Brecciated lineaments in Washington Land, North Greenland, and their relation to Nares Strait

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Linear crush zones at Kap Jefferson suggest strike-slip movement transverse to Nares Strait. Other parallel lineaments, fjords and valleys occur in North Greenland and may have similar structures in them. These may have been areas of incipient strike-slip movement related to an early compressional phase in the formation of the Nares submarine rift valley. These lineaments are approximately perpendicular to Palaeozoic folds and inferred gneissic trends. They may be incipient transform faults, controlled by the interplay between regional plate tectonic stresses at the time, and the influence of pre-existing structures.

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Kerr (1967a, b, 1980a, b, 1981) considered Nares Strait to be a submarine rift valley resulting from faulting during periods of crustal compression and extension when Greenland and Ellesmere Island rotated apart. Little evidence of this structure exists on land north of latitude 80°N on the Greenland side. The purpose of this paper is to focus attention on actual and inferred faults and crush zones in western North Greenland bordering Nares Strait, between Kane Basin and Lincoln Sea (Fig. 1), and to briefly discuss their relevance to Nares Strait.

Structures

Kap Jefferson is situated 40 km north of latitude 80°N on the western coast of Washington Land at the northern perimeter of Kane Basin (Fig. 1). Here there is a complex succession of Silurian basin slope deposits on the southern limb of the Hazen Trough (LBF and CSF; Fig. 2). These basin slope deposits lie conformably upon platform carbonates of Ordovician–Silurian age (AFF), and partly interfinger south-eastward with platform dolomites (ABF). This facies relation was outlined by Hurst (1980a, b) and is similar to the situation on Ellesmere Island (Kerr 1967a, Trettin et al. 1972) as well as on Devon Island (Morrow & Kerr 1977).

Several major lineaments at Kap Jefferson are aligned N10°W, trending at an angle of about 70° to the trend of Nares Strait (Figs 2 and 3). A second minor set of lineaments are aligned at N45°W (Fig. 3), but are not visible on the ground and can only be recognised on aerial photographs. The major lineaments cut through all platform deposits, and individual lineaments form topographic depressions up to 200 m wide. In some cliff exposures (Fig. 4) they have been eroded to a depth of 70 m. They preferentially form linear valleys and are followed by straight stream segments. The rocks in the major lineaments are extremely shattered, brecciated, and invaded by calcite veins, and grade laterally into undisturbed rock (Fig. 5). The crush zones consist almost entirely of fragments of the surrounding formation and there is little apparent offset of bedding across them (Fig. 5). The crush zones undoubtedly are fault breccias. Little vertical movement has occurred, however, because outcrop patterns have not been disrupted, and because beds appear to continue through the breccias. It is suggested that there has been some lateral displacement within these zones. Lateral displacement would be very hard or impossible to detect because the beds are so close to being horizontal. Vertical displacement, even

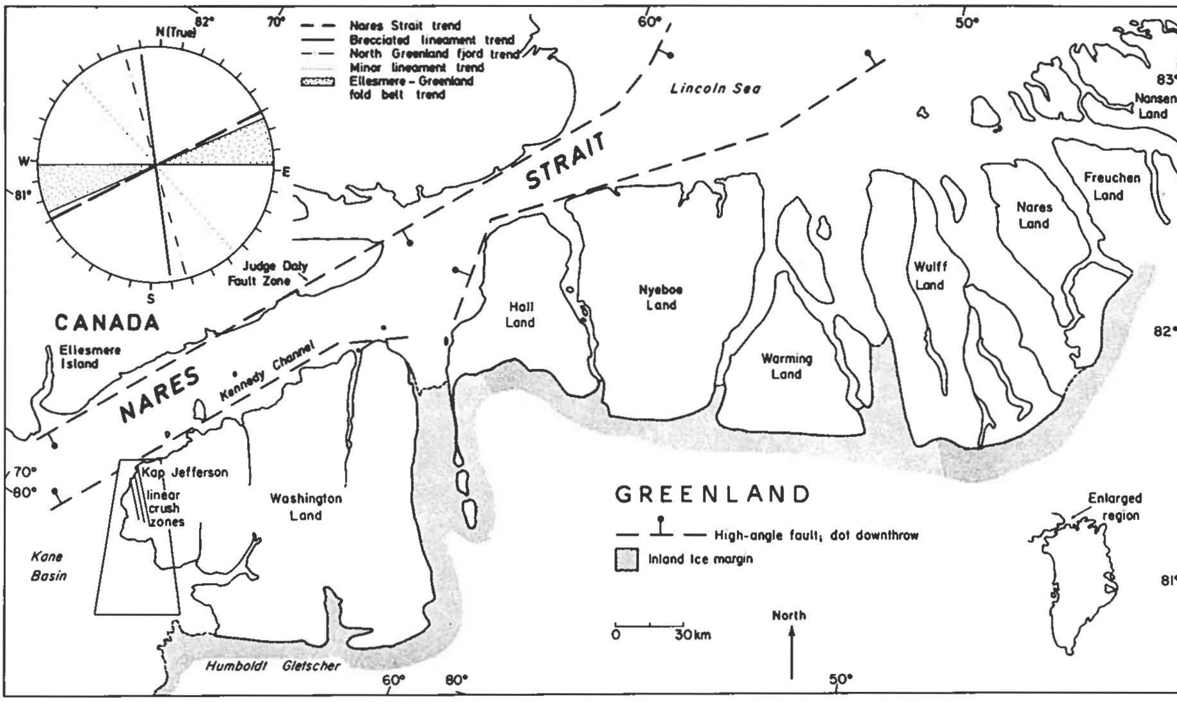

Fig. 1. Simplified map of western North Greenland and eastern Ellesmere Island, Canada, showing the northern part of the Nares submarine rift valley. Faults are after Kerr (1967a). Note the parallel alignment of the fjords in North Greenland with respect to each other and to the crush zones at Kap Jefferson. These are nearly at right angles to the pre-existing regional geological strike and nearly at right angles to the Nares submarine rift valley. Azimuths of the main structural features of the region shown in top left. Inset bottom left indicates region shown in Figs 2 and 3.

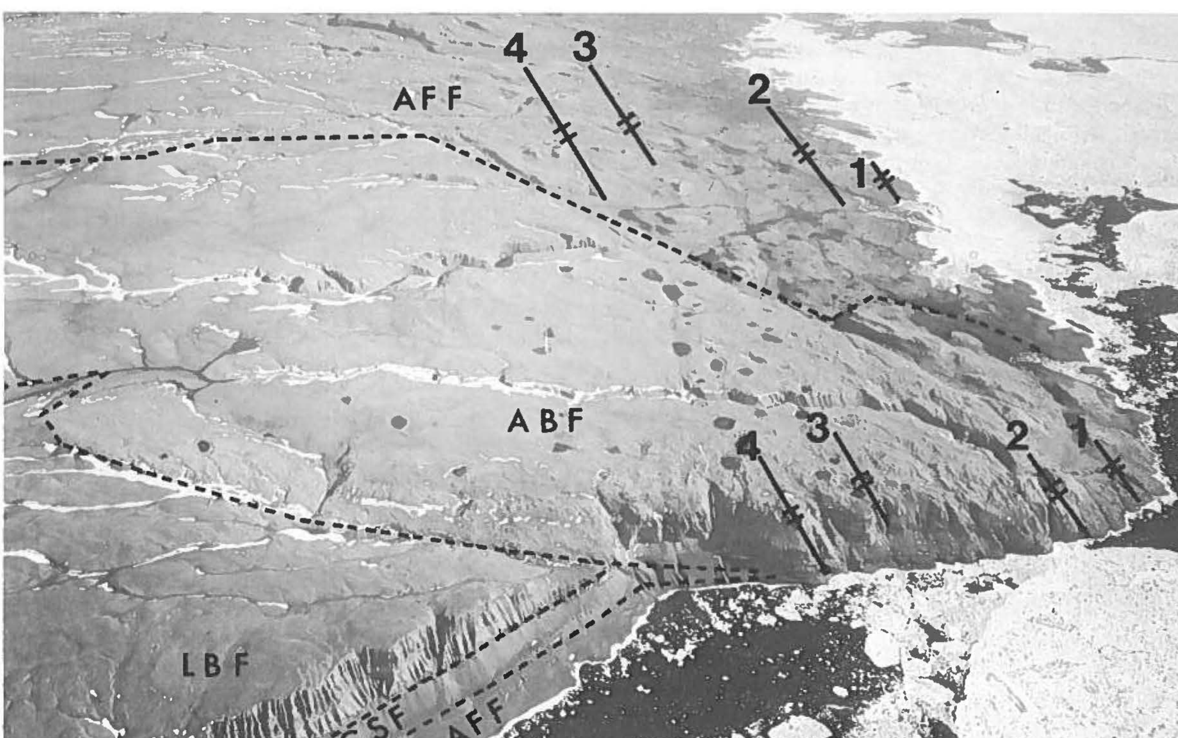

Fig. 2. Geological setting of Kap Jefferson, western Washington Land, viewed southwards (see Fig. 1). Four pronounced lineaments (1 to 4) cut the Aleqatsiaq Fjord Formation (AFF) and the Adams Bjerg Formation (ABF). Cape Schuchert Formation (CSF) and Lafayette Bugt Formation (LBF). Aerial photograph 545K–S, no. 11781; copyright Geodætisk Institut, Denmark.

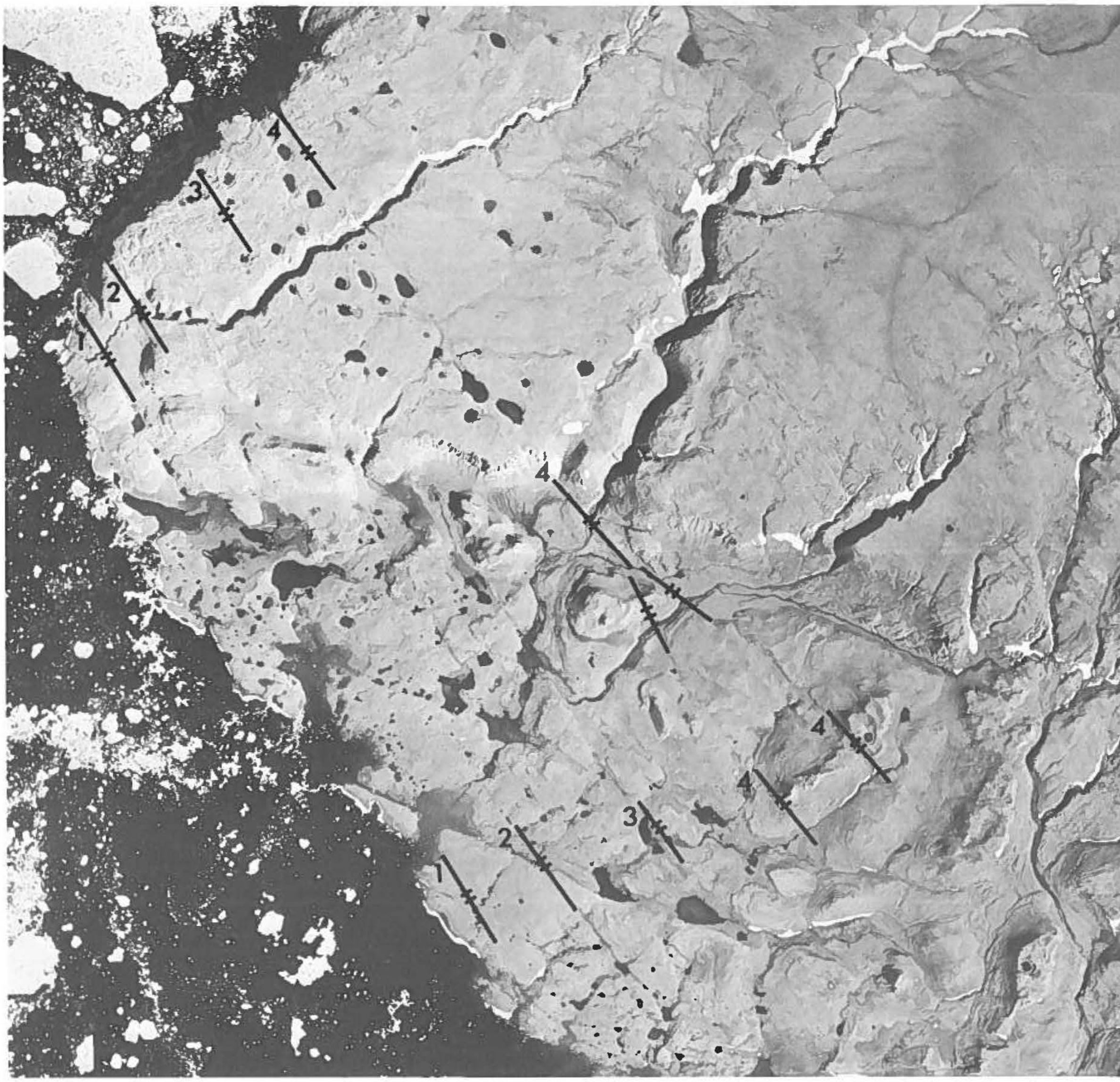

Fig. 3. The four pronounced major lineaments (1 to 4) cut by minor lineaments. Geology as in Fig. 2. Aerial photograph 240V, no. 179, copyright Geodætisk Institut, Denmark.

slight, would be readily observable. Throughout the general region south of Kap Jefferson where the platform dolomites are exposed (Fig. 2) approximately 50 km^2 are affected by crush zones, giving the regional rock surface a very fractured appearance. The four major lineaments at Kap Jefferson (Figs 2 and 3) are 100 to 200 m wide and contain within them numerous crush zones. Numerous other separate and minor crush zones occur between the four major lineaments.

The lineaments at Kap Jefferson are aligned at about N10°W. The most impressive feature of the North Greenland coast between Washington Land and Freuchen Land is a series of major fjords with approximately similar alignment. Also within the land area many major valleys have a similar alignment, some containing glacial tongues (Fig. 1). The parallelism between the linear crush zones and topographic features suggests that these features all have a similar origin. The main valleys may be glacially carved, but those glaciers probably selectively followed pre-existing pathways and lines of geological and geomorphological weakness. It is suggested here that the NW-trending fjords and valleys of the North Greenland coast may be major lineaments controlled by fault zones or fracture zones, similar to those at Kap Jefferson, that were modified by later glacial erosion.

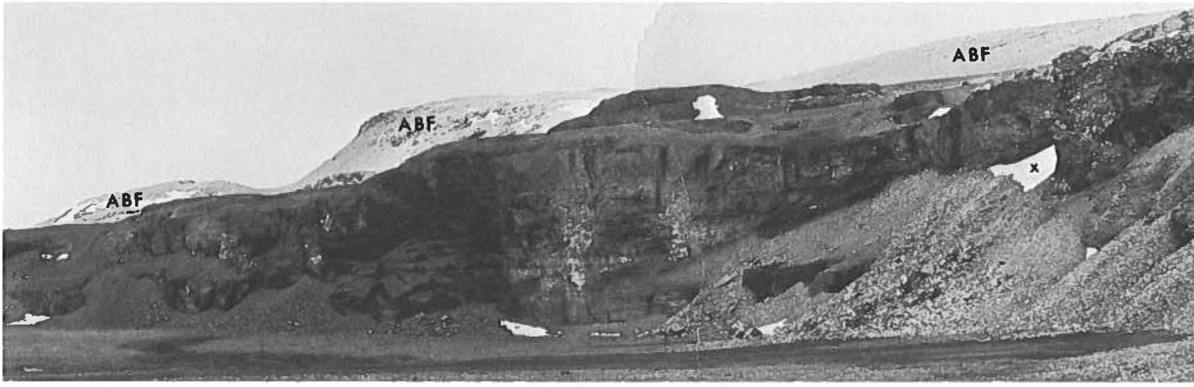

Fig. 4. Valley formed by major lineament 1 of Figs 2 and 3. Note normally-bedded Aleqatsiaq Fjord Formation passing into brecciated zone. Valley width 300 m, valley height 80 m. Adams Bjerg Formation (ABF). X marks the snowpatch in the centre of the area enlarged in Fig. 5.

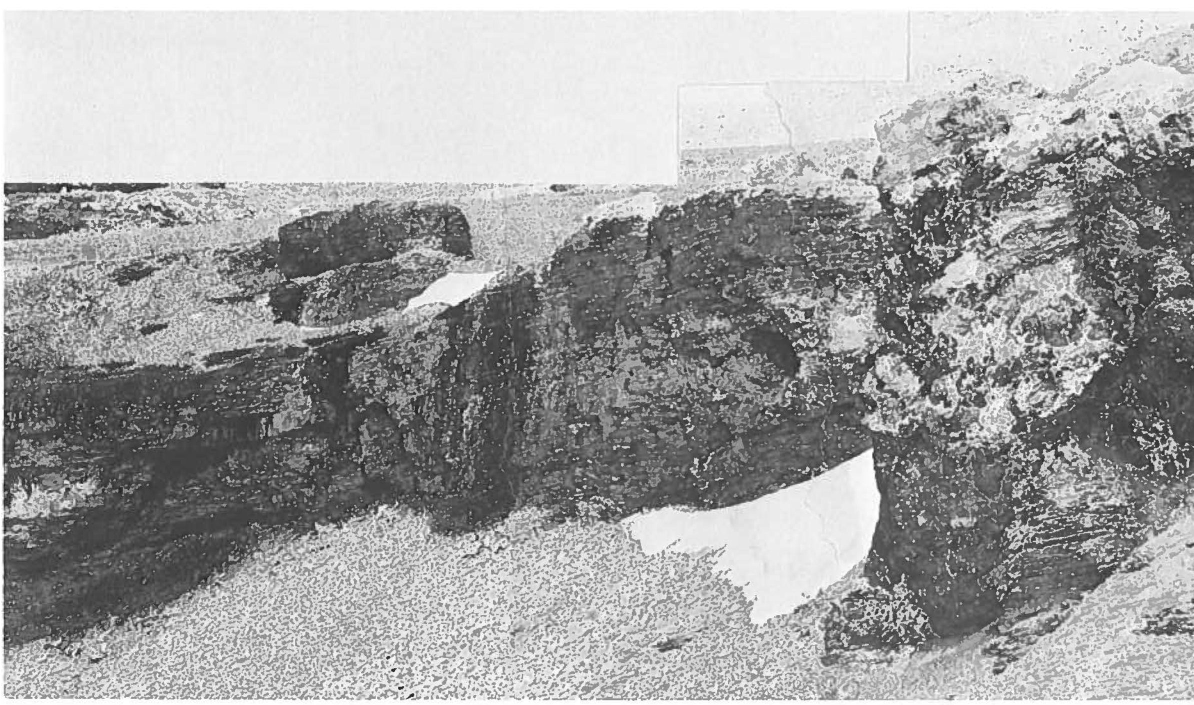

Fig. 5. Close view of crushed rock (Fig. 4) passing into less disturbed and finally undisturbed strata. Cliff height 20 m.

Interpretation

It is generally accepted that Nares Strait is a fault controlled feature of Cretaceous–Tertiary age. Many have considered that it is the locus of a strike-slip fault with hundreds of kilometres of left-lateral displacement (Wegener 1924, Wilson 1963, Srivastava 1978). Kerr (1967a) suggested that Nares Strait formed by a combination of minor strike-slip displacement and rotation apart of Greenland and Ellesmere Island. This involved first a period of extension in the southern Nares Strait region resulting from extension faults from Baffin Bay propagating northward in late Cretaceous to early Tertiary time. At this time extension occurred south of latitude 80°N only, with the region north of that subjected to compression and some left-lateral strike-slip. This is transpression in the sense of Harland (1971, 1973). Subsequently, in mid-Tertiary time the entire length of Nares Strait became a zone of extension faulting and the Nares submarine rift valley achieved its form as a downdropped structure. In this latter time Baffin Bay and Lincoln Sea were connected continuously by the extension zone, and the rotation apart of Ellesmere Island and Greenland ceased.

The structural trends that apparently existed prior to the Cretaceous–Tertiary rifting event are shown approximately on Fig. 1. The alignment of the lineations at Kap Jefferson and the major fjords and valleys farther north in Greenland is approximately at right angles to the local structures, which presumably also existed before rifting. The lineations, major fjords and valleys may have formed along jointing directions at right angles to the Palaeozoic structural trends while the Nares rift structure was forming. The fjords may be largely erosional and faults are only inferred. However, the crush zones in the Silurian rocks at Kap Jefferson certainly are fault controlled, and have some small displacement at least. These crush zones are post-depositional, and there is no evidence that they correspond to zones of facies changes. Indeed, the major facies change between platform rocks (carbonate) and basin slope rocks (shale) at Kap Jefferson is oblique to the crush zones (Fig. 2).

The age of formation of the lineaments at Kap Jefferson is uncertain. They clearly are post-depositional, unrelated to facies changes. It is inferred that they formed during the Cretaceous–Tertiary plate tectonic deformation outlined by Kerr (1981). Thus, they presumably are related directly to the formation of the Nares submarine rift valley. An analogue to that rifted zone was documented by Surlyk (1977, 1978) in East Greenland, where a dormant north-trending rift system is cut by transverse trending fjords which are inferred to be the site of cross faults. The crush zones at Kap Jefferson may have formed in the following way.

In an early stage of rifting extension took place south of lat. 80°N and transpression took place to the north (Fig. 6A). South of lat. 80°N extension faults in the Nares Strait region were controlled by gneissic and schistose trends of the basement (Kerr 1967a). Details of basement structural trends are unknown north of this latitude, where the region is covered by Palaeozoic

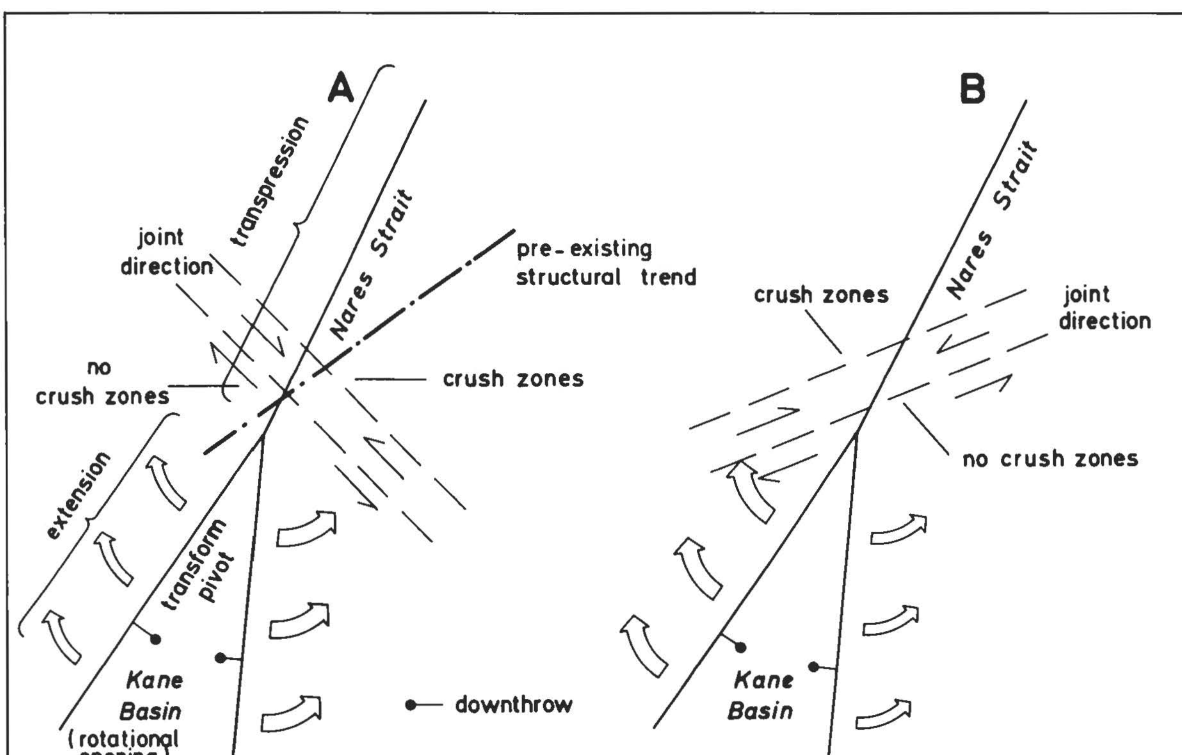

Fig. 6. Structural development of Nares Strait in the Kane Basin – Kennedy Channel area. A: Actual configuration of structures. Rotational opening and foundering in a zone of extension in the south merged across a transform pivot into a zone of transpression in the north. These were controlled by the pre-existing structural trend of folded Lower Palaeozoic sediments (which may reflect basement trends). Mainly strike-slip occurred along Kennedy Channel and mainly crush (incipient strike-slip) along cross trending joints, resulting in crush zones at Kap Jefferson. B: Hypothetical situation in which pre-existing structural trends offered little or no interference to rift advance. Both the pre-existing structural trends (N-trending), and the cross joints could allow extension without transpression.

sediments, but folds in these sediments cross Nares Strait acutely (Fig. 1), and basement trends are inferred to have similar orientation. The lineaments at Kap Jefferson may have been controlled by the northward extension of the structures forming Nares Strait. The lineaments at Kap Jefferson may reflect interference of basement and fold trends with the initiating stresses of the Nares submarine rift valley. These crush zones appear to only occur north of the zone of transformation, lending support to Kerr's (1967a) argument that compression occurred in that region. These crush zones may be incipient transform faults. They may have developed in the early or compressional phase of rifting in the manner shown in Fig. 6A. The compressional phase was then replaced by an extensional phase in which the extensional structures broke northward from southern Nares Strait to completely separate Ellesmere Island and Greenland.

It is interesting to speculate on why similar crush zones have not been reported on the coast of Ellesmere Island. This may have to do with the angular orientation of the extensional structures initiating Nares Strait, and the pre-existing structures and cross joints within them. A direction of jointing perpendicular to the pre-existing structural trend in the Kap Jefferson region was a possible zone of release for the counter-clockwise rotation of the Greenland block. Because the angle between these joints and the tendency of movement of Greenland was less than 90°, crush resulted from incipient transpression and strike-slip occurred along the structural trend. If the orientation of pre-existing structures had been slightly different (Fig. 6B) then crush zones might not have developed, and instead there might have been grabens formed along the cross trending joints.

In summary, the lineaments at Kap Jefferson are crush zones suggesting some small degree of lateral movement. They are approximately perpendicular to pre-existing fold trends and inferred basement trends, with those trends possibly controlling their orientation. They appear to be related to the formation of the Nares submarine rift valley, resulting from transpression as the result of the interplay between pre-existing structures and the orientation of the initiating stresses. Parallel aligned fjords and valleys farther north between Washington Land and Freuchen Land may have similar origin.

Acknowledgements

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