A geological case for movement between Canada and Greenland along Nares Strait

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Nares Strait, part of a 1400 km long lineament between Canada and Greenland, may be one arm (along with Lancaster Sound and Baffin Bay) of a triple junction.

Study of the geological literature on the area from northern Baffin Island to northern Greenland revealed a number of possibly important markers and structural features. The most important of these are: 1) the structural boundary between deformed and undeformed rocks at the margin of the Palaeozoic fold belt of northern Ellesmere Island and Greenland and 2) the large asymmetrical northwest-trending graben systems of northern Baffin Island and Greenland, whose fault blocks tilt to the northeast and southwest respectively. Correlation of these features across Nares Strait suggests that movement along the Strait of a minimum of 200 km has occurred since the mid-Palaeozoic, and a maximum of 300 km since late Precambrian times. It seems probable that the movement occurred in a number of episodes, beginning with rifting in the Proterozoic and ending in the Tertiary Eurekan orogeny.

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This paper is based on an M.Sc. thesis (Newman 1977, see also Newman, this volume) the geological part of which centred on an extensive literature survey that covered the northern Baffin Bay – Nares Strait region (Fig. 1). This survey was conducted largely during 1976–1977. The conclusions of this work, therefore, do not take into account most of the work carried out and published on the region since 1977. One purpose of the study was to see if, by obtaining a broad overview of the geology of the entire region, any correlations relating to movement along Nares Strait missed by people working on a more detailed scale, might become apparent.

This paper is not intended to be a detailed description of the pro-movement geological criteria. It is simply to direct attention to a few apparently major problems with a direct, no-movement correlation across Nares Strait, and to propose a possible alternative solution for discussion.

Detailed descriptions of the geology of the region have been published elsewhere and in this volume, e.g. Thorsteinsson & Tozer (1970) and Dawes (1976) give good overall coverage of the Canadian and Greenland sides of Nares Strait, respectively. Hence, there follows only a brief simplified description of the regional geological and tectonic setting (and condensed reference list) in order to set a general base for discussion.

Outline of regional tectonics

Reconstructions based primarily on interpretation of magnetic lineations in the Labrador Sea, the North Atlantic and the Arctic Ocean (Kristoffersen & Talwani 1977, Le Pichon et al. 1977, Srivastava 1978) suggest that there was some movement of Greenland with respect to Canada. Burke & Dewey (1973) proposed the existence of a plume-generated triple junction southeast of Devon Island. According to them, one arm spread and became Baffin Bay; one became inactive before spreading (Lancaster Sound); and left-lateral transform motion occurred along the third (Nares Strait).

There is little direct evidence for spreading in Baffin Bay. No definite central ridge has been found, though Keen et al. (1972) and Johnson (1971) mentioned a possible ridge in northern Baffin Bay. Jackson et al. (1979) showed that magnetic lineations could be mapped in Baffin Bay, and suggested that the anomalies fitted numbers 13 to 21. The crust in the central part of the Bay is oceanic (Keen et al. 1971) and spreading or opening of some sort could have occurred in Baffin Bay at approximately the same time as known Tertiary spreading in the Labrador Sea (Kristoffersen & Talwani 1977, Srivastava 1978). Martin (1973) suggested that the oceanic crust, like that of the Red Sea, is a product of rifting rather than spreading.

The inactive arm of the proposed triple junction, Lancaster Sound, is bounded by steep faults and contains a thick (about 10 km) sedimentary sequence similar to that of aulacogens (Jackson et al. 1977).

Some of the geological evidence for lateral motion along the third arm of the possible triple junction, Nares Strait, is examined here.

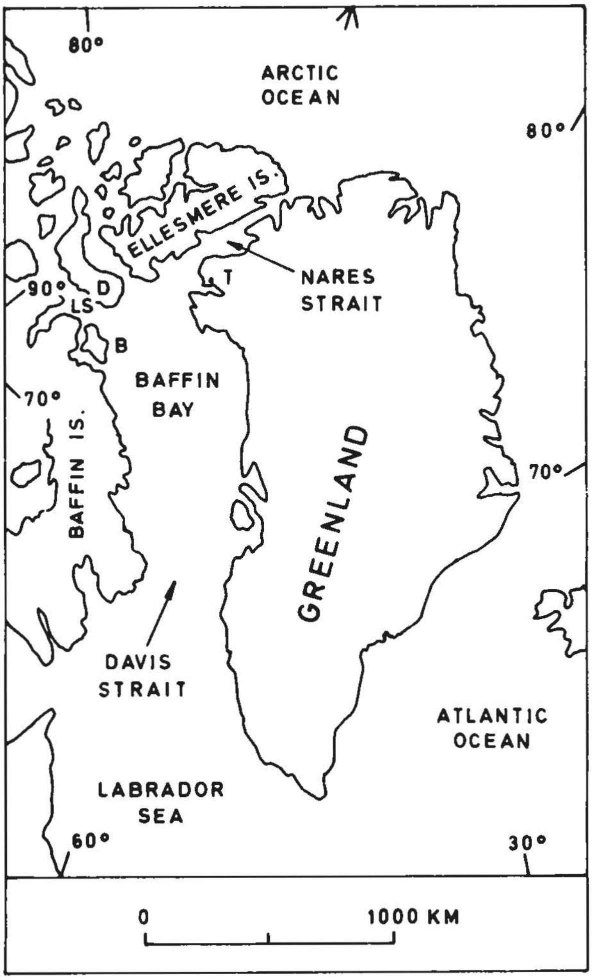

Fig. 1. Index map of the Baffin Bay – Nares Strait region. D = Devon Island, LS = Lancaster Sound, B = Bylot Island, T = Thule.

Outline of regional geology

Precambrian rocks are essentially restricted to the southern half of the map area (Fig. 2). These are predominantly granulite-facies gneisses of the Churchill Province, but thick sequences of relatively undisturbed Proterozoic strata (c. 1200 to c. 600 m.y.), including sandstone units, volcanic rocks, red beds and carbonate rocks are preserved in large northwest–southeast trending graben structures on northern Baffin Island and in the Thule district of Greenland (Jackson & Davidson 1975, Dawes 1976). A few small outcrops of a volcanic–sedimentary sequence similar to the lower portion of these major sequences are preserved on the tips of peninsulas of southeastern Ellesmere Island (Frisch et al. 1978). While these outcrops appear to have a much less clearly-defined structural setting, with only minor faulting, associated basic dykes generally trend north to northeast. Some faults associated with the graben of Baffin Island and the Thule district have been reactivated a number of times since the Proterozoic.

Proterozoic to Palaeozoic rocks surrounding the crystalline shield form a distinctive linear belt running roughly northeast. This essentially continuous succession of Proterozoic to Devonian strata forms the central stable platform and to the north the Franklinian geosyncline. The geosyncline did not undergo severe orogenesis until the late Devonian to mid-Pennsylvanian when it was transformed into the Ellesmere–Greenland fold belt (Thorsteinsson & Tozer 1970, Dawes 1976).

Carboniferous to Tertiary clastic and carbonate rocks deposited on the eroded fold belt form the Sverdrup Basin of west and north-central Ellesmere Island. The Tertiary Eurekan orogeny was the main event of deformation of the Sverdrup Basin, and it extensively overprints the Palaeozoic Ellesmerian structures of the Ellesmere–Greenland fold belt in both Canada and Greenland (Thorsteinsson & Tozer 1970, Dawes 1976).

In the Ellesmere–Greenland fold belt, the major thrusting on Ellesmere Island is directed southward, whereas in Greenland, it is to the north. Due to the extensive overprinting of structures by the later Tertiary orogeny, there is some debate as to how much of this thrusting belonged to the earlier Palaeozoic event. Thorsteinsson & Tozer (1970) believe that thrusting did not begin until the Tertiary on Ellesmere Island. In Greenland at least some of the major thrusts are of Tertiary age (Dawes & Soper 1971).

Correlation with 250 km displacement

The most frequently mentioned magnitude of the left-lateral displacement of Greenland relative to Canada is 200–300 km (Wegener 1924, Carey 1958, Clarke 1968, Johnson 1971, Keen & Barrett 1973, Srivastava 1978). Fig. 3 illustrates reconstruction with 250 km of displacement. Two striking correlations of the simplified geology are immediately apparent.

The large Proterozoic northwest-trending graben and horst systems of northern Baffin and Bylot Islands and the Thule district are brought into conjunction. The sedimentary sections appear to be very similar both in lithology and sequence. The thicknesses of the rocks of North-West Greenland and Bylot Island are comparable, although the Borden Peninsula section is substantially greater (Newman 1977). Both the Canadian and Greenland systems have been reactivated a number of times since the Precambrian (Blackadar 1957, Jackson & Davidson 1975, Dawes 1976). Both graben systems are asymmetrical, but in an opposite sense. The fault blocks of the North Baffin Rift Zone tilt strongly northeast (Jackson & Davidson 1975); those of the Thule district tilt southwest (Davies et al. 1963, Dawes 1976).

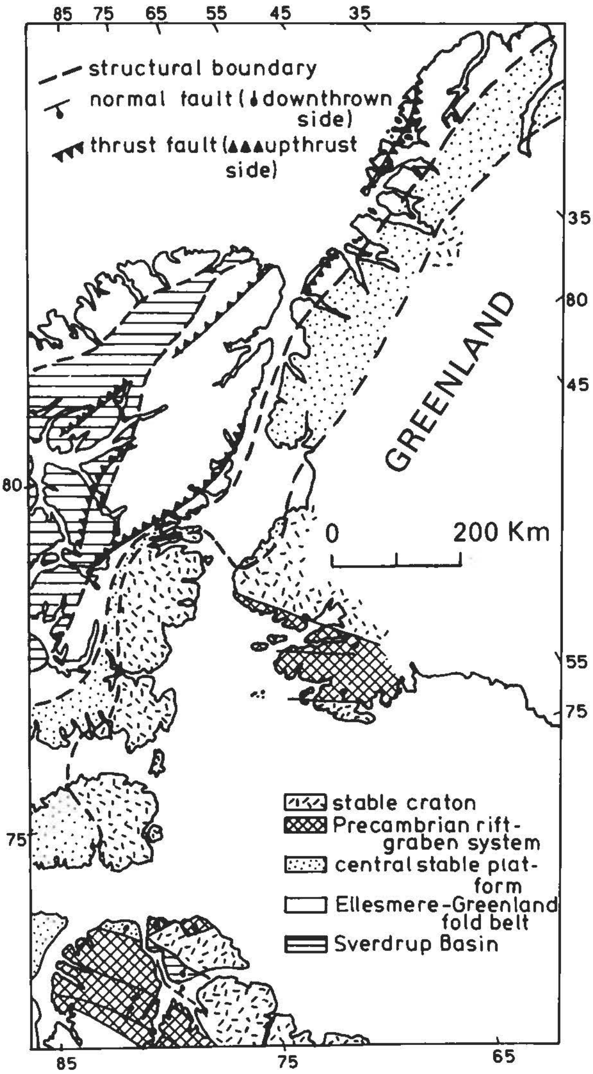

Fig. 2. Simplified geology/structure map of the Nares Strait region.

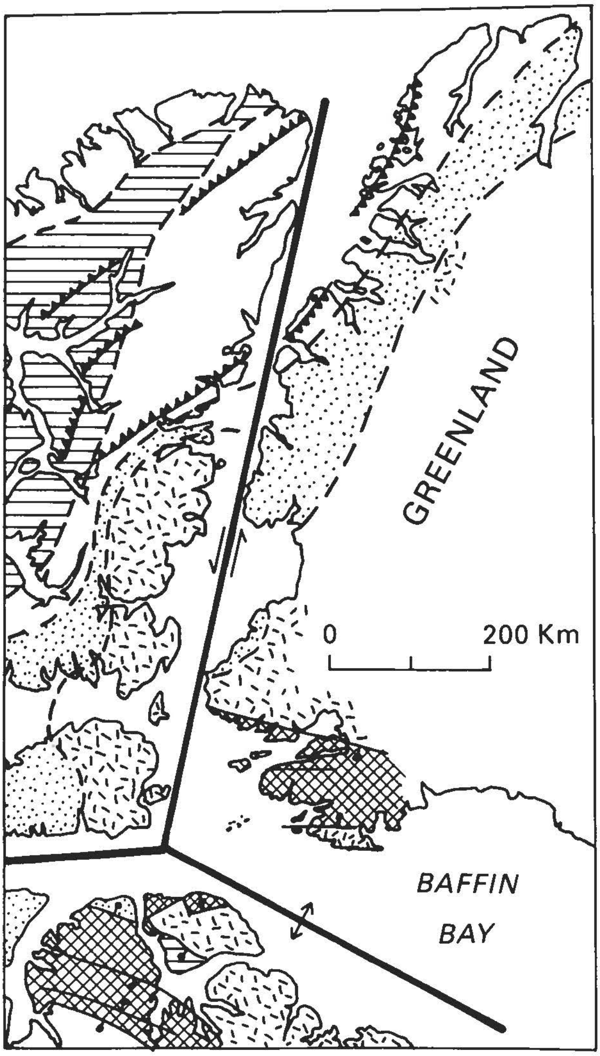

Fig. 3. 250 km reconstruction of simplified geology/structure map, showing possible triple junction. Legend as in Fig. 2.

These might be interpreted as opposite margins of a rift system. The greatest drop would be in the central rift, in this case, Baffin Bay (Fig. 4). On the 250 km reconstruction (Fig. 3) the central rift between the two graben zones of North-West Greenland and northern Baffin Island is oriented at an angle of about 120° to Lancaster Sound and Nares Strait, as is typical of the triple junction configuration.

In this orientation (Fig. 3), the Proterozoic sedimentary and volcanic rocks of southeastern Ellesmere Island have no equivalent directly across Nares Strait in Greenland. While there are very obvious sedimentological similarities between the Ellesmere and Greenland sections, the author believes that in the overall picture their differences are more important than their similarities, i.e. the differences in lateral extent, structural setting, strike of structural features and dykes, and completeness of section. In other words, while these two sequences were presumably once parts of a common sedimentary system, they were not necessarily directly opposite one another as in the present-day configuration of Nares Strait.

Given a triple-rift system, one could expect a common, continuous sedimentological system to all three rifts, with similar resultant rocks. The major differences would be in lateral extent, structural strike, thickness, and possibly volcanic content, determined by the extent of activity along each arm. Presumably, an arm/rift that did little more than open slightly and stop would have little, if anything, in the way of a sedimentary record of this exposed (e.g. Lancaster Sound). An arm along which there was continuing activity, primarily in a lat-

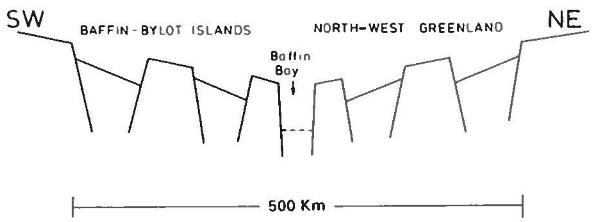

Fig. 4. Cartoon cross-section of reconstructed Baffin Bay with the Baffin–Bylot and Thule graben systems, based on literature description of asymmetrical tilted fault blocks. From Newman (1977).

eral sense, would possibly preserve and expose a series of small, narrow basins (e.g. Nares Strait, and the small Proterozoic outcrops of southeastern Ellesmere Island). The arm along which there was continuous rifting and opening activity would appear to be the arm along which, or parallel to which, one would expect to see sediments formed and preserved to the greatest lateral extent in a series of parallel graben (e.g. Baffin Bay and the Baffin–Bylot and Thule graben systems).

The second striking correlation in the 250 km configuration (Fig. 3) is the pronounced alignment of the highly folded and faulted Proterozoic to Devonian sedimentary sequence of the Ellesmere–Greenland fold belt. In all the literature surveyed during this study, there was only one marker horizon which all workers seemed able to identify and locate clearly, and agree on, and that was the structural boundary between deformed and undeformed rocks north of the stable craton. This boundary is shown on Figs 2 and 3, and it correlates well on the 250 km reconstruction.

It is interesting to note that the thrust faults on either side of the Strait are usually in opposing directions, i.e. Greenland shows predominantly northerly tectonic transport, while in Ellesmere Island it was mostly to the south. Rotational movement of Greenland with respect to Canada may provide a possible explanation (Kerr 1967, Srivastava 1978), but according to Freund (1965), reversal of thrust directions is to be expected across a strike-slip fault (Fig. 5).

In the 250 km reconstruction (Fig. 3), the boundary between the Precambrian crystalline basement and the Palaeozoic platform cover does not correlate well across the Strait. Considering the difference in width of stable platform deposits between Ellesmere Island and Greenland (Fig. 2), however, it is impossible to find a position which fits both boundaries. The southern boundary with the Precambrian basement is a depositional and erosional boundary, and is therefore dependent on the shape of the original depositional surface, and the depth of subsequent erosion. It seems more probable that this marker, rather than the structural boundary to the north, would have had an 'original' sharp bend in it. Scattered outliers of Palaeozoic carbonate rocks on southeastern Ellesmere Island (Christie 1962, Frisch et al. 1978) indicate that the Palaeozoic cover there was once much more extensive than at present. Therefore, the positions on the 250 km reconstruction of the original southern boundaries of the Palaeozoic sediments would possibly be not so far apart.

Using the geological evidence cited above, movement between Canada and Greenland of about 250 km appears to give a reasonable correlation. However, some Precambrian features correlate well to a maximum of about 300 km displacement, and the Palaeozoic markers, such as the fold boundary, will correlate to a minimum of 200 km if Nares Strait is allowed to widen slightly.

Timing

Most workers supporting movement between Canada and Greenland suggest that it occurred during the late Cretaceous to Tertiary. This interpretation is based on the timing of spreading (from magnetic lineations) in the Labrador Sea to the south, and that of various sections of the northern mid-Atlantic Ridge (Le Pichon et al. 1971, 1977, Srivastava 1978). Dawes (1973), however, pointed out that if the main overturning of fold structures in opposing directions on either side of the Strait is truly of Palaeozoic age, then Nares Strait was a prominent and influential feature at least that far back.

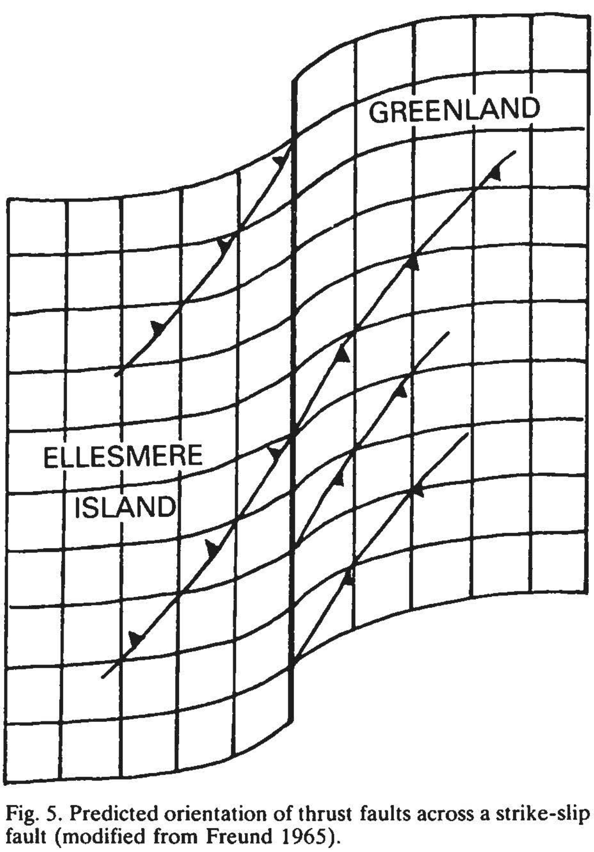

Fig. 5. Predicted orientation of thrust faults across a strike-slip fault (modified from Freund 1965).

Accepting that the boundary of the Palaeozoic fold belt was originally straight, and that the Baffin and Thule Proterozoic graben systems are related and were originally joined, there is no good geological fit with movement of less than 200 km. Le Pichon et al. (1977) believe that a maximum of 100 km of displacement occurred in the last 63 m.y. Preserved Carboniferous and younger sediments occur west of Nares Strait in the Sverdrup Basin, and therefore there are no distinctive younger markers to use in correlating across the Strait. The Tertiary orogeny reactivated many of the older structures, but these need not have been in their original relative positions. The crustal weaknesses would have continued to exist wherever the continents lay relative to one another and would have been susceptible to reactivation. Left-lateral displacement could have occurred along Nares Strait during both main orogenies. Perhaps the Ellesmerian orogeny moved Greenland 100 to 150 km, and the Eurekan orogeny the last 100 km.

Srivastava (1978) believes that 250 km of movement occurred in the last 63 m.y. Perhaps the Palaeozoic Ellesmerian orogeny and any possible earlier ones only formed compressional features and did not involve any lateral movement along Nares Strait. If the Palaeozoic fold boundary does correlate at the 250 km reconstruction as suggested, then the last 250 km of movement is of post-Palaeozoic age. The Tertiary Eurekan orogenic forces, at a low angle to the Palaeozoic compression, reactivated many of the older structures and could have initiated strike-slip displacement along the Strait. Thorsteinsson & Tozer (1970) believe that the Ellesmerian orogeny produced only folds, and that the prevalent southward thrusting did not begin until the Tertiary. This may indicate that substantial left-lateral movement did not occur until the Tertiary. Even if thrusting did occur during the Palaeozoic, it was strongly reinforced during the Eurekan orogeny (Kerr 1967, Dawes 1976) and perhaps was a more dominant feature of the later orogeny.

Conclusions

On the basis of the few large-scale features discussed above, a case can be made for considerable movement along Nares Strait. The left-lateral displacement between Greenland and Canada, to a total of about 250 km, probably occurred in a number of movements between late Precambrian time and the Tertiary. Major rifting activity took place during the Proterozoic and Devonian–Carboniferous, and substantial displacement during the late Cretaceous–Tertiary.

If a theory of no, or little, movement, i.e. direct geological correlation across Nares Strait, is to be maintained, then it must provide a reasonable explanation for the rather major features and problems discussed here.

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