The Eureka Sound Group of eastern Axel Heiberg Island: new data on the Eurekan Orogeny

Projects 850043 and 820035

B.D. Ricketts and D.J. McIntyre
Institute of Sedimentary and Petroleum Geology, Calgary

Ricketts, B.D. and McIntyre, D.J., The Eureka Sound Group of eastern Axel Heiberg Island: new data on the Eurekan Orogeny; in Current Research, Part B, Geological Survey of Canada, Paper 86-1B, p. 405-410, 1986.

Abstract

The stratigraphy of Tertiary conglomerate, sandstone, mudstone and lignite beds, which outcrop over a wide area of eastern Axel Heiberg Island, is reassessed. The deposits are considered to be synorogenic on the basis of structure (overthrust by older Sverdrup Basin units in the Stolz Thrust zone), lithology and palynology. The deposits are correlated with thick synorogenic conglomerates at Mokka Fiord, and are included in the Buchanan Lake Formation of the Eureka Sound Group. The timing of synorogenic sedimentation can now be interpreted as Middle Eocene, on the basis of well preserved palynofloras. The deposits accumulated in the Axel Heiberg foredeep, which was one of a series of orogenic foredeeps that developed along eastern Axel Heiberg Island and eastern Ellesmere Island.

Résumé

L'étude présente une réévaluation de la stratigraphie des couches tertiaires de conglomérat, de grès, de pélite et de lignite qui affleurent sur une grande région de l'est de l'île Axel Heiberg. La lithologie, la palynologie et la structure des dépôts, qui ont été chevauchés par les unités plus anciennes du bassin de Sverdrup dans la zone de charriage de Stolz, indiquent qu'ils seraient de nature synorogénique. Les dépôts ont été mis en corrélation avec d'épaisses couches de conglomérats synorogéniques au fjord Mokka, et font partie de la formation de Buchanan Lake du groupe d'Eureka Sound. Les palynoflores bien conservées indiquent que la sédimentation synorogénique aurait eu lieu durant l'Éocène moyen. Les dépôts se sont accumulés dans l'avant-fosse Axel Heiberg, qui faisait partie d'une série d'avant-fosses orogéniques formées le long de la partie est de l'île Axel Heiberg et de la partie est de l'île Ellesmere.

Introduction

Tertiary strata, distributed along eastern Axel Heiberg Island from Whitsunday Bay in the south, to Stang Bay (Fig. 43.1), provide information that is critical to an understanding of depositional and tectonic relationships during the latest stages of Sverdrup Basin evolution. In particular, thick sequences of conglomerate and sandstone from areas such as Mokka Fiord and Whitsunday Bay diapir, where coarse diabasic debris was shed off east-directed thrust blocks, have long been recognized as synorogenic (Tozer, 1960). An extensive swath of conglomerate and sandstone also underlies a broad alluvial plain between Mokka Fiord and Stang Bay, and east of Geodetic Hills, that originally was mapped as Eureka Sound Formation by Thorsteinsson and Tozer (Thorsteinsson, 1971). Exposures due east of Geodetic Hills and northwest of Stang Bay were later mapped as latest Tertiary, Beaufort Formation by Balkwill and Bustin (1975) and Bustin (1982).

During 1985, several aspects of the stratigraphy, structure and palynology of the deposits on eastern Axel Heiberg Island were re-examined. Our results indicate that all of the deposits belong to the Eureka Sound Group (Buchanan Lake Formation; see Ricketts, 1986, this volume, for definition of new formations) and previous assignment of the strata to the Beaufort Formation is likely in error. Furthermore, our data show that these deposits can now be dated as Middle Eocene, thus placing much more severe constraints on the timing of Eurekan deformation.

Distinguishing features of the Beaufort Formation

The name Beaufort Formation was formally introduced by Tozer (1956) for sand and gravel deposits exposed on Prince Patrick Island, and has since been extended to similar deposits at other localities in the western Arctic and islands of the Arctic Coastal Plain: for example, Meighen Island (Thorsteinsson, 1961), Banks Island (Thorsteinsson and Tozer, 1962), and Melville Island (Tozer, 1970). Beaufort strata overlie Eureka Sound Group and older Mesozoic units of Sverdrup Basin unconformably. Typically, the Beaufort Formation consists of unconsolidated sands and gravels that commonly contain uncompressed, unaltered wood. Well preserved cones of pine and spruce (**Picea banksii** Hills and Ogilive), and the fossil walnut **Juglans eocinera** Hills, Klovan and Sweet, have also been found on Banks Island (Hills and Ogilvie, 1970; Hills et al., 1974).

Strata exposed in the area of Geodetic Hills and Stang Bay, and included in the Beaufort Formation by Bustin (1982), also contain spruce cones that, despite some morphological differences, have been equated, along with the examples from Banks Island, with **Picea banksii** (Hills and Bustin, 1976). However, apart from this apparent similarity in cone type, there are few other similarities between the typical Beaufort of western Arctic, and that designated as Beaufort on Axel Heiberg Island. In the sections that follow, the important differences in lithology and structure are discussed.

Lithological criteria

Recent investigations indicate that the conglomerate, sandstone and coal deposits exposed in ridges and stream-cuts due east of Geodetic Hills, are identical to deposits that cover the entire area mapped as Eureka Sound Group, both north of Stang Bay, and on the broad alluvial plain north of Mokka Fiord. Representative stratigraphic sections from these localities are illustrated in Figure 43.2. Furthermore, the lithotypes are also remarkably similar to those of conglomerates exposed in the footwall of the Stolz Thrust zone at both Mokka Fiord and Whitsunday Bay diapirs. The last two examples are here considered to be some of the youngest deposits in the Eureka Sound Group; they are synorogenic, formed from coarse diabase debris shed from uplifted and thrust faulted Triassic rock farther west, and are themselves overthrust within the Stolz Thrust zone (Tozer, 1963; Balkwill, 1978; Bustin, 1982).

The sequence east of Geodetic Hills has been described by Bustin (1982). Very thick conglomerates, possibly greater than 1000 m thick, occur in a graben between Geodetic Hills and Stolz Thrust; the strata of the sequence dip to the west at 30 to 35°. The degree of induration is reflected in the high ridges and steep, stream-cut bluffs that are incised into the conglomerates. Conglomerate frameworks are clast supported, with cobbles and boulders (mostly diabase) moderately to well rounded. Similar fabrics are observed in thick grey diabase conglomerate at Mokka Fiord.

As indicated in Figure 43.2, most of the sequence along eastern Axel Heiberg Island is made up of conglomerate units, several metres thick, that are interbedded with units of lithic arenite and a few thin lignite seams; fining-upward sequences are common. Trough, planar and ripple cross-bedding abound, along with frequent indications of channeling. As Bustin (1982) has reported, the transition from the more massive, thick conglomerate facies, to the interbedded conglomerate-sandstone facies, is not exposed at Geodetic Hills because of faulting. However, this transition was observed in vertical sections in the area of Mokka Fiord.

A third lithofacies, that Bustin (1982) referred to as the sandstone-mudstone-siltstone facies, occurs in the Geodetic Hills area. The principal exposure of this facies is on a prominent ridge approximately 25 km northeast of Geodetic Hills, and contains thinly interbedded grey mudstone and fine grained sandstone, with numerous lignite seams. These seams contain abundant cones and leaf fossils of **Metasequoia**, and subordinate numbers of spruce cones and broad leaf angiosperms. Rather than being laterally equivalent to the conglomerate-sandstone facies, as suggested by Bustin, the coal-bearing strata, in fact, occur stratigraphically above them.

Comparison of the eastern Axel Heiberg deposits with typical Beaufort strata in the western Arctic Archipelago illustrates some important differences:

1. Some of the conglomerates and sandstones are weakly consolidated; however, the majority, including the thick conglomerates at Geodetic Hills and several calcite cemented units at Stang Bay, show degrees of lithification that are considerably greater than "typical" Beaufort. The degree of lithification is similar to that of some of the sandstones in other areas of Eureka Sound Group exposure, particularly in the uppermost sandstone units of the Iceberg Bay Formation on Fosheim Peninsula.

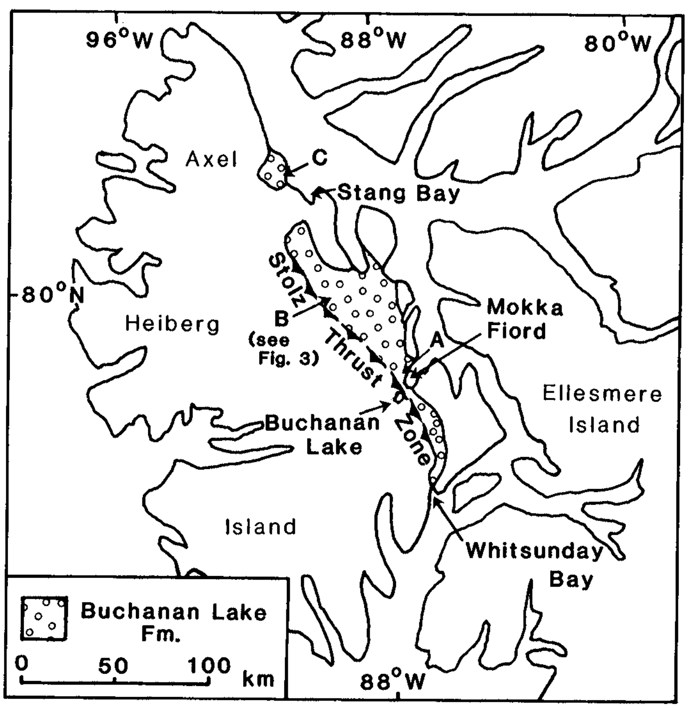

Figure 43.1. Map showing the general location of conglomerate-bearing strata on Axel Heiberg Island, and the stratigraphic sections A, B and C in Figure 43.2.

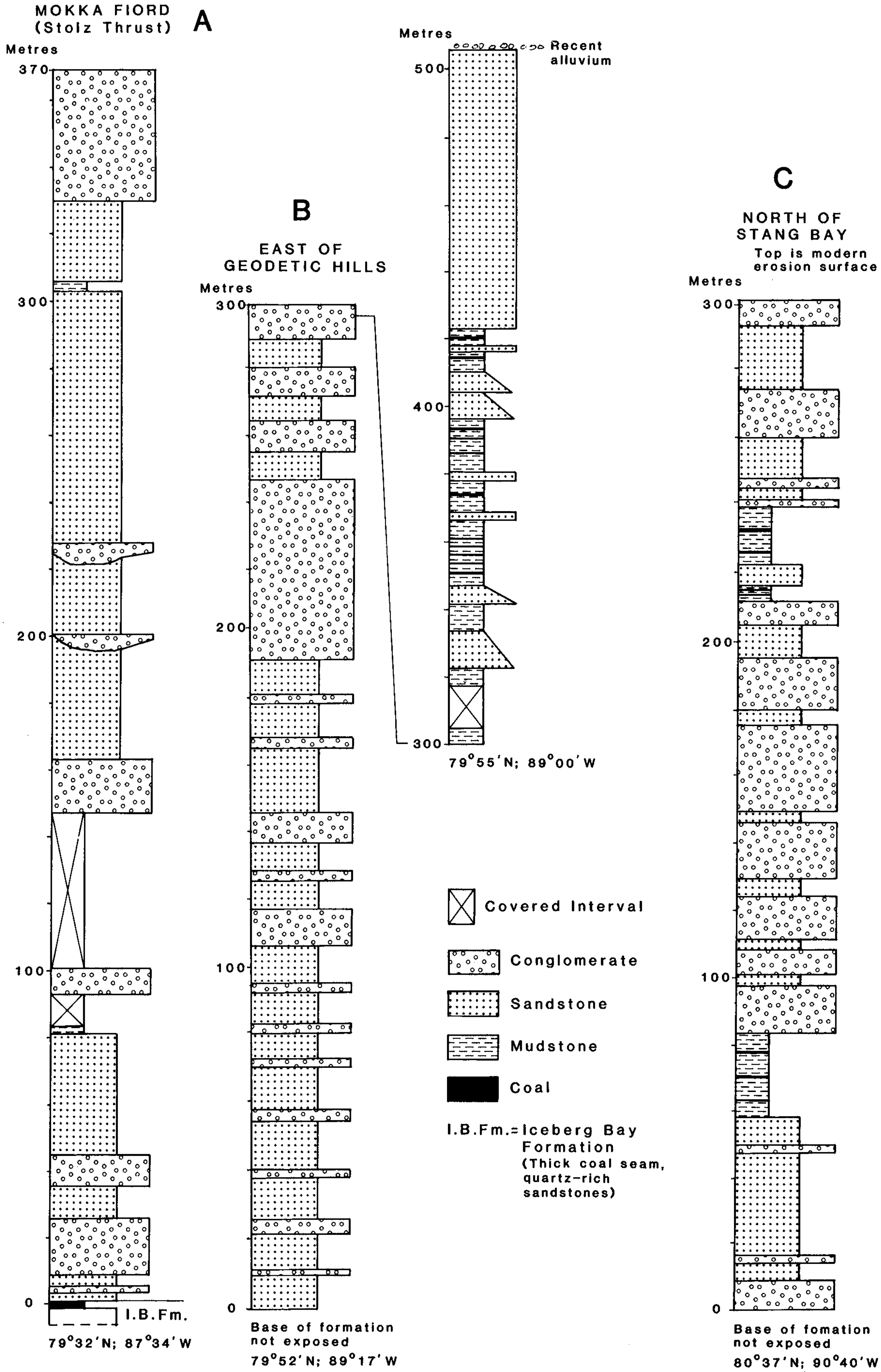

Figure 43.2. Three generalized stratigraphic sections of the Tertiary conglomerate-bearing sequence at Mokka Fiord (A), Geodetic Hills area (B), and north of Stang Bay (C). Note that section (B) is composite.

2. Wood, associated with the lignite beds, commonly is highly compressed (up to 10/1). Much of this wood is altered to low grade lignite, although there is some relatively unaltered wood similar to that present in the Beaufort Formation. This wood can be compared with wood altered to low grade lignite, which occurs in the weakly lithified sandstones at the top of the Eureka Sound Group at Hot Weather Creek. Some beds, especially channel-fill sandstones and conglomerates, contain large wood fragments that are completely mineralized, and are remarkably similar to mineralized wood in the Eureka Sound Group (especially the Iceberg Bay Formation). It is in these beds that the best preserved spruce cones are found.

Structural criteria

Structural and stratigraphic relationships are complex in the area of Geodetic Hills and in the hanging wall of Stolz Thrust (Fig. 43.3). On the original 1:250,000 scale map (Strand Fiord map sheet of Thorsteinsson, 1971), the northern end of Stolz Thrust was depicted as a splay of three normal faults, and the extension of the thrust trace was a fault with an opposite sense of displacement (downthrown to the west). A more logical extension of the thrust would be the easternmost fault of the splay (downthrown to the east). During the present investigation, an overthrust relationship was observed here, with Triassic strata (Blaa Mountain Group and Heiberg Formation) occurring over the Tertiary conglomerate and sandstone (Fig. 43.3). The thrust plane dips to the west at about 30°. Thus a relationship can reasonably be inferred between the thrusting and deposition of the diabase-rich conglomerates that were derived by erosion of the sills and dykes that abound in the Triassic strata.

The small graben situated east of Geodetic Hills and in the hanging wall of Stolz Thrust (Fig. 43.3), is structurally complex. Here, thick conglomerate overlies, in succession, white sandstone and dark grey shale of the Isachsen and Christopher formations. This implies that differential movement and erosion of older Sverdrup Basin strata took place prior to conglomerate deposition and, therefore, also preceded the main phase of faulting on Stolz Thrust.

Differential movement within the conglomerate-sandstone sequence outboard (east) of Stolz Thrust is also indicated, where thick conglomerate beds exposed near the snout of a large glacier (Fig. 43.3), occur at a topographically lower level than equivalent strata on the adjacent ridge; either there is a substantial east-northeast striking fault, or a broad, open fold within the Tertiary sequence. Large-scale faulting or folding, which resulted in rotation of strata to dips exceeding 40°, also occurs in the area north of Stang Bay.

Palynology

Samples for palynological study were collected from intervals of suitable lithology from each of the stratigraphic sections (Fig. 43.2). The characteristics of the pollen assemblages are summarized in this section; details of the assemblages will be presented in a later publication.

In general, the samples examined contain rich, diverse and well preserved pollen assemblages that are similar to the Middle Eocene microfloras found in the highest stratigraphic levels of sections at Strand Fiord (Axel Heiberg Island) and Strathcona Fiord (Ellesmere Island); viz. the Iceberg Bay Formation.

In the section east of Geodetic Hills, the eight samples from lignite seams and grey mudstone beds, found in the upper 200 m of the Buchanan Lake Formation, yielded rich pollen floras. Common constitutents of the assemblages include pollen of **Picea** (occasionally abundant), **Pinus, Tsuga** (rare to common), Taxodiaceae (including **Sequoiapollenites**), **Alnus** and **Betula** (both usually abundant), **Carya** and **Tilia** (both often abundant), **Juglans** (common near top of section), Ericaceae, **Liliacidites, Ulmus** and **Quercus.** Other pollen that may be present includes **Nyssapollenites, Engelhardtia,** **?Fagus** and **Tricolporopollenites kruschii** (of Rouse, 1977). Abundant **Metasequoia** cones and leaves and some **Picea** cones occur in some intervals of this section. Reworked palynomorphs (Cretaceous pollen and dinoflagellates, Late Paleozoic spores) are rare in the Geodetic Hills section and are readily distinguished from autochthonous forms.

The Geodetic Hills pollen assemblages are similar to those recorded from Middle and Late Eocene by Rouse (1977) and differ significantly from Oligocene assemblages documented by Peil (1971), Rouse (1977) and Ioannides and McIntyre (1980). **Carya viridifluminipites** (Wodehouse) Wilson and Webster and **C. veripites** Wilson and Webster (both often abundant in Geodetic Hills samples) are common in both the Eocene and Oligocene of the Arctic, whereas **Tilia vescipites** Wodehouse, usually common in Geodetic Hills samples, and **T. crassipites** Wodehouse were not recorded from the Oligocene in the Arctic by Rouse (1977) although they occur in Oligocene strata in other parts of Canada. Hills et al. (1974) noted, however, the presence of **Tilia** in the Beaufort Formation from northwestern Banks Island. Other pollen types present, which are common in both Eocene and Oligocene strata, include **Tsuga, Juglans** and **?Fagus.** Rouse (1977) recorded **Fagus** no earlier than Late Eocene and **Juglans** from Lower-Middle Eocene. **Tsuga** and **Juglans** were recorded from Lower or Middle Eocene by Ioannides and McIntyre (1980). Pollen of **Engelhardtia** type (**Momipites coryloides** Form A of Rouse, 1977) is common in a

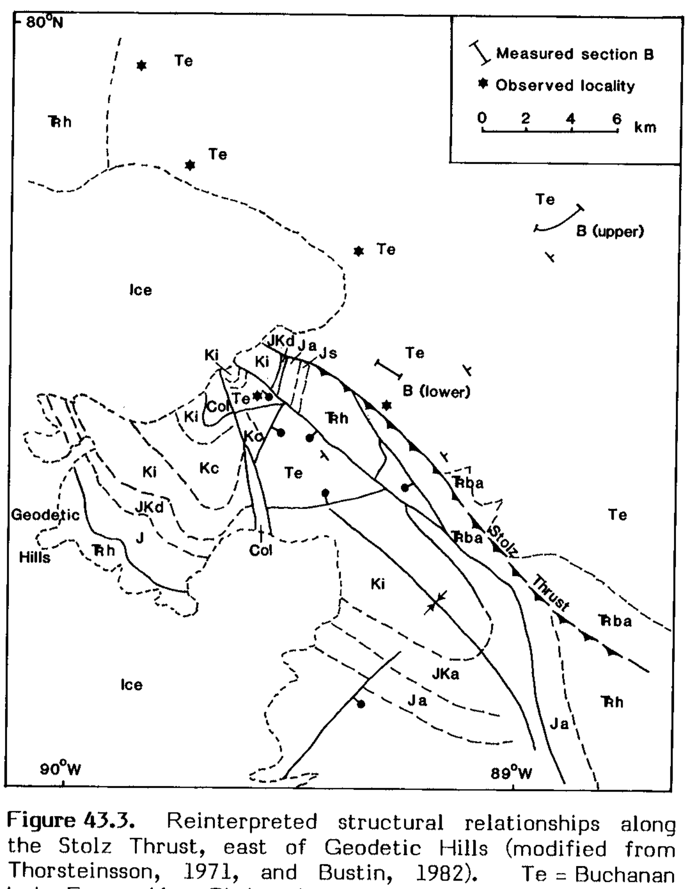

Figure 43.3. Reinterpreted structural relationships along the Stolz Thrust, east of Geodetic Hills (modified from Thorsteinsson, 1971, and Bustin, 1982). Te = Buchanan Lake Fm.; Kc = Christopher Fm.; Ki = Isachsen Fm.; JKd = Deer Bay Fm.; Ja = Awingak Fm.; Js = Savik Fm.; TRh = Heiberg Group; TRba = Blaa Mountain Group; Col = Diapirs. Extensional faults have downthrown block indicated; Stolz Thrust has teeth on upthrust block.

few samples. This type differs from Paleocene forms of **Momipites** and is apparently restricted to the Eocene and possibly Oligocene of northern Canada. **Tricolporopollenites kruschii** was recorded from the Lower-Middle Eocene by Rouse (1977). Species characteristic of the Oligocene (Piel, 1971; Rouse, 1977; Ioannides and McIntyre, 1980) were not seen in the Geodetic Hills samples. However, the Lower-Middle Eocene **Lonicera**-type of Rouse (1977) occurs rarely and the onagraceous pollen recorded by Ioannides and McIntyre (1980), from Paleocene to Middle Eocene strata of the Caribou Hills section of the Mackenzie Delta area, is common in some samples. The presence of **Pistillipollenites mcgregorii** Rouse, not known from rocks younger than Middle Eocene, provides further important evidence for an Eocene age. The palynological evidence, therefore, indicates that the Geodetic Hills samples examined are most likely of Middle Eocene age. There is no evidence that the uppermost part of the section is as young as Late Eocene. Palynological assemblages from the Beaufort Formation of Miocene-?Pliocene age were discussed briefly by Craig and Fyles (1960) and Hills et al. (1974). The Beaufort assemblages, however, are apparently less varied than Eureka Sound assemblages and lack the distinctive Eocene pollen forms recorded in the Geodetic Hills material.

In the section north of Stang Bay, lignite seams and mudstone beds compose the upper components of fining-upward sequences of conglomerate and sandstone. The pollen assemblages here are similar to those from Geodetic Hills but are of slightly lower diversity. Reworked Cretaceous palynomorphs are rare in the Stang Bay section. The presence of pollen of **Tsuga, Juglans, Tilia vescipites** and **T. crassipites** together suggests a Middle Eocene age. Onagraceous pollen and **Saxonipollis**, both recorded up to Middle Eocene by Ioannides and McIntyre (1980) provide further evidence for Middle Eocene age.

Sections at Mokka Fiord contain lignite only as discontinuous stringers; mudstones occur locally but comprise only a very small proportion of the succession. Pollen assemblages are similar to those from Geodetic Hills but generally contain fewer specimens, although **Carya viridifluminipites, Alnus** and Taxodiaceae may be abundant. Reworked Cretaceous spores, pollen and dinoflagellates are abundant in some of the samples. Paleozoic spores may also be present and samples near the top of the section contain some Paleocene pollen, including **Caryapollenties wodehousei** Nichols and Ott, which is also considered to be reworked. The presence of **Tilia vescipites** (sometimes abundant), **Tricolporopollenites kruschii, Pistillipollenites mcgregorii** and **Juglans** indicates that the Mokka Fiord deposits are also of Middle Eocene age.

Conclusions

Important differences in lithology, structure and palynology exist between the Tertiary conglomerate deposits of eastern Axel Heiberg Island, and the Beaufort Formation of the western Arctic. In particular, overthrust relationships observed at Geodetic Hills indicate that the episode of syntectonic sedimentation was the same as that inferred for the Mokka Fiord and Whitsunday Bay areas. All of the criteria presented here demonstrate that the Tertiary strata of eastern Axel Heiberg Island should be equated with syntectonic units of the Eureka Sound Group (Fig. 43.4), representing deposition during the Eurekan Orogeny. Therefore, conglomerate-bearing strata at Geodetic Hills, Stang Bay and other areas of eastern Axel Heiberg Island belong to the Buchanan Lake Formation, and correlate with similar synorogenic units at Lake Hazen, Franklin Pierce Bay and Judge Daly Peninsula.

In previous investigations, the age of Eurekan deformation has been bracketed between Middle Eocene (the date of the youngest typical Eureka Sound Group), and Early Miocene (an age based primarily on the oldest Beaufort Formation that unconformably overlies Eureka Sound rocks). The lignite seams on eastern Axel Heiberg that are part of the syntectonic deposits contain well preserved pollen floras

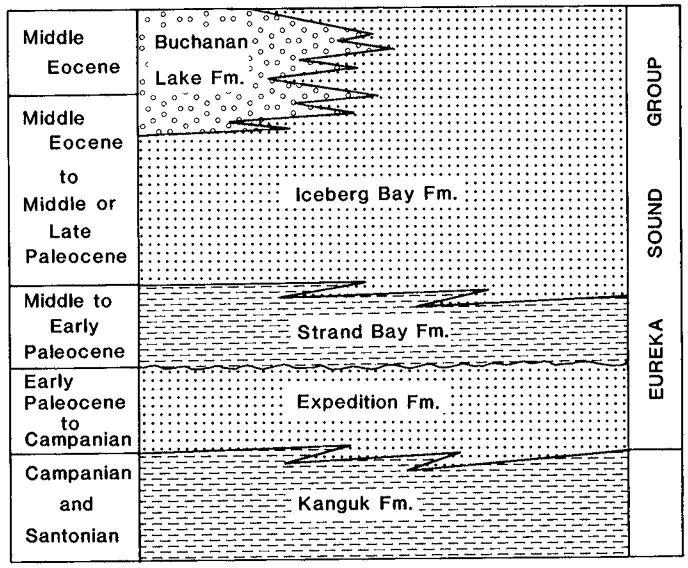

Figure 43.4. Formations of the Eureka Sound Group (see Ricketts, 1986 for details).

that suggest an age range restricted to Middle Eocene. This indicates that thrusting and folding was well underway by the end of the Eocene, but does not preclude the possibility that deformation continued into the Oligocene.

Indications of a much younger (Miocene) age for the conglomerate-bearing sequence on Axel Heiberg Island (Balkwill and Bustin, 1975; Hills and Bustin, 1976) were based primarily on the presence of cones identified as **Picea banksii.** The genus **Picea**, however, occurs throughout the Tertiary, but cones are rarely found in the older strata (compared to Beaufort strata). In comparing the Axel Heiberg spruce cones with **P. banksii** from Beaufort deposits

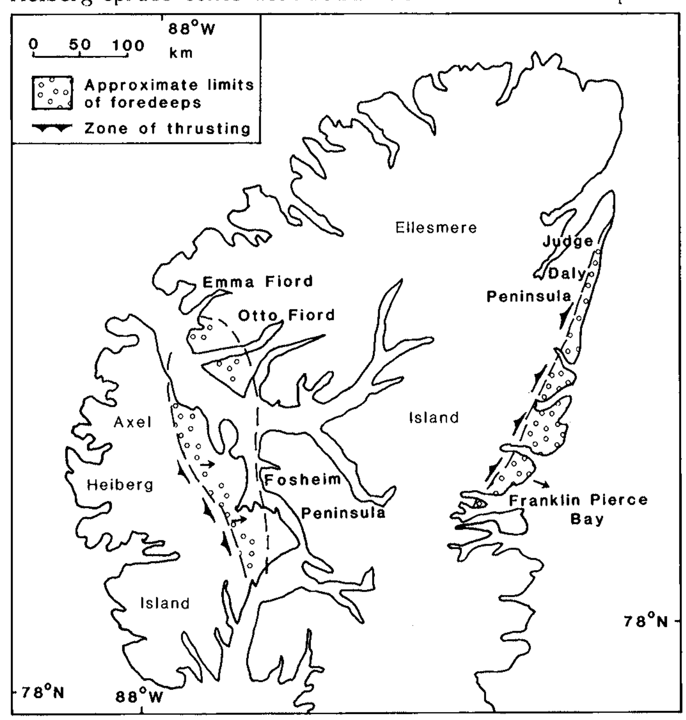

Figure 43.5. The location of orogenic foredeeps on Axel Heiberg and Ellesmere islands, shown schematically. The western limit of the Axel Heiberg foredeep is approximated by the Stolz Thrust zone. The eastern limits are unknown, but can reasonably be inferred to have been no farther east than Fosheim Peninsula, on the basis of lateral facies changes in the conglomerates, and the stratigraphic level of Eureka Sound Group strata exposed on north Fosheim. Thick conglomerates at Otto Fiord and Emma Fiord may represent the northern limits of the Axel Heiberg foredeep.

on Banks Island, Hills and Bustin (1976) noted considerably greater morphological diversity in the Axel Heiberg examples, and attributed these differences to environmental stress; differences in age were discounted. In view of our results, the validity of using this spruce flora in biostratigraphic determinations needs to be reassessed. Either **P. banksii** occurs in deposits that are older than Beaufort Formation, or the cones on Axel Heiberg Island are not comparable to **P. banksii**, but to a different **Picea** species. Bustin (1982) also used microfloral results to support the Miocene/(?)Pliocene Beaufort Formation interpretation but did not provide details of the assemblages. Re-examination of these samples shows that the assemblages are also Eocene and do not suggest a younger age.

Implications for tectonic history

Reworked Lower and Upper Cretaceous, older Mesozoic, and Paleozoic palynomorphs are relatively common in the conglomerate deposits at Mokka Fiord. Notably, some reworked Paleocene pollen was also found in a few samples. Sediment transport directions, inferred from crossbed measurements (Bustin, 1982; this study) indicate that the bulk of the syntectonic sequence on eastern Axel Heiberg Island was derived from a terrane farther west. The source rocks apparently ranged in age from Devonian to Paleocene, and therefore would have included reworked Eureka Sound Group strata from central and/or western Axel Heiberg; the younger Sverdrup Basin strata were subsequently stripped from the central Princess Margaret Range.

The coarse grained deposits on eastern Axel Heiberg Island (viz. Buchanan Lake Formation), represent alluvial fan and braidplain sedimentation, where debris was shed east and southeast from uplifted and thrust faulted Mesozoic (and possibly older) strata. Thus, the sedimentary basin can be considered as an orogenic foredeep and is informally referred to here as the Axel Heiberg foredeep. The broadly east-dipping paleoslope also represents a complete reversal of the basin configuration that prevailed during much of the earlier Eureka Sound Group sedimentation in the western Ellesmere Island region. The Axel Heiberg foredeep extended from somewhere north of Stang Bay, almost to the southern end of Axel Heiberg Island (Fig. 43.5).

Correlative conglomerate-bearing strata on eastern Ellesmere Island (Franklin Pierce Bay to Judge Daly Peninsula) also represent sedimentation in an east-southeast dipping foredeep, which developed outboard of the Parrish Glacier Thrust and associated faults, during the Eurekan Orogeny (Fig. 43.5).

Eureka Sound Group sedimentation in the Axel Heiberg foredeep may have ended by Middle Eocene time. A main phase of faulting and folding, which represents the Eurekan Orogeny, was well underway by the end of the Eocene.

The previous designation of the Axel Heiberg conglomerates, as Beaufort Formation of Miocene or younger age, implied an episode of considerable post-orogenic faulting and folding (or rotation of fault blocks). Much of this faulting can now be attributed to the Eurekan Orogeny. However, this does not preclude the possibility of younger extensional faulting. It appears now that deposits correlative with the Beaufort Formation are restricted or possibly absent in the eastern Arctic (onshore).

References

Balkwill, H.R.
1978: Evolution of Sverdrup Basin, Arctic Canada; American Association of Petroleum Geologists, Bulletin, v. 62, p. 1014-1028.

Balkwill, H.R. and Bustin, R.M.
1975: Stratigraphic and structural studies, central Ellesmere Island and eastern Axel Heiberg Island, District of Franklin; in Current Research, Part A, Geological Survey of Canada, Paper 75-1A, p. 513-517.

Bustin, R.M.
1982: Beaufort Formation, eastern Axel Heiberg Island, Canadian Arctic Archipelago; Bulletin of Canadian Petroleum Geology, v. 30, p. 140-149.

Craig, B.G. and Fyles, J.G.
1960: Pleistocene geology of Arctic Canada; Geological Survey of Canada, Paper 60-10.

Hills, L.V. and Bustin, R.M.
1976: **Picea banksii** Hills and Ogilvie from Axel Heiberg Island, District of Franklin; in Current Research, Part B, Geological Survey of Canada, Paper 76-1B, p. 61-63.

Hills, L.V. and Ogilvie, R.T.
1970: **Picea banksii** n. sp., Beaufort Formation (Tertiary), Banks Island, Arctic Canada; Canadian Journal of Botany, v. 48, p. 457-464.

Hills, L.V., Klovan, J.E., and Sweet, A.R.
1974: **Juglans eocinerea** n. sp., Beaufort Formation, southwestern Banks Island, Arctic Canada; Canadian Journal of Botany, v. 52, p. 65-90.

Ioannides, N.S. and McIntyre, D.J.
1980: A preliminary palynological study of the Caribou Hills outcrop section along the Mackenzie River, District of Mackenzie; in Current Research, Part A, Geological Survey of Canada, Paper 80-1A, p. 197-208.

Piel, K.M.
1971: Palynology of Oligocene sediments from central British Columbia; Canadian Journal of Botany, v. 49, p. 1885-1920.

Ricketts, B.D.
1986: New formations in the Eureka Sound Group; in Current Research, Part B, Geological Survey of Canada, Paper 86-1B.

Rouse, G.
1977: Paleogene palynomorph ranges in western and northern Canada; in Contributions of Stratigraphic Palynology, volume 1, Cenozoic Palynology; American Association of Stratigraphic Palynologists, Contribution Series No. 5A, p. 48-65.

Thorsteinsson, R.
1971: Geology, Strand Fiord, District of Franklin; Geological Survey of Canada, Map 1301A.

1961: History and geology of Meighen Island; Geological Survey of Canada, Bulletin 75.

Thorsteinsson, R. and Tozer, E.T.
1962: Banks, Victoria and Stefansson Islands, Arctic Archipelago; Geological Survey of Canada, Memoir 330.

Tozer, E.T.
1956: Geological reconnaissance Prince Patrick, Eglinton and western Melville Islands, Arctic Archipelago, Northwest Territories; Geological Survey of Canada, Paper 55-5.

1960: Summary account of Mesozoic and Tertiary stratigraphy, Canadian Arctic Archipelago; Geological Survey of Canada, Paper 60-5.

1963: Mesozoic and Tertiary stratigraphy, western Ellesmere Island and Axel Heiberg Island, District of Franklin; Geological Survey of Canada, Paper 63-30.

1970: Mesozoic and Cenozoic; in Geology and Economic Minerals of Canada, ed. R.J.W. Douglas; Geological Survey of Canada, Economic Geology Report no. 1, p. 574-589.