UPPER CRETACEOUS PALEOSHORELINES OF THE NORTHEASTERN SVERDRUP BASIN, ELLESMERE ISLAND, CANADIAN ARCTIC ARCHIPELAGO

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ABSTRACT

The Carboniferous to Early Tertiary Sverdrup Basin includes a wide area of the Canadian Arctic Archipelago. The margins of the present-day triangular Sverdrup Basin are mainly erosional but may also be depositional. The last major transgression deposited the widespread Turonian to Campanian Kanguk Formation which is unconformably underlain by the Albian Hassel Formation. Locally, on Axel Heiberg Island the Albian Bastion Ridge Formation occurs between the Hassel and Kanguk formations. In a typical vertical sequence of the Kanguk Formation the lower bituminous mudstones coarsen upwards and grade into silt-rich mudstones interbedded with thin, fine-grained sandstones in the upper part of the unit. This sequence represents a shallowing upward trend from offshore anoxic deposition to prodelta conditions. Decimetre- to metre-thick bentonite beds occur throughout the Kanguk Formation but are more abundant interbedded with the bituminous mudstones of the lower part. The bentonites indicate low shear-stress conditions of deposition.

On easternmost Ellesmere Island the lower Kanguk Formation is atypical and comprises bioturbated siltstones and sandstones, some of them pedogenically altered, and a single bentonite bed. These lower Kanguk sandstones have been palynologically dated as Turonian. They represent shallow marine deposition, most likely on coastal settings with brief subaerial exposure and moderate development of paleosols. These sandstones are overlain by the typical bituminous mudstones of the lower Kanguk Formation. Therefore, the sandstones represent Turonian paleoshoreline positions of the northeastern Sverdrup Basin before further transgression of the Kanguk sea and deposition of the offshore bituminous mudstones.

INTRODUCTION: STUDY AREA AND REGIONAL GEOLOGY

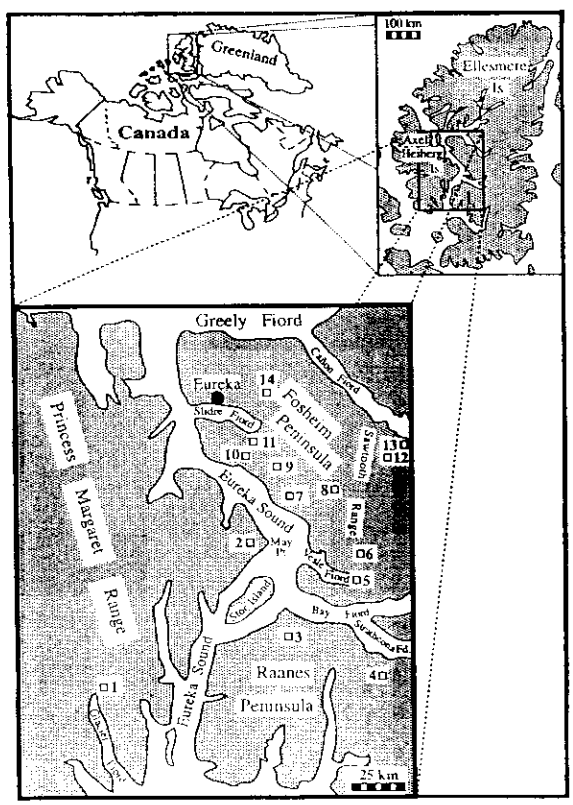

Fig. 1. Study area: southeastern Axel Heiberg and west-central Ellesmere Island. Reference numbers indicate sections included in this study and are located as follows:
A. Sections on Axel Heiberg Island:
1 - Glacier Fiord, 78°38'N, 89°55'W;
2 - May Point, 79°19'39"N, 85°32'27"W.
B. Sections on Ellesmere Island:
3 - Strathcona Fiord, 78°32'70'N, 82°54'55'W;
4 - Bay Fiord, 78°50'N, 85°28'W;
5 - Vesle Fiord, 79°02'07'N, 83°09'36'W;
6 - Mount James, 79°10'42'N, 83°00'45'W;
7 - Fosheim South, 79°26'59'N, 84°09'28'W;
8 - Sawtooth Range, 79°35'47'N, 83°33'58'W;
9 - Fosheim Anticline, 79°42'N, 84°45'W;
10 - Eureka Sound, 79°45'N, 85°36'W;
11 - Romulus Lake, 79°51'49'N, 85°19'16'W;
12 - Mount Bridgeman, 79°45'11'N, 82°39'12'W;
13 - Canon Fiord, 79°52'33"N, 82°14'16"W and
14 - Remus Creek, 79°56'N, 85°09'W.

The study area (Fig. 1) is included within the northeastern part of the Sverdrup Basin which contains a thick and relatively complete stratigraphic sedimentary package. Fourteen sections were included in this study. The Sverdrup Basin (Fig. 2) represents an active depocentre in the Arctic Islands from Carboniferous to Early Tertiary (Embry, 1991) and contains up to 13,000 m of strata (Balkwill, 1978). Tectonic activity in the early Tertiary ended deposition in this basin and folded and faulted the units of the eastern Sverdrup Basin providing with excellent outcrops. The Kanguk Formation is widespread in the Canadian Arctic and crops out in many areas of this basin and also in adjacent geological areas such as Banks and Eglinton basins, the Franlinian Mobile Belt, and the Arctic Platform (Fig. 2).

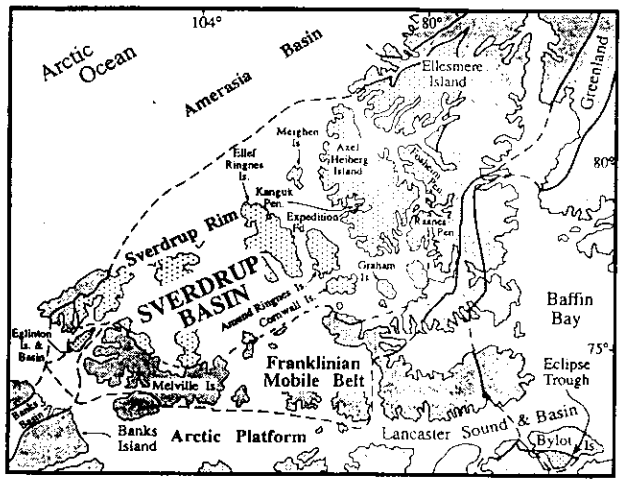

Fig. 2. Geographic and geologic map of the Canadian Arctic Archipelago. Structural provinces compiled and modified after Balkwill (1978), De Paor et al. (1989), and Embry, (1991).

The Sverdrup Basin covers most of the Canadian Arctic Archipelago. Presently it is approximately triangular in shape, almost 1,000 km long, and about 350 km wide at its widest point. This basin, a consequence of continental rifting and associated subsidence, has expanded and contracted several times, following mainly tectonic episodes.

Numerous transgressive-regressive cycles or depositional sequences can be recognized in the Sverdrup Basin (Embry and Prodruski, 1988). These sequences are usually represented by a regressive succession of marine shale and siltstone which coarsens upward into shallow marine and deltaic sandstones with subaerial unconformities on the basin margins marking the cycle boundaries (Embry, 1991). The youngest major marine sequence, the ?late Cenomanian/Turonian to Campanian/Maastrichtian cycle is constituted by the Kanguk Formation and, in most areas, the base of the overlying Eureka Sound Group (Expedition Formation). On northern Ellesmere Island the Hansen Point volcanics occur in the upper part of this sequence. This Upper Cretaceous depositional sequence is not only present in the Sverdrup Basin but also on the continental shelves and slopes of the Arctic Ocean and Baffin Bay, and in Lancaster Sound (Hea et al., 1980).

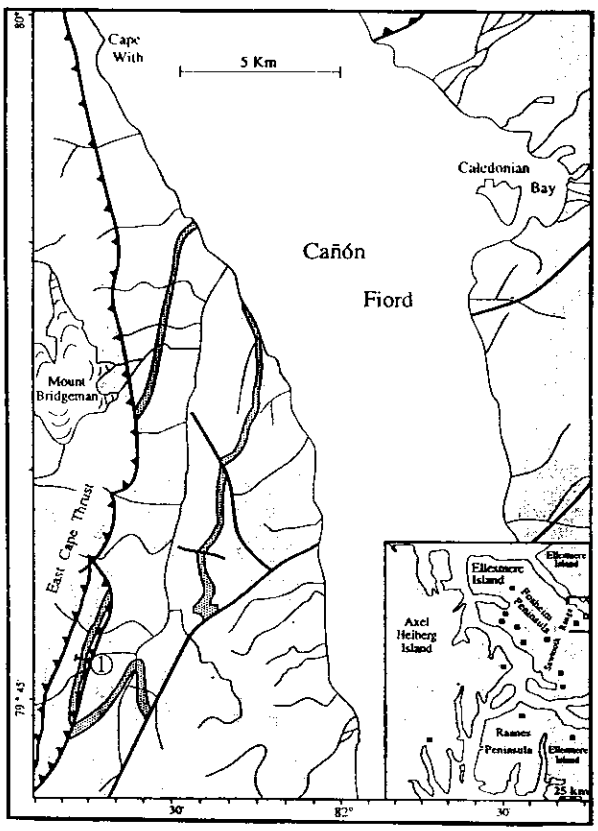

Fig. 3. Distribution of Kanguk Formation (dark band) in the vicinity of Canon Fiord, east-central Fosheim Peninsula, Ellesmere Island. (1) Mount Bridgeman section.

The Kanguk Formation rests unconformably on the Upper Albian Hassel Formation in most of the Sverdrup Basin. However, in some areas it rests on older strata. Yet, on southern Axel Heiberg Island another Upper Albian unit, the Bastion Ridge Formation, occurs between the Hassel and Kanguk formations, and on central Axel Heiberg Island the Strand Fiord volcanics intertongue and overly the Bastion Ridge Formation (Núñez-Betelu et al., 1994).

Generally the Kanguk Formation consists of dark, organic-rich mudstones in the lower part and claystones, siltstones, and very fine-grained sandstones in the upper part. The lower bituminous mudstones and interbedded bentonites were deposited in a disoxic to anoxic, low energy environment that permitted the accumulation of high rates of organic matter and a variety of marine palynomorph assemblages. The upper silty mudstones, siltstones, and sandstones record shallow shelf and close to shoreline facies with abundant life including a rich and diverse marine and terrestrial palynomorph assemblage, metresized inoceramids, big marine vertebrates, and other life forms. However, the easternmost sections of the Kanguk Formation include also mudstone to fine-grained sandstones, coarsening upward cycles in the lower part. Some of these cycles present paleosol development at top. These cycles are best developed at the Mount Bridgeman section (Fig. 3).

Also, locally on west-central Ellesmere Island there is an unconformity on top of the Kanguk Formation and the Expedition and Strand Bay formations (the lower units of the Eureka Sound Group) are missing. This unconformity is present usually within the Eureka Sound Group and is widespread in the Sverdrup Basin. It is

not only recognized within this Basin but also to the south including the Baffin Bay-Labrador-Scotian Shelf area. It represents a variable time hiatus that may span from Upper Maastrichtian to the Lower Danian in some areas (northern Baffin Bay) and from Campanian to Upper Paleocene in other regions (i.e. Fosheim Anticline locality, central Ellesmere Island).

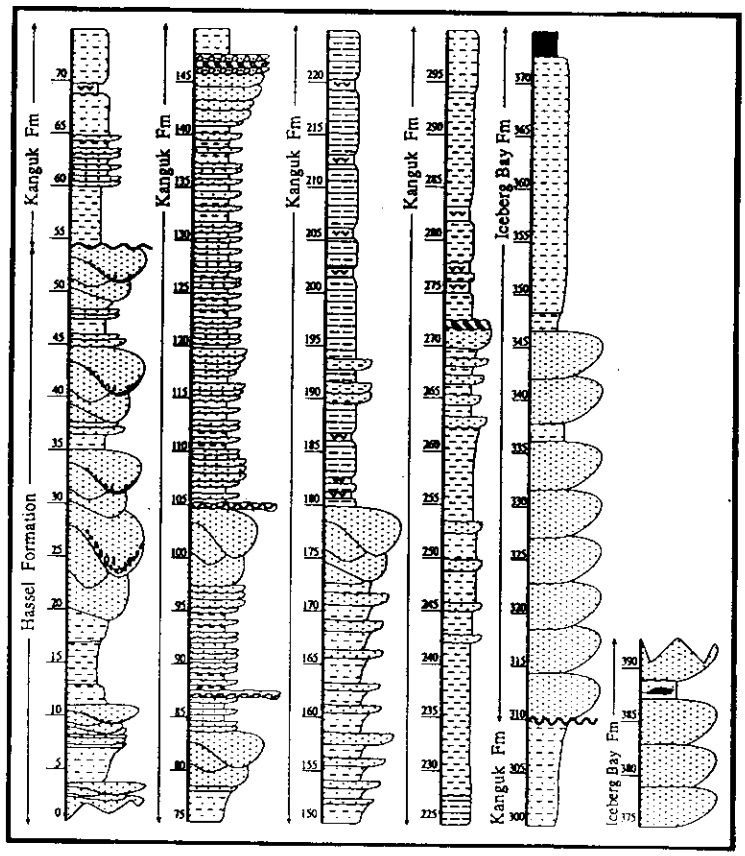

Fig. 4. Lithological summary of the Mount Bridgemen section, east-central Fosheim Peninsula, Ellesmere Island. This section includes the upper Hassel, Kanguk, and lower Iceberg Bay formations.

The two unconformities that bound the Upper Cretaceous depositional sequence have a tectonic origin, probably in relation with the adjacent Amerasia Basin (Embry, 1991). Other lower rank unconformities may be recognized in the basin but have a limited extent along the margins and are interpreted as a result of either eustatic sea level falls or minor tectonic episodes (Embry, 1991). These minor unconformities are not always lithologically expressed but can be recognized within the Kanguk Formation utilizing palynological analyses (Núñez-Betelu, 1991). These transgressive-regressive sequences may be equivalent to third-order depositional sequences and were probably generated by a combination of varying rates of eustatic sea-level changes, subsidence and uplift, and sediment supply. Yet, tectonism was probably the main factor in the origin of these sequences.

The Sverdrup Rim (Fig. 2), a linear high along the northwestern margin of the Sverdrup Basin, was intermittently exposed during the Mesozoic. In the Cretaceous renewed uplifting of the Sverdrup Rim formed basin-ward tapering unconformities. Renewed rifting in the nearby Amerasia Basin induced a period of broad thermal subsidence and marine incursion from the Turonian to the Campanian with deposition of the Kanguk Formation (Balkwill, 1978; Kerr, 1981; Embry, 1991). During the Turonian and Coniacian low supplies of bituminous muds and volcanic ash were deposited on the offshore shelf areas that constituted most of the basin. Sedimentation rates increased during the Santonian. In the Campanian tectonic pulses disturbed the eastern region of the Sverdrup Basin. At that time deltaic systems started prograding southward and westward as a result of the first episodes of the Eurekan orogeny.

MOUNT BRIDGEMAN SECTION

This section (79°45'11'N, 82°39'12'W) is located on eastern Fosheim Peninsula, on the east side of East side of East Cape Thrust, and about 7 km south of Mount Bridgeman (Fig. 3). The section is exposed on the south side of a steep hill, is continuous, and entirely exposed. This section is about 395 m thick and includes the upper Hassel (54 m), the Kanguk (256 m), and the lower Iceberg Bay (85 m) formations. These three units are separated by unconformities.

The Hassel Formation facies indicate several stages of upper delta development and deposition in shoreface to intertidal settings. The Kanguk Formation is very atypical and includes several cycles of coarsening-upward mudstones and silty sandstones in the lower half of the section (Fig. 4). These sandstones were deposited in a coastal setting with subaerial exposure and paleosol development. These sandstones were submerged and buried

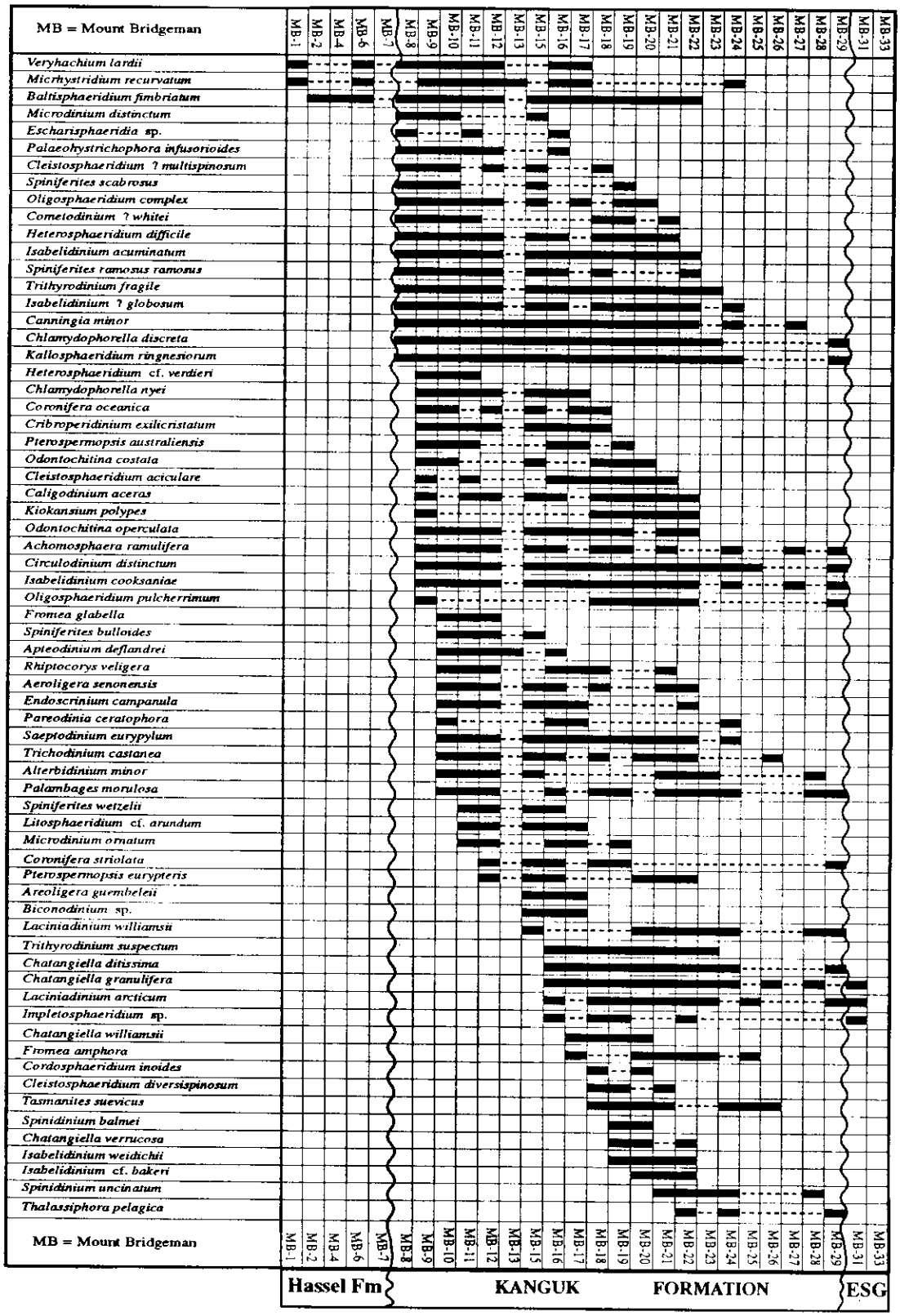

Fig. 5. Range-chart for selected marine palynomorphs of the Mount Bridgeman section, east-central Fosheim Peninsula, Ellesmere Island.

by offshore papery and blocky mud-stones several times as reflected by several coarsening upward cycles. Inoceramids are restricted to a short interval in the upper part. Bentonite beds are also present in this section. The lowest bentonite bed occurs interbedded with the silty mudstones of the first cycle. In this section a total of 15 bentonites are present and together contribute to a total thickness of 2.38 m.

The Iceberg Bay Formation rocks are very similar to the lower Iceberg Bay Formation on other localities of this study, and represent braided river sand flat and swamp deposites with coal beds An angular unconformity separates the Kanguk and the Iceberg Bay formations.

PALYNOLOGICAL ANALYSIS OF THE MOUNT BRIDGEMAN SECTION

Palynomorphs are common to abundant and very well preserved in samples from the Hassel, Kanguk, and Iceberg Bay formations. Palynological assemblages recovered from the Hassel and Iceberg Bay formations include almost exclusively terrestrial forms (spores, pollen and bisaccates). In contrast, marine palynomorphs (dinocysts and acritarchs) are consistently present throughout the Kanguk Formation samples. Marine assemblages dominate the lower part of the Kanguk Formation whereas terrestrial taxa dominate in the upper part. In overall terrestrial palynomorphs are slightly more abundant than marine individuals as expressed by the percentage of specimens whereas marine taxa are slightly more abundant than terrestrial forms in terms of percentage of species. However, if only the marine dominated part (approximately the lower 160 m of the Kanguk Formation at this section) is considered, then the marine palynomorphs are highly dominant whereas the terrestrial palynomorphs account for about only 20 to 25 % of the total both in percentage of specimens and in percentage of species. However, the opposite occurs in the upper part (upper 100 m) of the Kanguk Formation. Marine palynomorphs are dominant in the lower, coarsening-upward cycles and in the bituminous mudstones whereas they are a minority in the upper part of the Kanguk Formation. The base of the Kanguk Formation is Turonian in age based on the presence of dinocysts such as Apteodinium spp., Cribroperidinium spp. and Isabelidinium ? globosum (Núñez-Betelu and HIlls, 1992) whereas the top is rich in terrestrial palynoflora in part similar to the Campanian boreal complex of the Ust-Yenissey Subprovince I and Middle Yenissey Subprovince II of Siberia (Russia) as reported by Samoilovich (1966, 1967). This assemblage is considered to be Campanian in age based on the presence of a variety of Triprojectate pollen grains.

The samples for the Hassel Formation are dominated by terrestrial forms. Bisaccates are more abundant in terms of specimens in the first samples and decrease upwards but the percentage of species remains relatively constant for the Hassel samples. Acritarchs are the only indicator of a marine environment, these samples are very rich in terrestrial palynomorphs and very poor in marine taxa which are mainly acritarchs. The terrestrial palynomorph assemblage is dominated by spores such as Concavissimisporites spp., Impardecispora spp., and Triporoletes spp., and by Taxodiaceae pollen. This assemblage is similar to that reported by Hopkins and Balkwill (1973) and is considered to be late Albian in age. A drastic change from terrestrially dominated assemblages to marine dominated assemblages (Figs. 5 and 6) occurs at the Hassel/Kanguk Formation boundary. Many terrestrial taxa disappear and some reappear only higher in the sections, whereas many marine palynomorphs first occur at the base of the Kanguk Formation. The presence of a late Albian palynological assemblage in the upper Hassel samples and of a ? latest Cenomanian or Turonian assemblage within the Kanguk Formation documents the presence of a major unconformity between these two formations.

The Iceberg Bay Formation assemblages are dominated by terrestrial palynomorphs whereas the marine forms rapidly disappear. These marine taxa are considered to be reworked in these samples. In contrast with the Hassel samples the Iceberg Bay samples contain a very high percentage of pollen grains and a low percentage of spores. Bisaccates are common in the Iceberg Bay samples with a higher number of species than in the Hassel samples. These samples are very rich in gymnosperm pollen and some contain rare, reworked, poorly-preserved marine palynomorphs. These samples contain characteristic Cycadopites spp., Juglanspollenites spp., Miricipites spp., and abundant fungal spores and fruiting bodies. The palynological assemblage is similar to that from the TIb zone (Doerenkamp et al., 1976) of the Eureka Sound Formation on Banks Island that is Paleocene in age. This age assignment is also supported by the similar composition of assemblages reported from elsewhere in North America (i.e., Leffingwell, 1970; Rose and Srivastava, 1972). The difference in age between the Campanian upper Kanguk beds and the Paleocene Iceberg Bay Formation indicates the presence of a major unconformity between these two formations.

CONCLUSIONS

On eastern Fosheim Peninsula (central Ellesmere Island) thick sandstone beds interbedded with mudstones overlie the underlying Hassel Formation and occur, in part, interbedded with organic-rich, bituminous mudstones

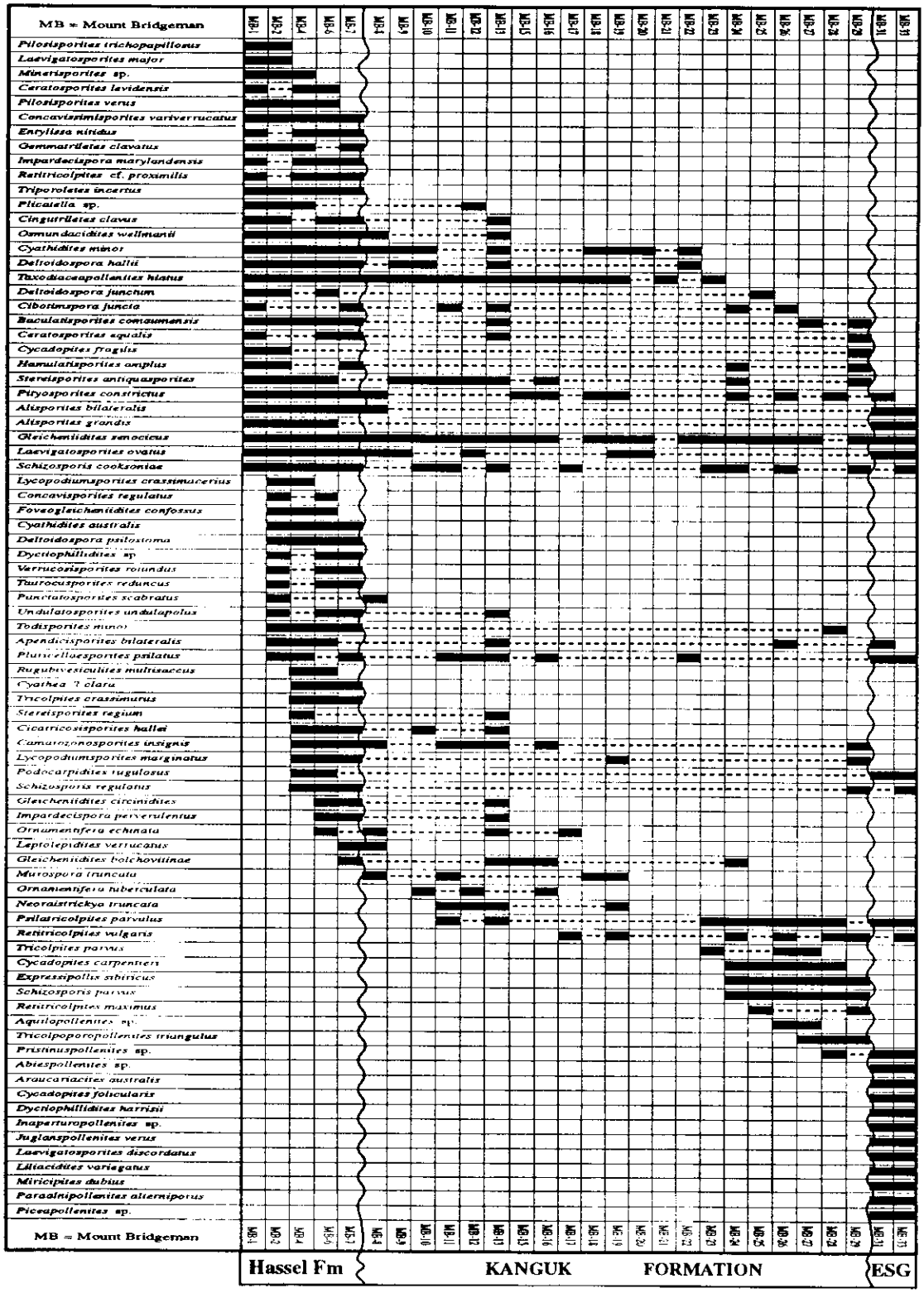

Fig. 6. Range-chart for selected terrestrial palynomorphs of the Mount Bridgeman section, east-central Fosheim Peninsula, Ellesmere Island.

of the lower Kanguk Formation. Based on their palynological content these muddy and silty sandstones are Turonian in age and contain assemblages very alike to those typical of the lower part of the Kanguk Formation,

and, therefore, are included in the Kanguk Formation. These sandstones represent coastal facies. Thus, the presence of these Turonian sandstones in the lower Kanguk Formation indicates shoreline depositional facies preserved in the Upper Cretaceous northeastern Sverdrup Basin.

The study of the palynological content of the top of the Hassel Formation, the Kanguk Formation, and the base of the Iceberg Bay Formation established the stratigraphic relationship between the sections. The palynological assemblages found in this study indicate the presence of major unconformities between the Hassel and Kanguk formations and between the Kanguk and Iceberg Bay formations.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the logistic support of Polar Continental Shelf Project. Financial support was provided by American Association of Petroleum Geologists, American Association of Stratigraphic Palynologists, Geological Society of America, Northern Scientific Training Program (Department of Indian and Northern Affairs, Government of Canada), and the University of Calgary (Thesis Research Grants) to L.K.Núñez-Betelu, and Natural Sciences and Engineering Research Council Grants in Aid of Research to Dr. L.V.Hills. We want to warmly thank Ms. L.Bloom and Ms. B.Rhoades, who efficiently processed the palynological samples.

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