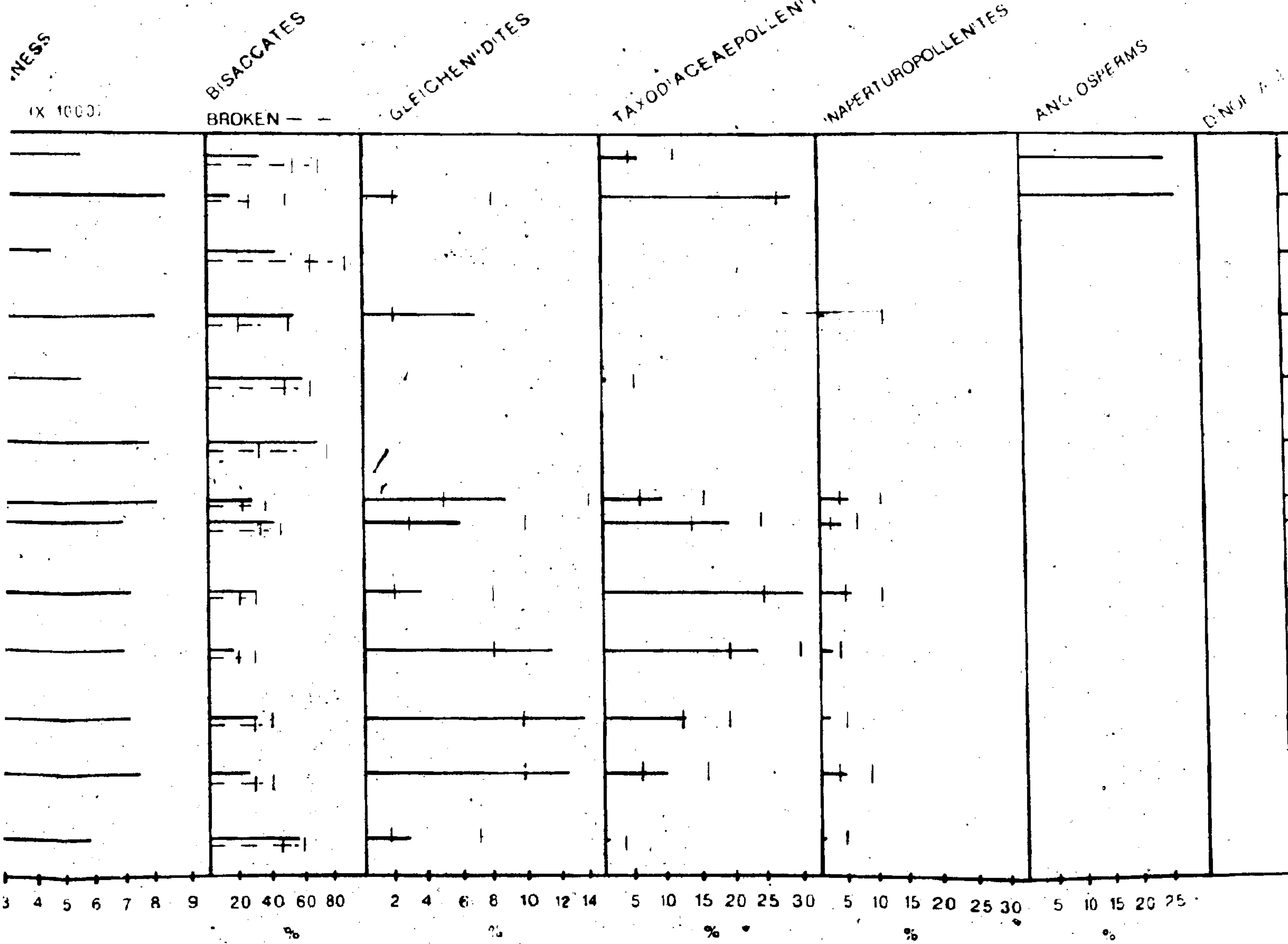
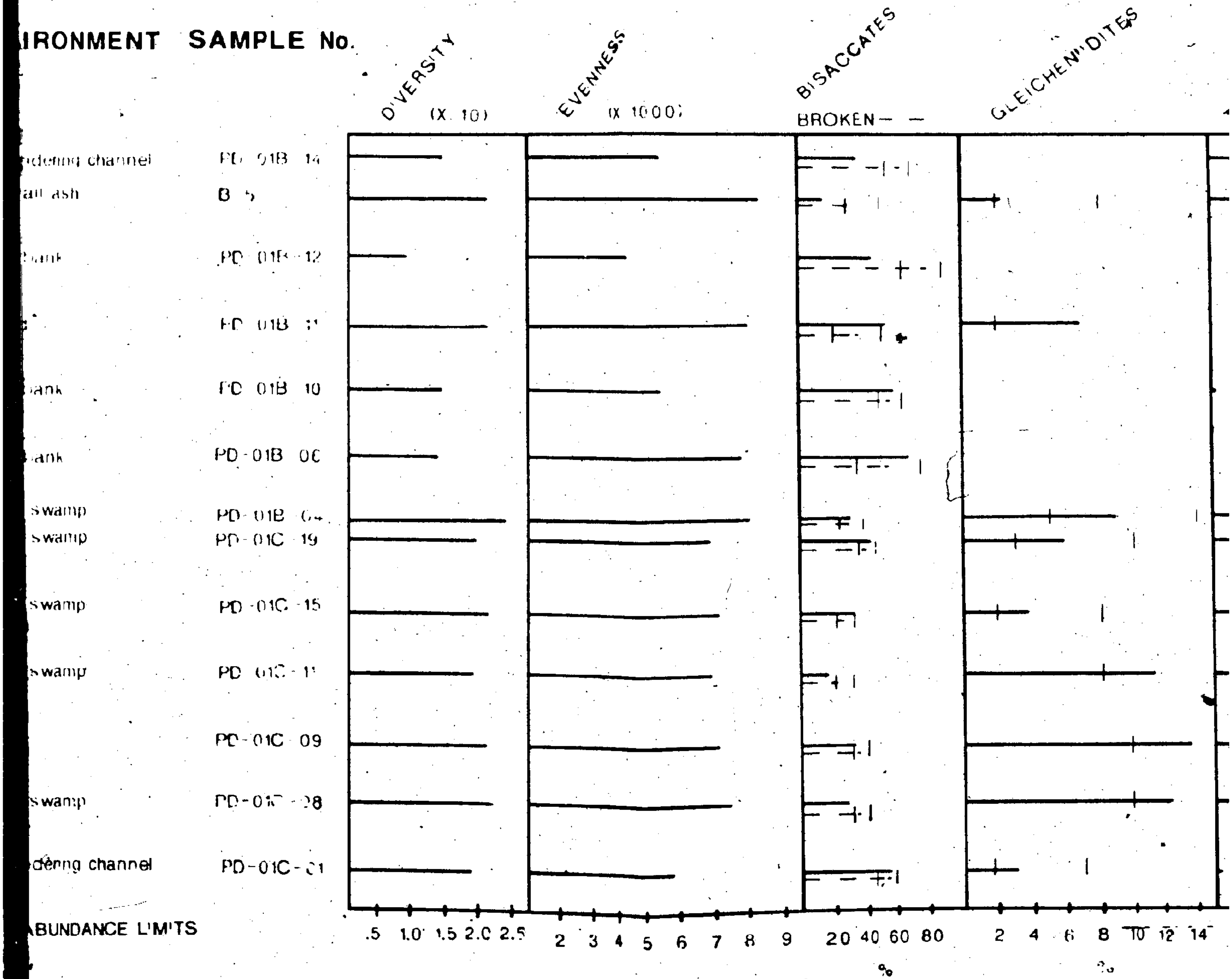
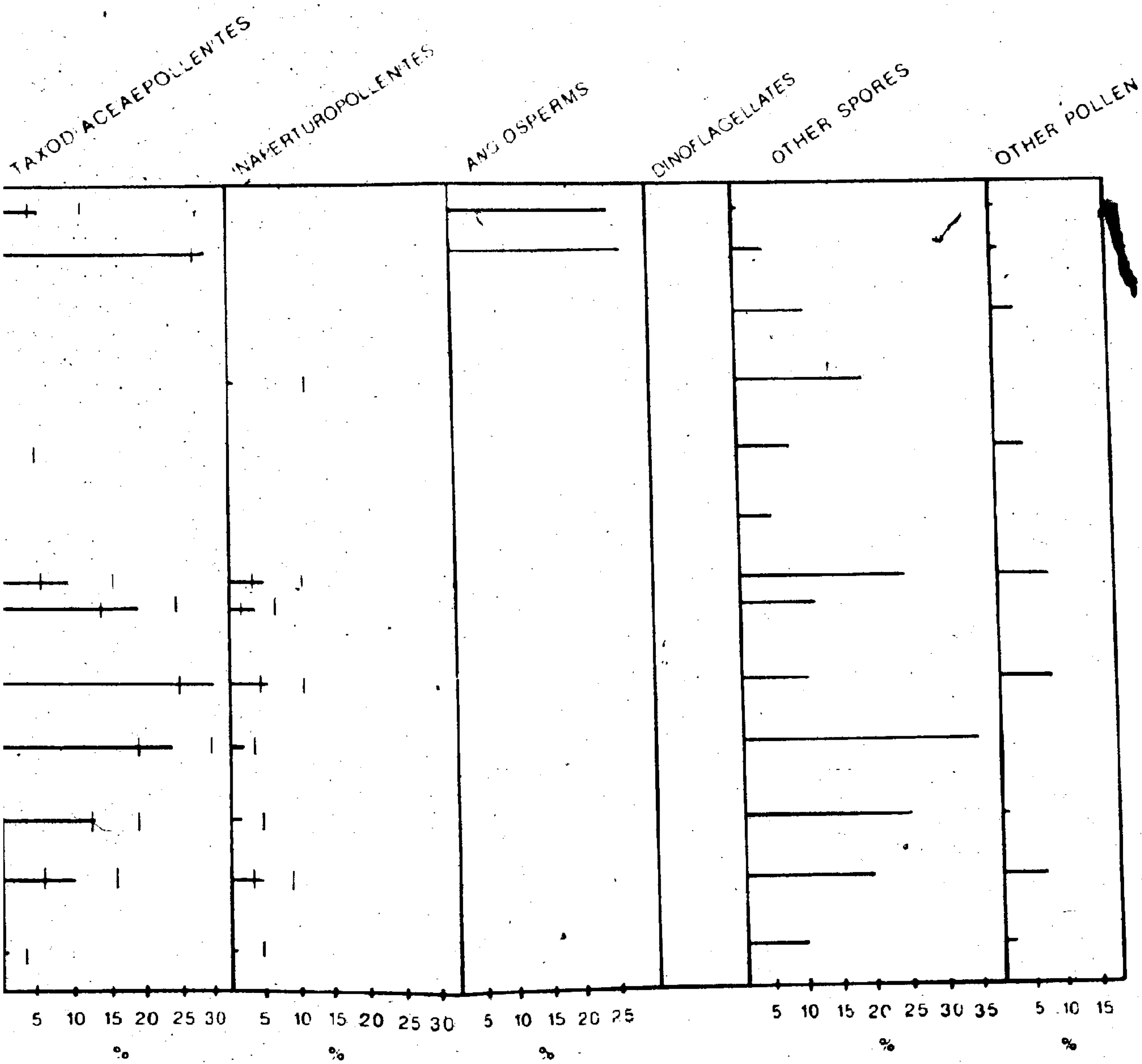


**FIGURE 3.1**

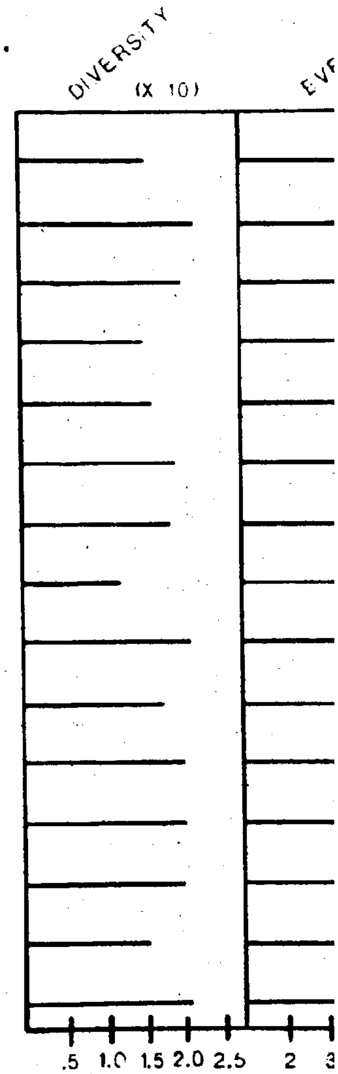
**POLLEN DIAGRAM - PADLOPING**



## G ISLAND SECTION 1



| STRATIGRAPHIC LOCATION (M) | ENVIRONMENT | SAMPLE No. |
|---|---|---|
| 101 | overbank | PD-02A-70 |
| 96 | overbank | PD-02A-68 |
| 92 | overbank | PD-02A-67 |
| 87 | meandering channel | PD-02A-65 |
| 82 | pond | PD-02A-57 |
| 77 | overbank | PD-02A-52 |
| 65 | overbank | PD-02A-49 |
| 60 | overbank | PD-02A-47 |
| 55 | overbank | PD-02A-45 |
| 50 | pond | PD-02A-43 |
| 43 | overbank | PD-02A-36 |
| 37 | overbank | PD-02A-17 |
| 33 | overbank | PD-02A-10 |
| 14 | braided channel | PD-02B-08 |
| 7 | overbank | PD-02B-05 |




BARS INDICATE ABUNDANCE LIMITS

## FIGURE 3.2
## POLLEN DIAGRAM – PADLOPING ISLAND SECTION 2

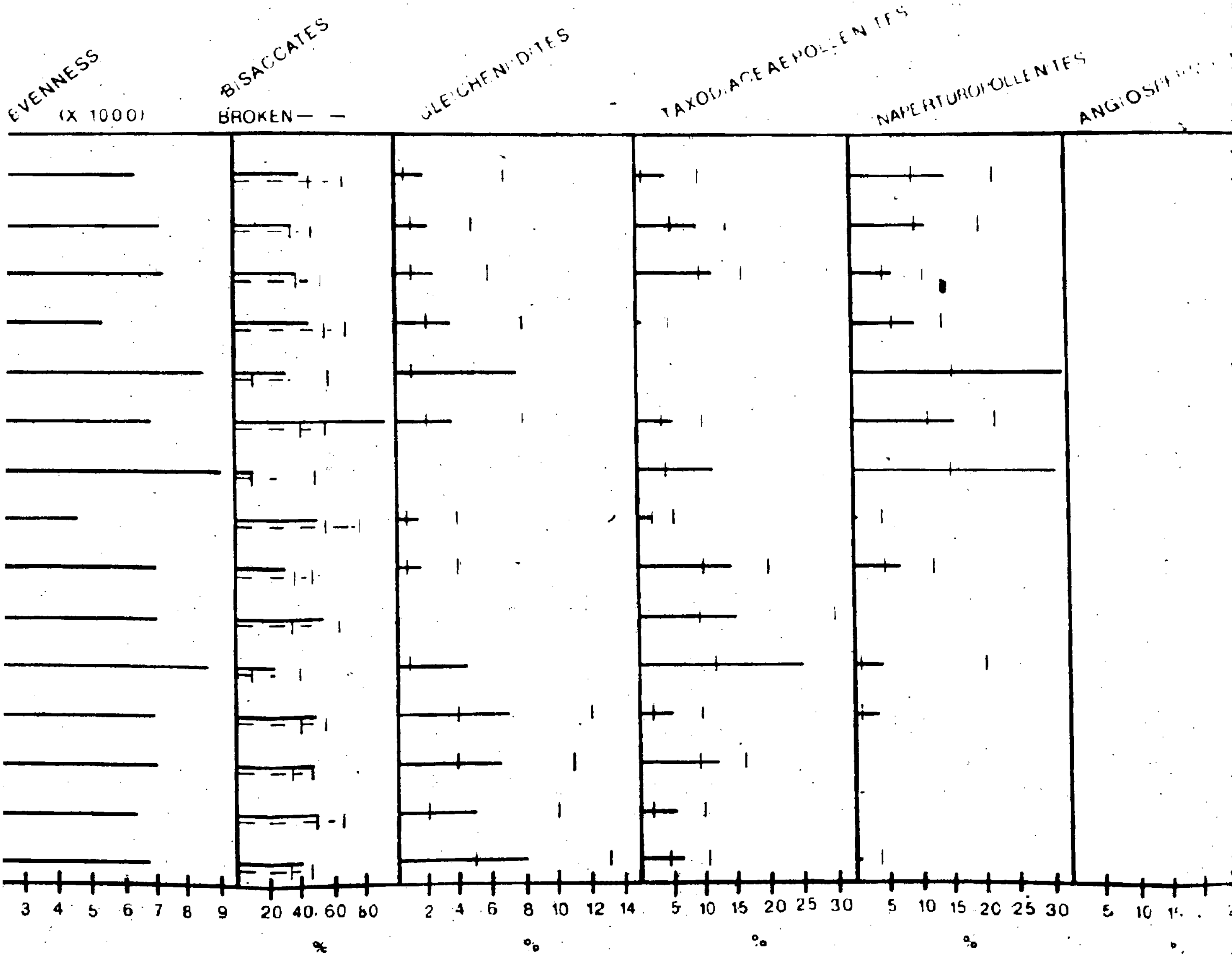
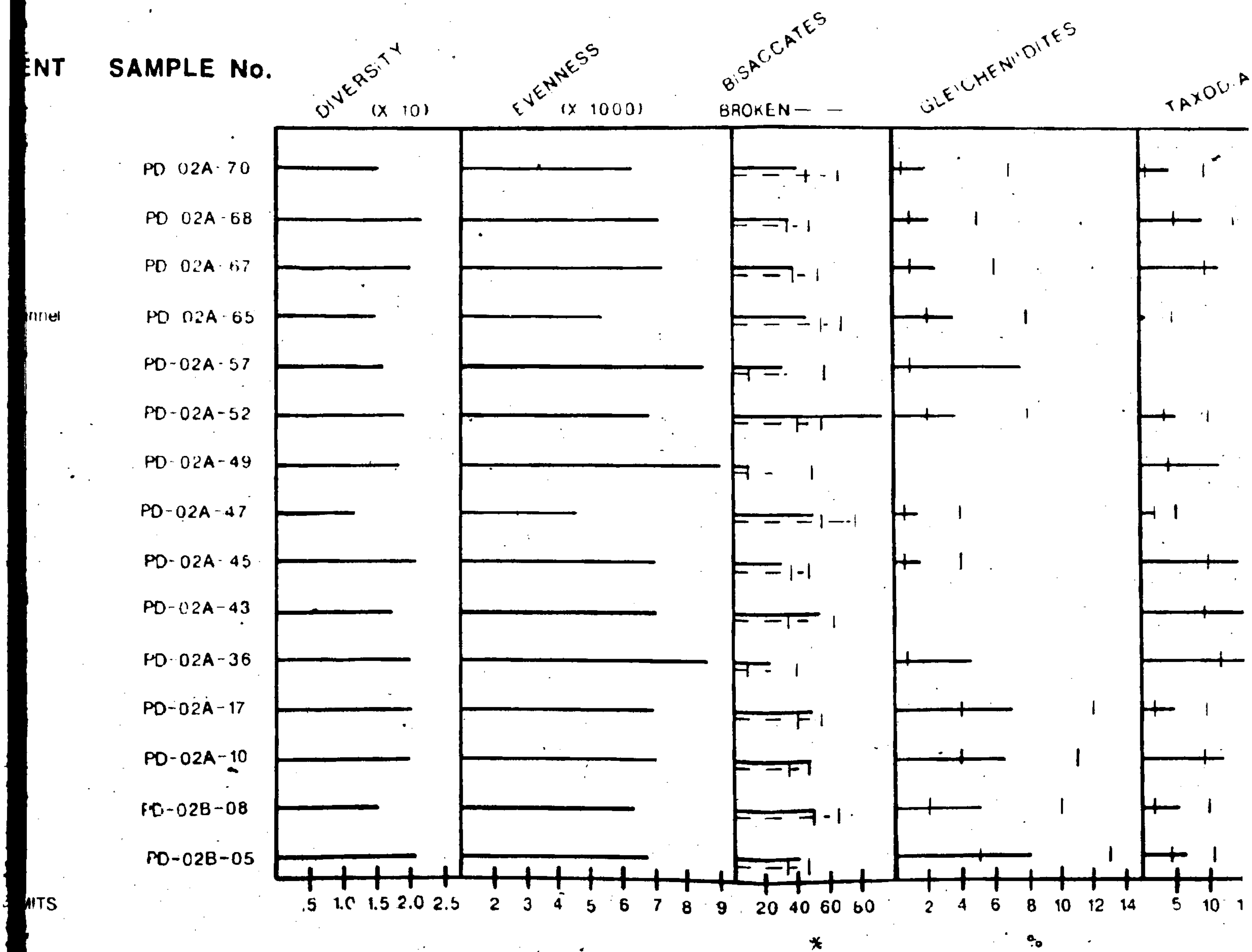


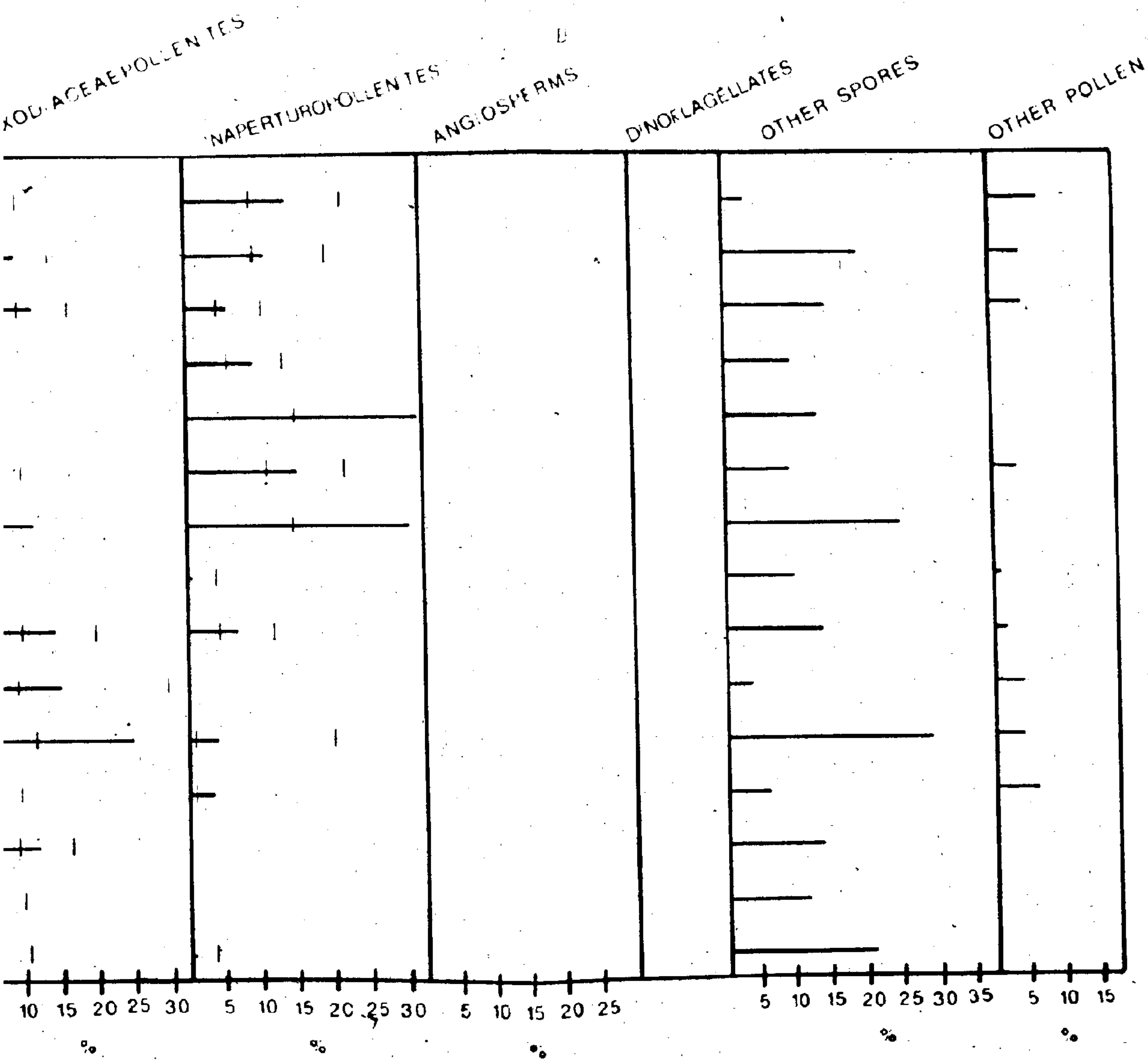
FIGURE 3.2

POLLEN DIAGRAM - PADLOI

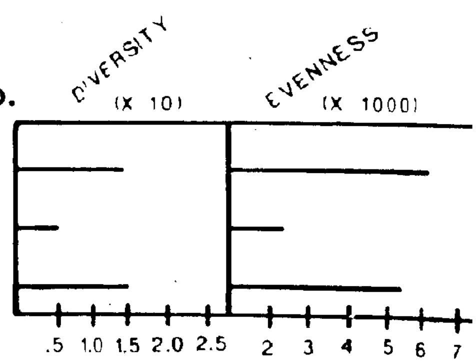


**.2**

**LOPING ISLAND SECTION 2**



| STRATIGRAPHIC LOCATION (M) | ENVIRONMENT | SAMPLE No. |
|---|---|---|
| 26.5 | air-fall ash | QU-01A-03 |
| 26 | pond | QU-01A-02 |
| 24 | pond | QU-01A-01 |

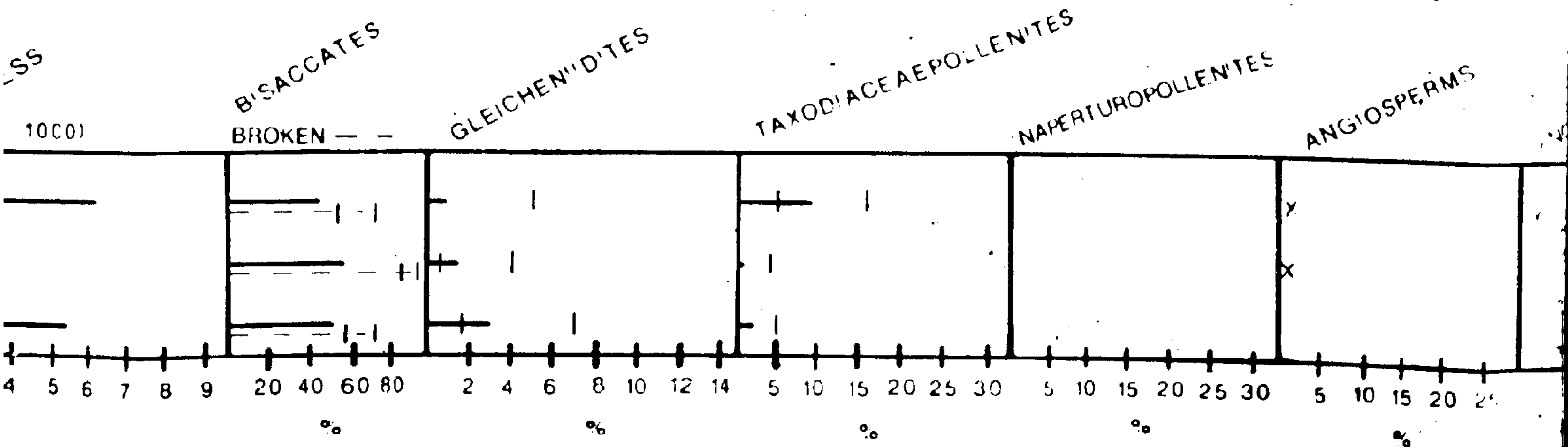



BARS INDICATE ABUNDANCE LIMITS

X INDICATES PRESENT < .5 %

## FIGURE 3.3

## POLLEN DIAGRAM - QUQALUIT ISLAND SECTION 1



FIGU

POLLEN DIAGRAM – QUC

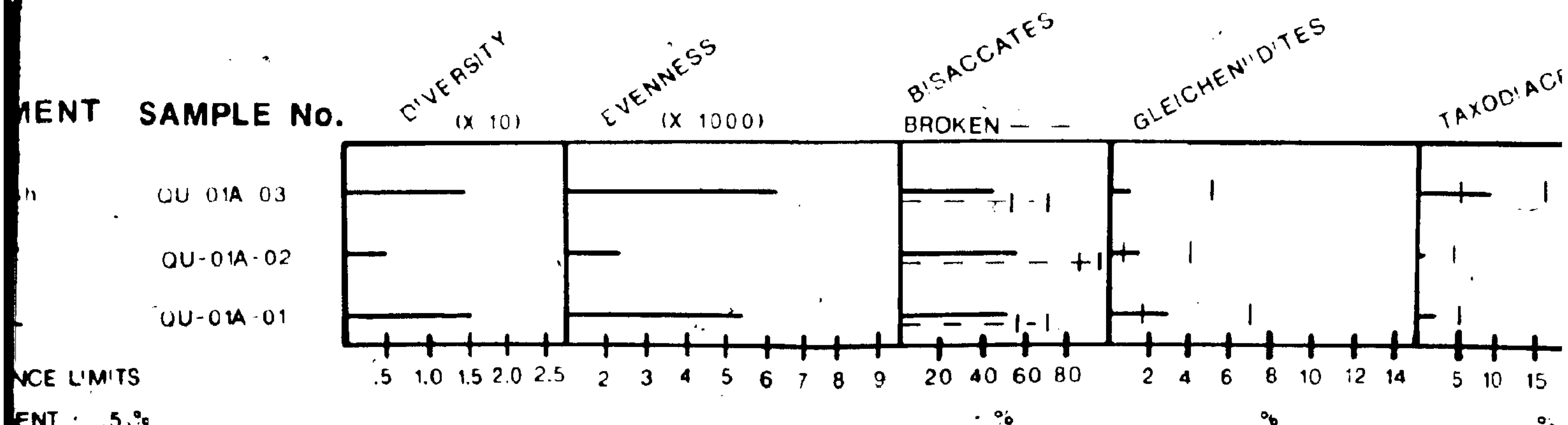
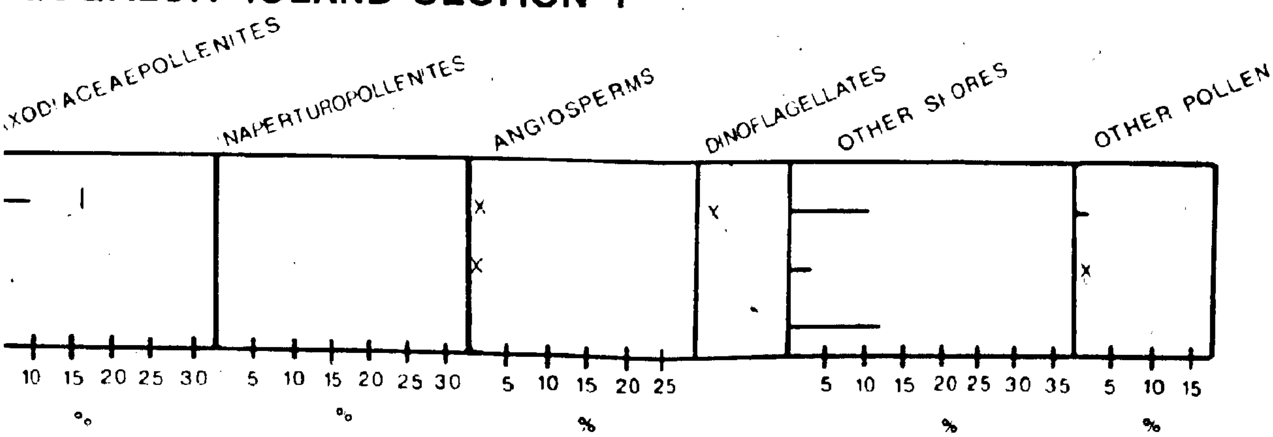
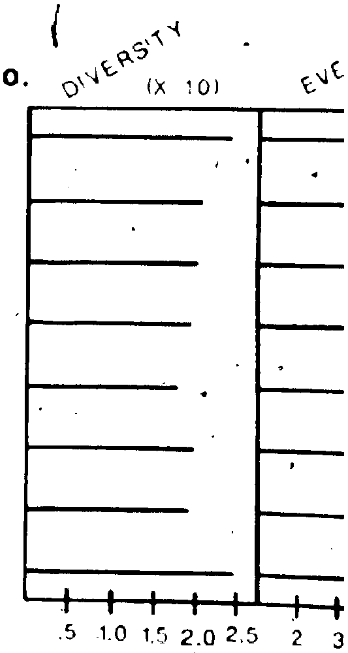


FIGURE 3.3

QUQALUIT ISLAND SECTION 1

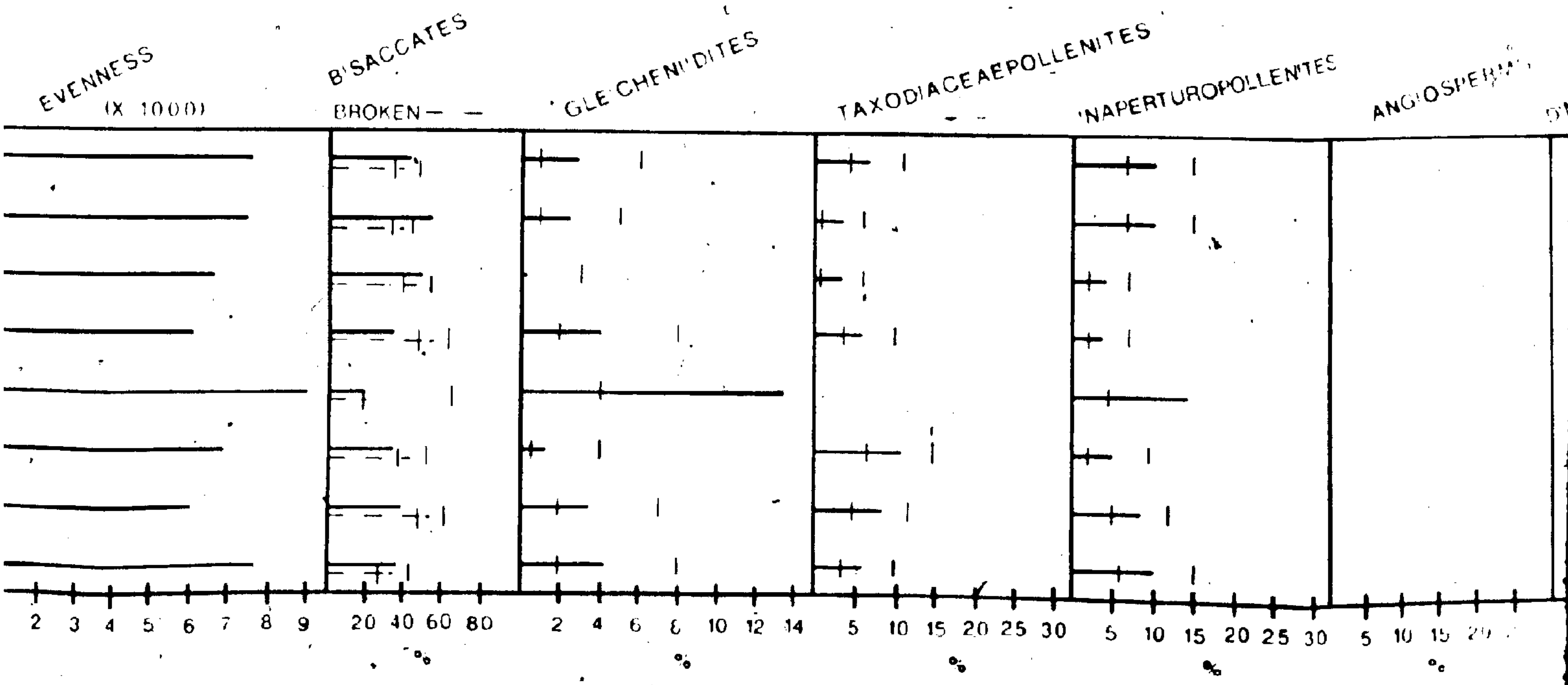


| STRATIGRAPHIC LOCATION (M) | ENVIRONMENT | SAMPLE No. |
|---|---|---|
| 90 | pond | QU-01B-27 |
| 60 | overbank | QU 01B-23 |
| 54 | overbank | QU-01B-19 |
| 41 | overbank | QU-01B-14 |
| 30 | overbank | QU 01B-12 |
| 20 | overbank | QU 01B 09 |
| 15 | overbank | QU 01B-07 |
| 6 | overbank | QU-01B-05 |



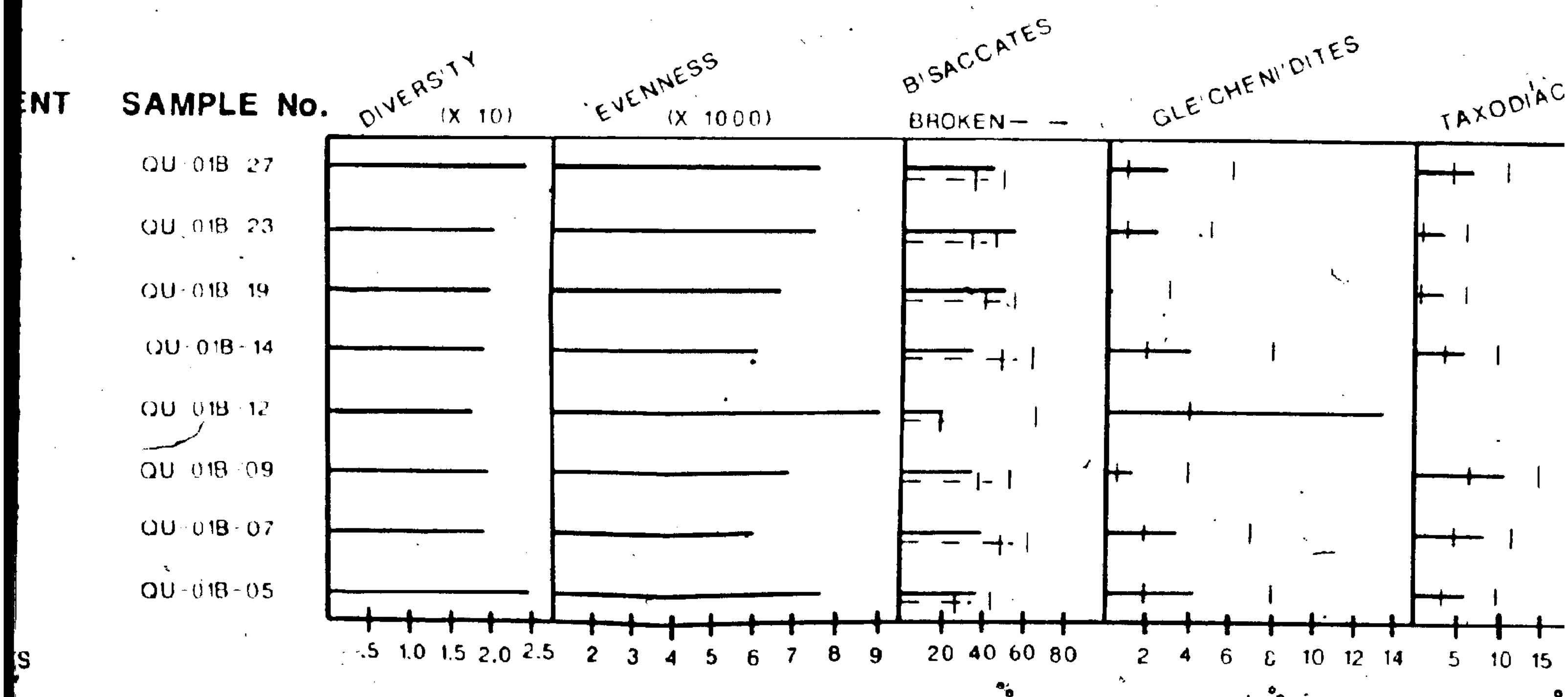

BARS INDICATE ABUNDANCE LIMITS

## FIGURE 3.4
## POLLEN DIAGRAM - QUQALUIT ISLAND SECTION 2

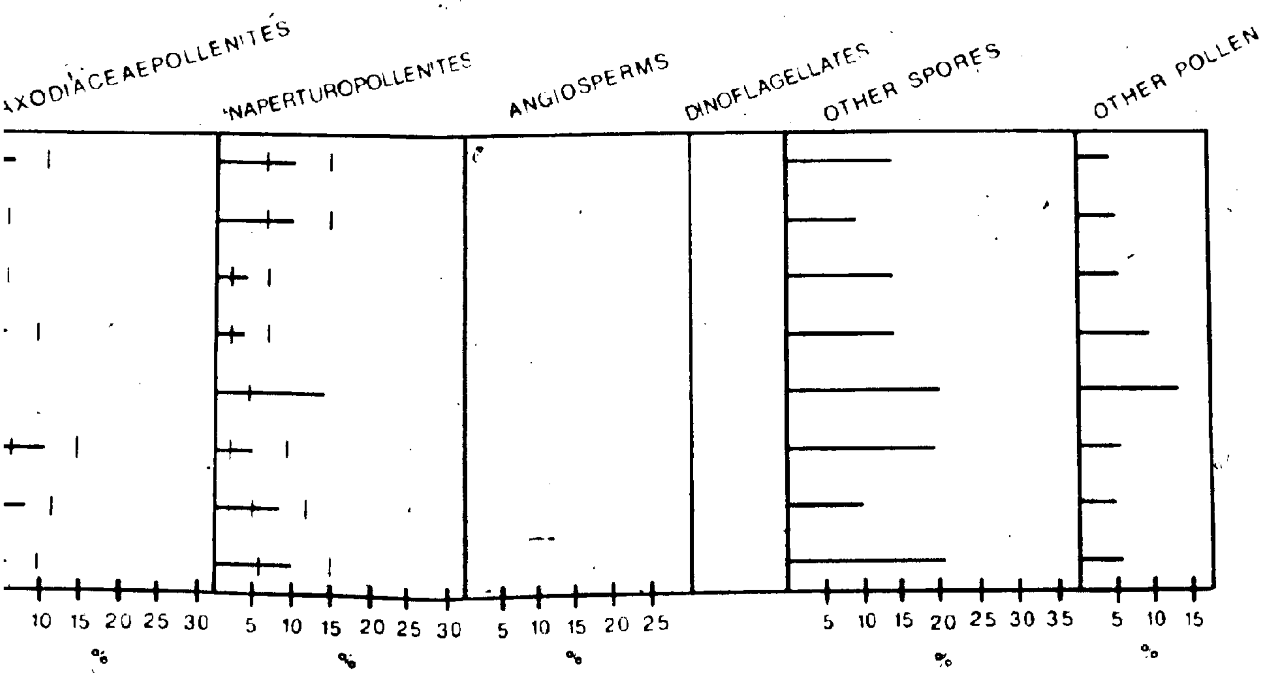


## FIGURE 3.4

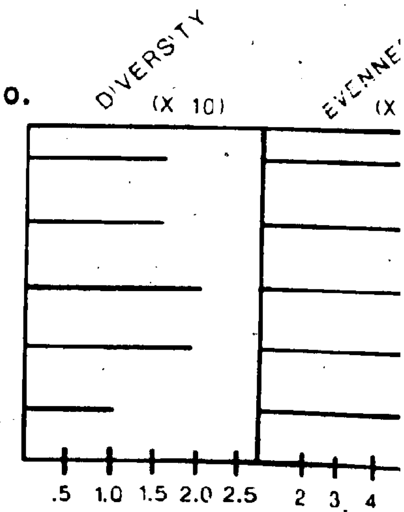
## POLLEN DIAGRAM - QUQALUIT ISL



## ISLAND SECTION 2



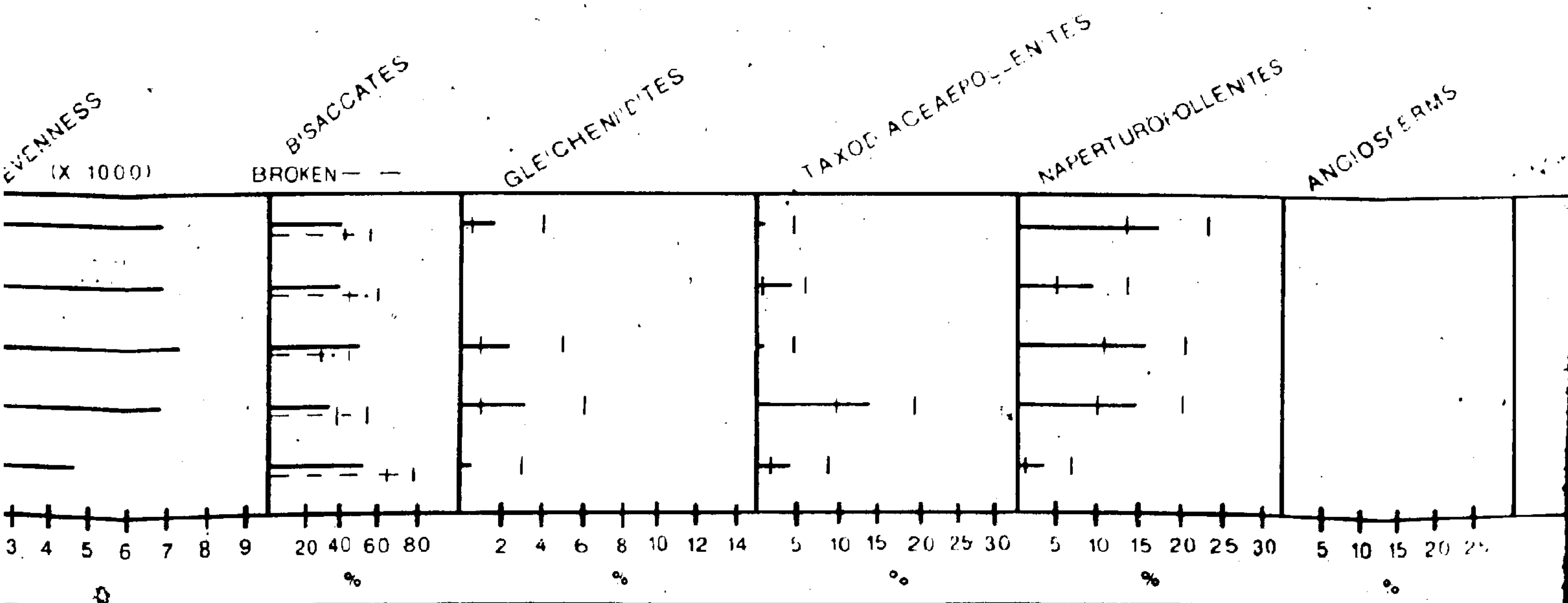
| STRATIGRAPHIC LOCATION (M) | ENVIRONMENT | SAMPLE No. |
| --- | --- | --- |
| 94 | distal alluvial fan | DN-01A-18 |
| 78 | distal alluvial fan | DN-01A-16 |
| 61 | distal alluvial fan | DN-01A-14 |
| 40 | overbank | DN-01A-10 |
| 27 | pond | DN-01A-07 |



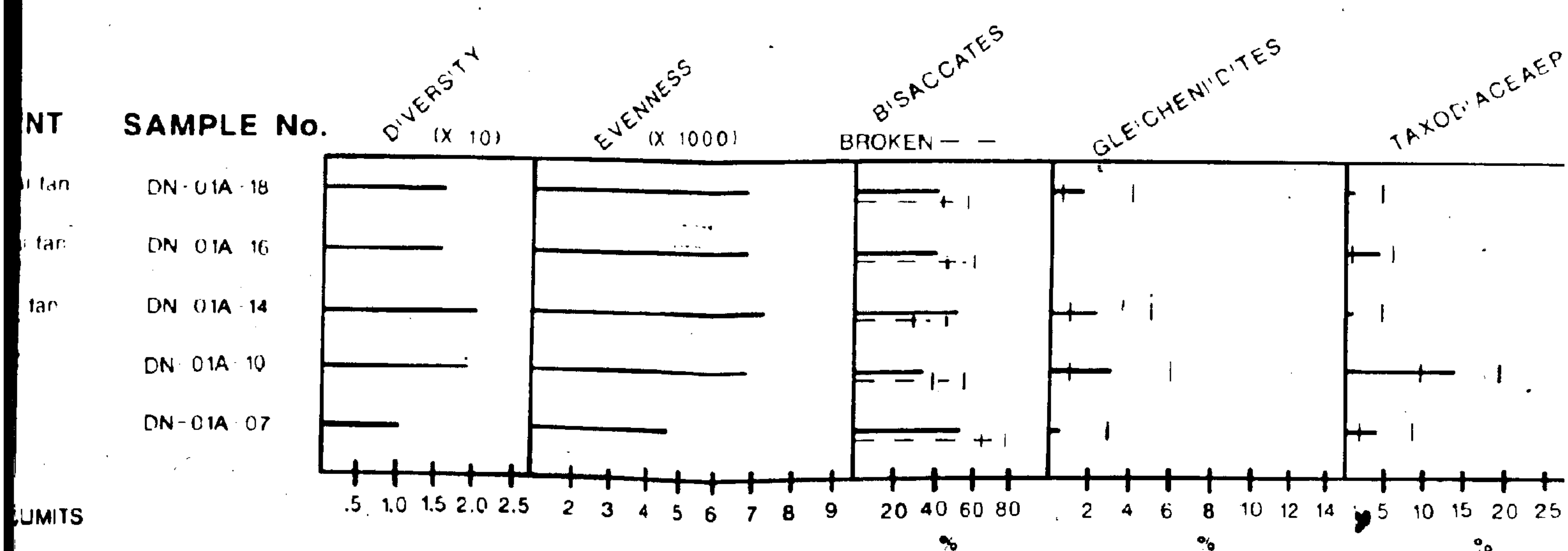

BARS INDICATE ABUNDANCE LIMITS

FIGURE 3.5

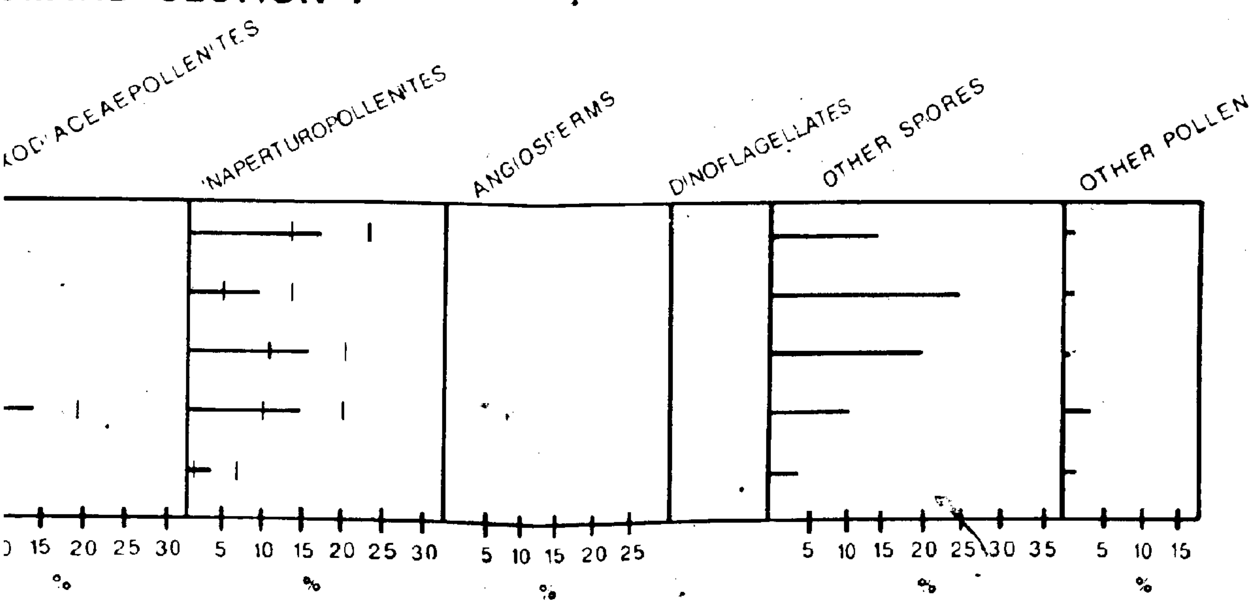
POLLEN DIAGRAM - DURBAN ISLAND SECTION 1



## FIGURE 3.5
## POLLEN DIAGRAM – DURBAN ISLAND



## SLAND SECTION 1



# APPENDIX D

## PALYNOMORPH COUNTS FOR S1

RANGE CHART OF NUMBER OF SPECIMENS BY ALPHABETICAL ORDER

(X INDICATES PRESENCE)

| Sample | Abiespollenites sp | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | Cyathidites minor | [illegible] | Deltoidospora hallii | [illegible] | [illegible] | Dinoflagellate Type 1 | Dinoflagellate Type 2 | [illegible] | [illegible] | [illegible] | [illegible] | Gleicheniidites senonicus | Granulatisporites sp | Hamulatisporis sp | [illegible] | Inaperturopollenites sp | [illegible] | Laevigatosporites ovatus | [illegible] | [illegible] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DW 01A 07 | 1 | | 15 | 1 | | | | | | | | 1 | 12 | 4 | | | | | | | | | | | 3 | | | 2 | | | | | | | | 1 | | | | 8 | | | | |
| DW 01A 10 | | | 7 | 2 | | | | | 1 | | | 2 | 7 | 5 | | | | 1 | | | | | | | 14 | | 6 | 1 | | | | | | | | 6 | | | | 29 | | | | |
| DW 01A 14 | 1 | | 10 | 4 | | | | | | | | 2 | 22 | 1 | | | | | | | | | | | 17 | | 4 | | 2 | | | | | | | 4 | | | | 28 | | | | |
| DW 01A 16 | | | 6 | 4 | | | | | | | | 1 | 9 | 3 | | | | | | | | | | | 27 | | 6 | | 3 | | | | | | | | | | | 15 | | | | |
| DW 01A 18 | | | 11 | 3 | | 1 | | | | | | 4 | 9 | 5 | | | | | | | | | | | 17 | | 8 | | 4 | | | | | | | 3 | | | | 35 | | | | |
| WU 01B 06 | 2 | | 10 | 6 | | | 2 | | 16 | | | 7 | 5 | 9 | | | | 3 | | | | X | | | 2 | 1 | 3 | | 6 | | | X | | | | 8 | 1 | | | 19 | | | | 1 |
| WU 01B 07 | | 2 | 12 | | | | 2 | | 1 | | | 1 | 10 | 6 | | | | | | | | | | | 8 | 2 | 1 | | 1 | | | | | | | 7 | 1 | | | 18 | | | | |
| WU 01B 09 | | | 2 | | | | X | | 7 | | | 4 | 26 | 12 | | | | | | | | | | | 19 | 1 | 1 | | 4 | | | | | | | 3 | | | | 10 | | 2 | | |
| WU 01B 12 | | | | | | | | | 2 | | | | | 2 | | | | | | | | | | | 1 | | | | | | | | | | | 2 | | | | 2 | | | | |
| WU 01B 16 | | 1 | 10 | 1 | | 1 | 7 | | 3 | | | | 7 | 11 | 1 | | | 3 | | | | | | | 7 | | 1 | 1 | 1 | | | | | | | 8 | | | | 7 | | | | |
| WU 01B 19 | | X | 20 | 4 | | | 4 | 3 | 5 | | | 5 | 23 | 9 | | | X | X | | | | | X | | 7 | X | 1 | | 3 | | | | X | | | 1 | X | | | 8 | | 1 | X | |
| WU 01B 23 | | X | 30 | 5 | | | 5 | | 2 | | | 7 | 31 | 5 | | | | | X | X | | | | | 6 | 1 | 1 | | 5 | | | X | | | | 6 | | | | 22 | | | X | |
| WU 01B 27 | | | 10 | 6 | | | 5 | | 4 | | | | 11 | 2 | | | | 1 | | | | | | | 9 | | 3 | | | | | | | | X | 5 | 1 | | | 19 | | | | |
| WU 01A 01 | | 4 | 7 | 11 | | 1 | | | 10 | X | | | 16 | | | | | | | | | | | | 1 | | 1 | | | | | | | | | 8 | X | 1 | | | | | | |
| WU 01A 02 | | 1 | X | 1 | | X | | X | | X | X | | 8 | X | | | | X | | | | | | | X | | | X | X | | | | | | | 3 | | | X | | | | | |
| WU 01A 03 | | | 6 | | | | | | 3 | | | | 8 | 2 | | | | | | | | | | | 6 | | | | | X | X | | | | | 1 | | | | | | | | |
| PD 02B 05 | | | 13 | 1 | | 1 | | | 1 | | | 1 | 26 | | | | | 3 | | | | | | | 21 | 1 | 4 | | 1 | | | | | | | 16 | | | | 1 | | 3 | | |
| PD 02B 06 | | | 8 | | | | | | | | | 3 | 18 | | | | | | | | | | | | 5 | 2 | 4 | | | | | | | | | 7 | | | | | | 1 | | |
| PD 02A 16 | | 2 | 27 | 2 | | | | | | | | 5 | 27 | | | | | | | | 1 | | | | 19 | | 2 | | | | | | | | | 13 | | | | | | | | |
| PD 02A 27 | | | 18 | 6 | | | 3 | | 4 | | | 4 | 13 | 8 | | | | 1 | | | | | | | 1 | | 3 | | | | | | | | | 13 | | | | 8 | | 1 | | |
| PD 02A 36 | | | 2 | | | | | | | | | | 1 | | | | | | | | | | | | 5 | 1 | | | | | | | | | | 1 | | | | 1 | | 1 | | |
| PD 02A 43 | | | 8 | 1 | | | | | | | | 1 | 7 | 1 | | | | | | | | | | | 1 | 1 | | 1 | | | | | | | | | | | | | | | | |
| PD 02A 45 | 1 | | 16 | 1 | | | | | 3 | | | 8 | 15 | 4 | | | | | | | | | | | 4 | X | 1 | | 5 | | | | | | | 3 | | | | 14 | | 2 | | |
| PD 02A 47 | | | 17 | 1 | | | | | 6 | | | | 10 | 3 | | | | 1 | | | | | | | 8 | | 1 | X | 1 | | | | 2 | X | | 3 | 1 | | | 2 | | | | |
| PD 02A 48 | | | | | | | | | 2 | | | 1 | | | | | | 1 | | | | | | | | | | | 1 | | | | | | | | | | | 5 | | | | |
| PD 02A 52 | | 2 | 8 | 2 | | | | | 1 | | | | 11 | 5 | | | | | | | | | | | 6 | | 2 | | | | | | | | | 8 | | | | 26 | | | | |
| PD 02A 57 | 3 | | | | | | | | 1 | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | 5 | | | | |
| PD 02A 65 | | | 5 | | | 2 | | | 1 | | | | 21 | | | | | 1 | | | | | | | 8 | | 2 | 1 | | | | | | | | 9 | 1 | | | 18 | | 1 | | |
| PD 02A 67 | | | 14 | 2 | | | 6 | | 6 | | | 1 | 10 | 3 | | | | | | | | | | | 8 | | 6 | | | | | | | | | 4 | | | | 11 | | | | |
| PD 02A 68 | | | 12 | 3 | | 1 | | | 10 | | | 1 | 8 | 7 | | | | 2 | | | | | | | 5 | | 3 | | 3 | | | | | | | 4 | 1 | | | 28 | | | | |
| PD 02A 70 | | | 8 | | | | | | 1 | | | 2 | 7 | 6 | | | | | | | | | | | | 1 | | | | | | | | | 1 | 2 | | | | 15 | | | | |
| PD 01C 01 | | | 20 | 5 | | 1 | 1 | | 1 | | | 8 | 26 | 2 | | | | 1 | | | | | | | 1 | 1 | 1 | | | | | | | | | 6 | 2 | | | 2 | | 2 | | |
| PD 01C 06 | | | 2 | | | | 2 | | 7 | | | 2 | 10 | | | 3 | | | | | | 1 | | | 14 | 12 | 2 | | 2 | | | | | | | 26 | 2 | | | 10 | | 4 | | |
| PD 01C 09 | | | 4 | 2 | | | 1 | | | | | | 7 | | | | | | | | 1 | | | | 18 | 2 | 8 | 3 | 2 | | | | | | | 25 | 1 | | | 3 | | 4 | | |
| PD 01C 11 | | | 2 | | | | | | 1 | | | | 5 | | | | | 2 | | | 1 | | | | 32 | | 27 | 2 | | | | | | | | 24 | | | | 3 | | | | |
| PD 01C 15 | | | 14 | | | | | | 4 | | | 4 | 8 | 16 | | | | 1 | | | | | | | 4 | | 7 | | 1 | | | | | | | 8 | | | | 13 | | | | X |
| PD 01C 18 | | 1 | 28 | 1 | 7 | | | | 1 | | | 14 | 8 | 1 | | | | | | | | | | | 11 | | 3 | 1 | | | | | | | | 12 | 2 | | | 8 | | 1 | | |
| PD 01B 04 | | | 16 | | | | 9 | | | | | 3 | | 2 | | | | | | | | | | | 10 | | 5 | | | | | | | | | 12 | 1 | | | 8 | | 10 | | |
| PD 01B 06 | | | 3 | 2 | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | |
| PD 01B 10 | | | 12 | 2 | 1 | | 3 | | | | | | 28 | 2 | | | | 1 | | | | | | | 3 | | | 3 | 1 | | | | | | | | 1 | | | | | 1 | | |
| PD 01B 11 | | | 8 | 3 | | | | | | | | 1 | 8 | | | | | 1 | | | | | | | 2 | | 2 | | | | | | | | | 3 | | | | 1 | 1 | 1 | | |
| PD 01B 17 | | | 1 | | | | | | | | | | 1 | 1 | | | | | | | | | | | 1 | | | 1 | | | | | | | | | 1 | | | | | | | |
| B 5 | | | | | | | | | | 10 | | | 6 | | | | | | | | | | | X | 6 | | | | 1 | | | | | | | 5 | | | | | | | | |
| PD 01B 14 | | | 2 | | | | | | | 13 | | | 7 | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | |

IX D

OR STUDY AREA

| Laevigatosporites ovatus | Lycopodiacidites canaliculatus | [illegible] | [illegible] annulites | Neoraistrickia truncata | Oligosphaeridium complex | Osmundacidites wellmanii | Pesavis tagluensis | Piceaepollenites sp. | Pityosporites [illegible] | Podocarpidites [illegible] | Podocarpidites minisculus | Podocarpidites multesimus | Polycingulatisporites [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] sp. | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] sp. | [illegible] sp. | [illegible] sp. | [illegible] sp. | [illegible] sp. | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|||||||||||1||||||||||||||||||||8|||||||||||DW 01A 07|
|||||||||||||||||||||||||||||||27|||||||||||DW 01A 10|
|||||||||1||2|3||||||12|||||||||||||2|||||||||2||DW 01A 14|
||||||||||||||||||8|||||||||||||5|||||||||||DW 01A 18|
|||||||||6||||||||||||||||||||||3|||||||||||DW 01A-18|
|||1||||4||2|1|1|||||||2|||||||||||3|7|11|||||||||||QU 01B 05|
|||||||||2|||1|2|||||2|||||||||||||14|||||||||4||QU 01B-07|
|2||||||2|||X|X|||||||2||||||||||||X|23|||||||||3||QU 01B-09|
||||||||||||||||||||||||||||||||||||||||||QU 01B-12|
||||||||||||||||||1|||||||||||||12|||||||||6||QU 01B 14|
|1|X|||||4||1||||X|||X|X|1||X|X|||X|||||X|1|8||||||||X|3||QU 01B-19|
||X|||||||3|||||||||4|||||||||||X||6||||||||X|X||QU 01B-23|
|||||||||2||2|4|4|||||4|||||||||||3||11||||||||2|||QU 01B 27|
||||||||X||1|3||||||||||||||||||||4||||||||1|||QU 01A 01|
|||||X|||||||||X||||X|||||||||||||3|X|||||||1|3||QU 01A 02|
||||||X||X|||3|||||||||||X|||X|X|X|X|||10|||||||||4||QU 01A 03|
|3||||||1|||1|2||||||1|1|2||||||||||||12|||||||||2|2|PD 02B 06|
|1||||||||||3|||||||3|||||||||||||7|||||||||||PD 02B-09|
||||||||||1|||3|||||1|||||||||||||24||||||1||1||1|PD 02A-10|
|1||||||1||1||3||||||||||||||||||||7|||||||||3|1|PD 02A-17|
|1||||||||||||||||||||||||||||||8|||||||||||PD 02A 36|
|||||||||1||||||||||||||||||||||7|||||||||||PD 02A 43|
|2||||||8||2|||||||||2|1||||||||||||28|||||||||2||PD 02A 45|
||||||||||1|||||||||||||||||||||4|||||||||||PD 02A 47|
|||||||||||||||||||||||||||||||2|||||||||||PD 02A-48|
|||||||||2||2|||||||3|||||||||||1||8|||||||||||PD 02A 52|
||||||||||||||||||||||||||||||||||||||||||PD 02A 57|
|1||||1||||2|1|1||||||||||||||||||||3|||||||||||PD 02A-66|
|||||||1|||||||||||3|||||||||||||21|||||||||||PD 02A 67|
|||||1||4||2|3||||||||4|||||||||||2||17||||||1|||||PD 02A-68|
|||||||||||||||||||||||||||||||6||||||||||1|PD 02A 70|
|2||||1||||1||4||||||||1||||||||||||1||||||||3|||PD 01C 01|
|4||||||5||||1||||||||1||||||||||3||22|||||||||||PD 01C 06|
|4||||||||||3|||||||3|||||||||||4||24||||||||2|2|2|PD 01C 08|
|||||||1|||||||||||2|||||||||||||50||||||||3|3|4|PD 01C 11|
|||2||||1||1||4||||||||||||||||||||62||||||||1|2|1|PD 01C 15|
|1||||||1||||||||||||||||||||||||37|||||||||1|1|PD 01C-18|
|10||||||1|||1|||1|||||4|||||||||||2||14||||||||2|||PD 01B-04|
|||||||||1|1||||||||||||||||||||||||||||||||PD 01B 06|
|1|||||||||1|2||||||||||||||||||||2|||||||||||PD 01B-10|
|1||||||||||1||||||||||||||||||||||||||1|||||PD 01B-11|
||||||||||||||||||||||||||||||||||||||||||PD 01B 12|
||||6|1|||X|||||||1(||||||||3||||||||56|3|X|X|X|X||27||||B 5|
||||3||||X|||1||||1||||||||1||||||||10|1||||||10||||PD 01B 14|